# Analysis And Design of Transmission Tower Using STADD- PRO

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***Abstract-*** *In this project, the design of steel lattice tower prescribed for transmission of electricity by the categorized gravity and lateral loads has been studied and analyzed for the employment of the project. The analysis has been done by taking different combination of loads and then the design has been come into picture using the code module IS 800:2007. The present work describes the analysis and design of transmission line tower of 22meter height viz. various parameters. In design of tower for weight optimization some parameters are considered such as; base width, height of tower, outline of tower. Using STAAD. Pro analysis of transmission towers has been carried out as a 3-D structure.*

***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

The large population residing all over the globe and the electricity supply need of this population creates requirement of a large transmission and distribution system. The disposition of the primary resources for electrical power generation viz., coal, hydro potential is quite uneven hence again adding to the transmission requirements. It is an integrated system consisting of conductor subsystem, ground wire subsystem and one subsystem for each category of support structure. About 28 to 42 % of the total cost of the Transmission Lines is taken up by the towers. The increasing demand for electrical energy can be met more economical by developing different light weight configurations of transmission line towers.

A transmission tower known as a power transmission tower, power tower, or electricity pylon is a tall structure used to support an overhead power line. Also, In electrical grids, they are used to carry high voltage transmission lines that transport bulk electric power from generating stations to electrical substations; utility poles are used to support lower-voltage sub-transmission and distribution lines that transport power from substations to electric customers.

Transmission towers need to carry the heavy transmission conductors at a sufficient safe height from the ground including, all towers have to sustain all kinds of natural calamities. Hence transmission tower design is an important engineering job where civil, mechanical, and electrical engineering concepts are equally applicable. A power transmission tower is a key part of a power transmission system.

High-voltage direct current (HVDC) transmission lines are either monopolar or bipolar systems. With bipolar systems, a conductor arrangement with one conductor on each side of the tower is used. On some schemes, the ground conductor is used as electrode line or ground return. In this case, it had to be installed with insulators equipped with surge arrestors on the pylons in order to prevent electrochemical corrosion of the pylons.

**Transmission Tower Parts:**

A power transmission tower consists of the following parts:

1. The peak of the transmission tower
2. The cross arm of the transmission tower
3. The boom of transmission tower
4. Cage of transmission tower
5. Transmission Tower Body
6. Leg of transmission tower
7. Stub/Anchor Bolt and Baseplate assembly of the transmission tower.

**1. Peak of Transmission Tower**

The portion above the top cross arm is called peak of transmission tower. Generally earth shield wire connected to the tip of this peak.

**2. Cross Arm of Transmission Tower**

Cross arms of transmission tower hold the transmission conductor. The dimension of cross arm depends on the level of transmission voltage, configuration and minimum forming angle for stress distribution.

**3. Cage of Transmission Tower**

The portion between tower body and peak is known as cage of transmission tower. This portion of the tower holds the cross arm.

**4. Transmission Tower Body**

The portion from the bottom cross arms up to the ground level is called the transmission tower body. This portion of the tower plays a vital role in maintaining the required ground clearance of the bottom **conductor of the transmission line.**

**5. Importance of Transmission Line towers**

The structures of overhead transmission lines, comprising essentially the supports and foundations, have the role of keeping the conductors at the necessary distance from one another and form earth, with the specified factor of safety to facilitate the flow of power through conductor form one point to another with reliability, security and safety.

Electrical energy, being the most convenient and cleanest form of energy, is finding the maximum usage the world over for development and growth of economy and therefore generation, transmission and utilization of the same in ever increasing quantities as economically as the latest technological advancements permit, are receiving great attention.

## II. OBJECTIVES

The technical, environmental and economic considerations involve in sitting and development of power generation projects required for meeting the demand for electrical energy are gradually resulting in longer transmission distances and introduction of higher and higher transmission voltages, and use of high voltage direct current transmission systems.

1. analyze and design self- supporting transmission line tower with different types of bracings using hot- rolled steel sections using STAAD Pro Software.
2. To do the cost analysis of transmission line tower.
3. To compare different towers for their structural stability at varied wind loads.

**Data:**

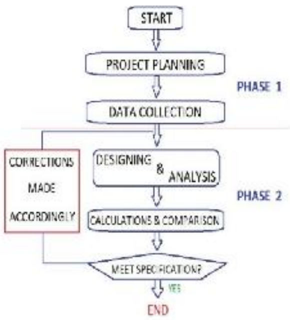
1. Height of the Tower: 22 m
2. Centre to Centre spacing between the footings: 4m Centre to Centre between legs of tower on both side.
3. Length of the cross arm: 3 m
4. Support type: Fixed
5. Height of the cross arm from the ground: 15 m

## III. METHODOLOGY

STAAD. Pro Software has been used for the analysis of Transmission Tower. Then loads like Dead Load and Wind Load will be calculated for the designed structure. The models with different type of bracing are observed for the analysis of cost cutting. Different bracing models are analyzed for the safety and stability of the structure.

STEP 1: Project planning with collection of required data.
STEP 2: Designing & analysis of transmission tower under various load using STAAD. Pro.
STEP 3: Manual calculations under different wind speed for analysis of safety and stability.
STEP 4: Study and comparison for different types of Bracings of transmission tower.
STEP 5: Proper study and analysis of transmission tower to go for the Conclusion.

**FLOWCHART:**




**DATA:**

- Height of tower: 22m
- Centre to centre spacing of footings: 4m
- Length of cross arms: 3m
- Support type: Fixed
- Height of cross arms from ground: 15m
- Wind speed: 39m/s, 44m/s, 49m/S

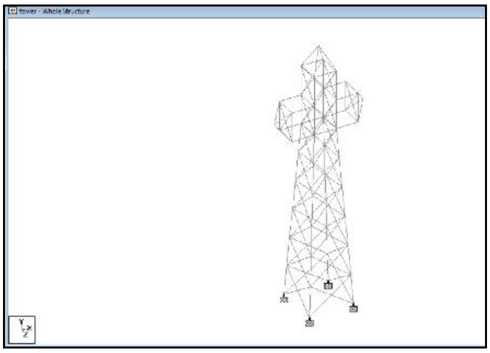


Figure 1 Design model of transmission tower in STADD PRO

### IV. MODELLING IN STAAD.PRO

**Data:**

- Height of the Tower: 22 m
- Centre to Centre spacing between the footings: 4m Centre to Centre between legs of tower on both side.
- Length of the cross arm: 3 m
- Support type: Fixed
- Height of the cross arm from the ground: 15 m

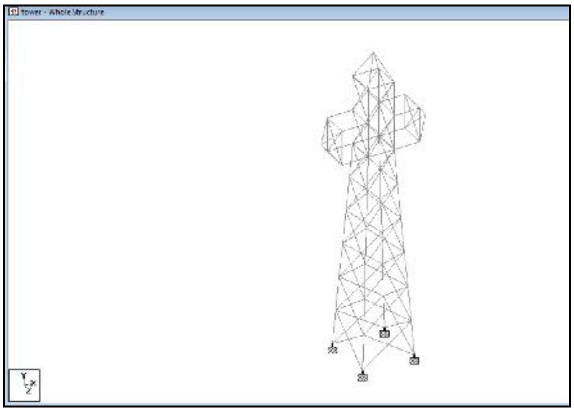


Figure 2 Isometric view of the Staad. Pro Model

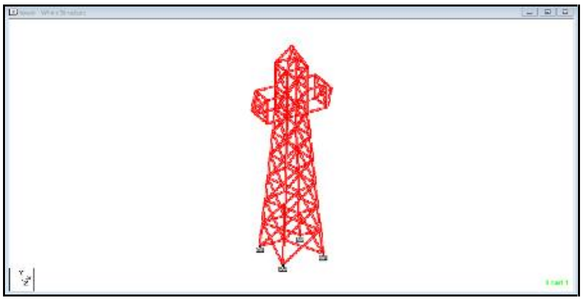


Figure 3 Self-weight Assigned to the structure

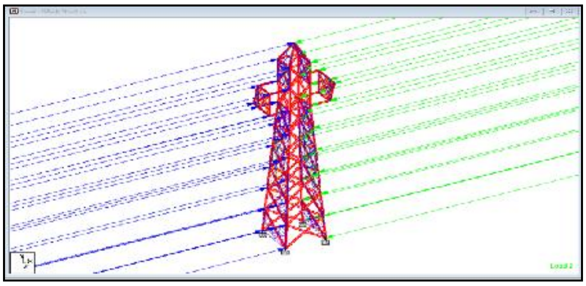


Figure 4 Wind Load Application in X direction

The wind load applied here is based upon the direction in which the wind flows.

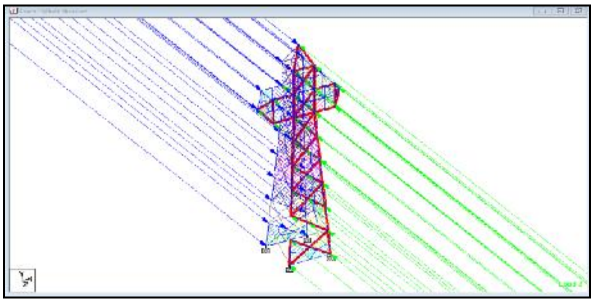


Figure 5 Wind Load Application in Y direction

The wind load applied here is based upon the direction in which the wind flows.

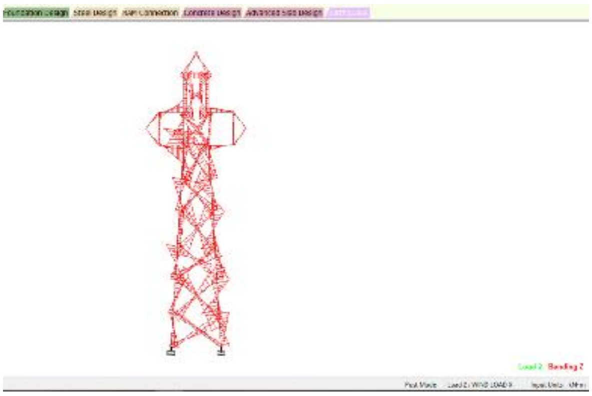
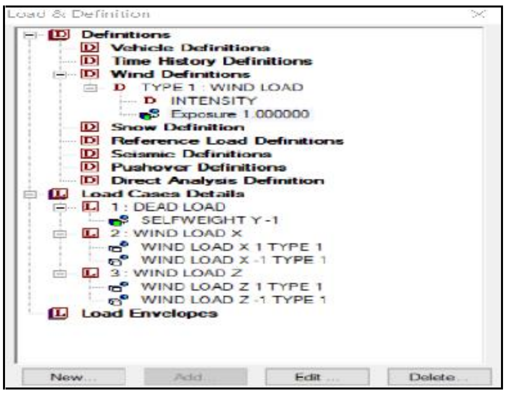


Figure 6:- Bending Moment Diagram of the model



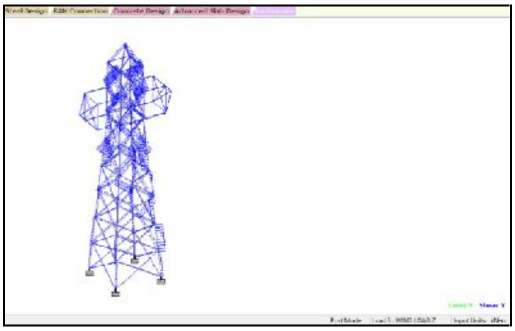


Figure 7 Shear Force Diagram of the model

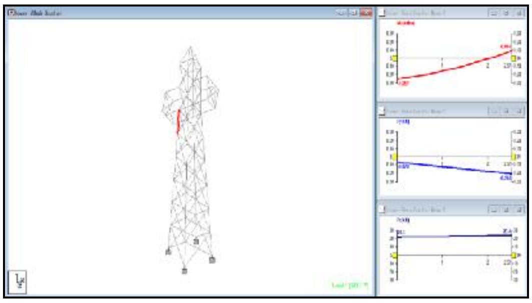


Figure 8 Graphs for the beam selected in the model with its value

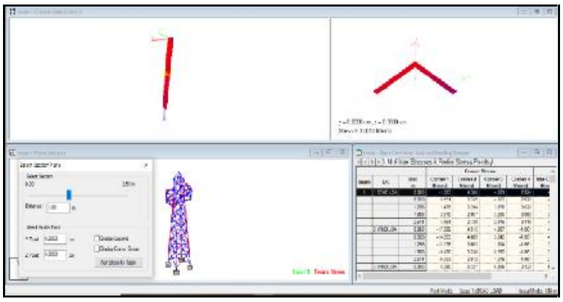


Figure 9:- Beam stresses

Table 1: Support Reactions Extracted from the software

| | | Horizontal | Vertical | Horizontal | Moment | | |
|---|---|---|---|---|---|---|---|
| **Node** | L/C | FxkN | FykN | FzkN | 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 | 198.399 | -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 | 60.433 | -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

| | | | | Horizontal | Vertical | Horizontal | Resultant |
|---|---|---|---|---|---|---|---|
| | Beam | L/C | Node | X mm | Y mm | Z mm | 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

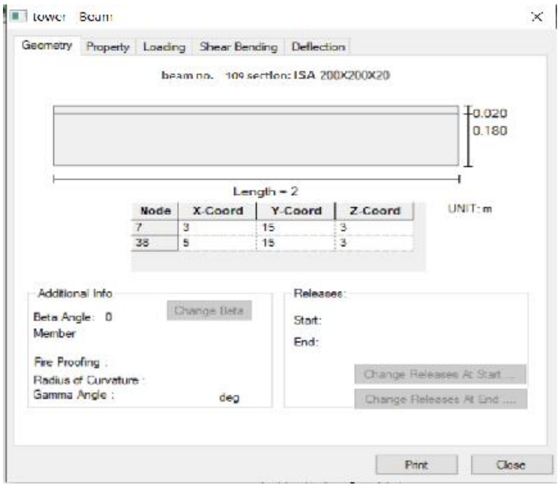



Figure10:- Geometry of the beam

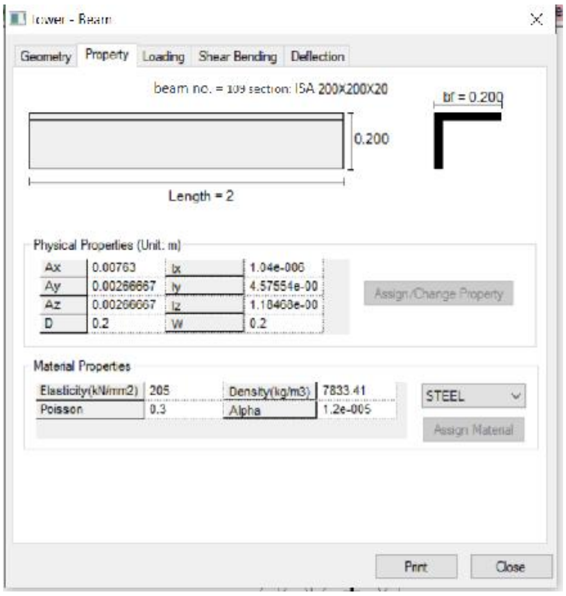



Figure 11:- Property of the beam

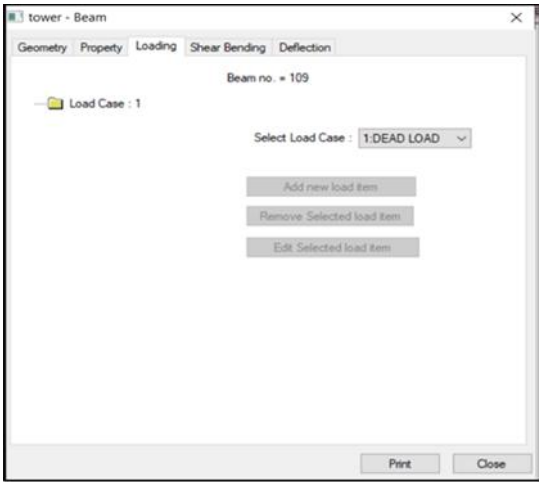



Figure 12:-Loading of the beam

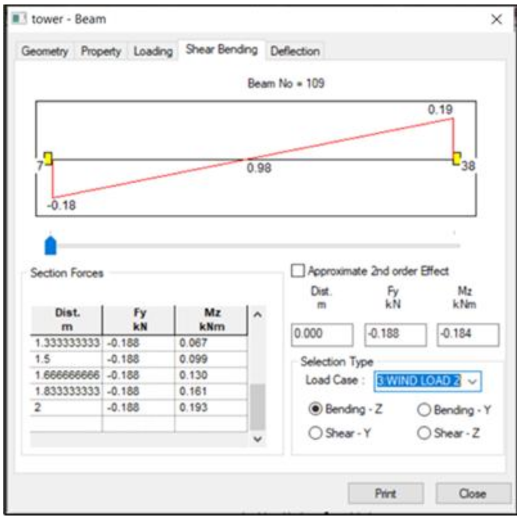



Figure13:-Shear bending of beam

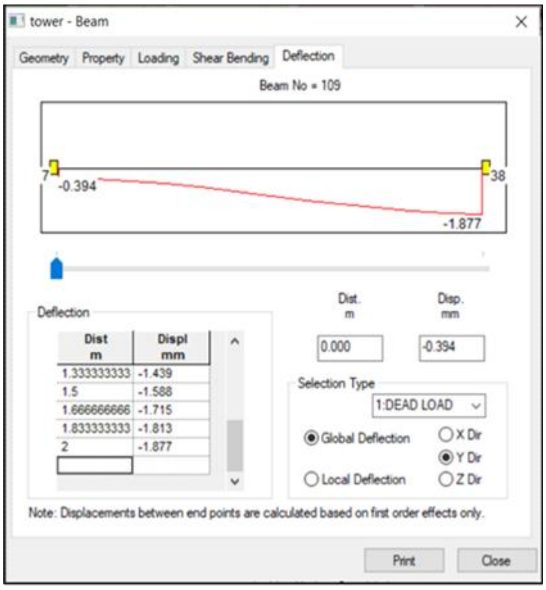



Figure 14:-Deflection of the beam

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## 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<br>200x200x16<br>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<br>200x200x16<br>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<br>200x200x16<br>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.

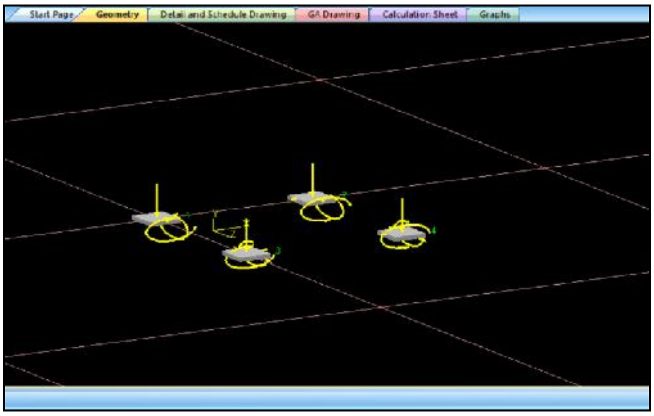


Figure 15:- Isolated footings geometry

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 |

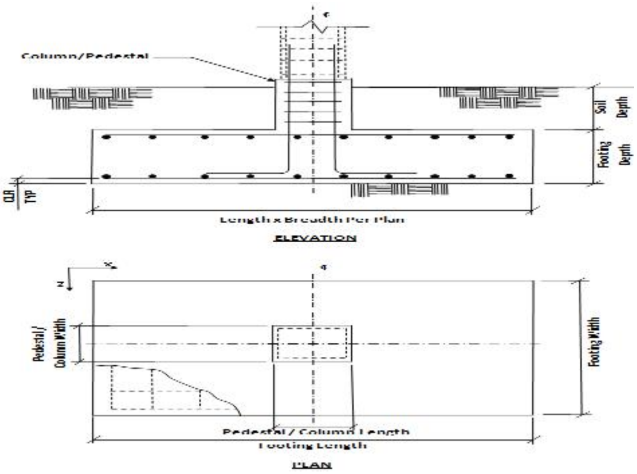


Figure 16:- Plan and Elevation of Footing

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 |
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| 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 ($q_4$) ($kN/m^2$) |
|---|---|---|---|---|
| **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 $A_m$ = | | = 1.800 | sq.m | |
| $V_{max}$ = | $P_r \times (B \times H - A_m)$ | = 703.998 | kN | |
| $V_u$ = | $\frac{V_{max}}{2 \times (b + h - 6 \times d) \times d}$ | = 291.098 | $kN/m^2$ | |
| $V_{c1}$ = | $min(11 \times \sqrt{f_{cu}}, 5)$ | 4000.000 | $kN/m^2$ | IS456 : 2000 |
| | $V_u$<= $V_{c1}$ | hence, safe | | |
| Critical Perimeter $P_m$ = | $2 \times (b + h + 6 \times d)$ | 5.448 | m | |
| $V_{u1}$ | $\frac{V_d}{P_m \times d}$ | 285.888 | $kN/m^2$ | |
| $V_1$ = | $min(pt_{reqd}, 3)$ | 0.145 | $N/mm^2$ | |
| $V_2$ = | $max\left(\frac{400}{d}, 1\right)$ | 1.000 | $N/mm^2$ | |
| $V_3$ | $min\left(\frac{f_{cu}, 40}{25}\right)^{\frac{1}{3}}$ | 1.000 | $N/mm^2$ | |
| $V_c$ = | $\frac{0.79 \times (V1)^{\frac{1}{3}} \times (V2)^{\frac{1}{4}} \times (V3)}{1.25}$ | 552.254 | $kN/m^2$ | |
| | $V_{u1}$ <= $V_c$ | 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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