Optimum Design of Transmission Towers using STAAD.pro with Joints' and Foundation Design in MS Excel-VBA

A PROJECT

Submitted in partial fulfillment of the requirements for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

CIVIL ENGINEERING

Under the supervision of

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To

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May, 2015

DECLARATION

I hereby declare that the project work presented in this Project entitled *"Optimum Design of Transmission Towers using STAAD.pro with Joints' and Foundation Design in MS Excel-VBA"* submitted for the partial fulfillment of the degree of bachelor of technology in the Department of Civil Engineering, Jaypee University of Information Technology Waknaghat, is original and our own account of work. This project work is independent and its main content work has not previously been submitted for degree at any university in India or Abroad.

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CERTIFICATE

This is to certify that the work which is being presented in the project title "**Optimum Design of Transmission Towers using STAAD.pro with Joints' and Foundation Design in MS Excel VBA**" in partial fulfillment of the requirements for the award of the degree of Bachelor of technology and submitted in Civil Engineering Department, Jaypee University of Information Technology, Waknaghat is an authentic record of work carried out by **Harshal Chandna, Ajay Rampal, Saurabh Bhardwaj** during a period from August 2014 to May 2015 under the supervision of **Mr. Anil Dhiman** Assistant Professor, Civil Engineering Department, Jaypee University of Information Technology, Waknaghat.

The above statement made is correct to the best of my knowledge.

Date:

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ACKNOWLEDGEMENT

The success of any project depends largely on the encouragement and guidelines of many others. Therefore we take this opportunity to express our sincere gratitude to the people who have been instrumental in the successful completion of the project.

We would like to express our sincere appreciation and gratitude to our guide **Mr. Anil Dhiman** without whose able guidance, tremendous support and continuous motivation the project would not have been carried to perfection. We sincerely thank him for spending all his valuable time and energies during the execution of project.

We take this opportunity to express our sincere gratitude to the Professor and Head of Department of Civil Engineering, **Dr. Ashok Kumar Gupta** for all his support and valuable inputs. We thank him for reviving Civil Engineering as the overall mentor by leading with a vision and teaching us with a knowledge imparting attitude.

The successful compilation of final year project depends on the knowledge and attitude inculcated in the total length of course. So we want to express our sincere gratitude to all the faculties who taught us during the four years of B.Tech.

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ABSTRACT

India has a large population spread all over the country and huge demand of electricity supply by this population creates requirement of a large transmission and distribution system. In the project, transmission towers have been designed with foundations for two different zones differing in basic wind speed and terrain category. Optimization in terms of members' requirement also has been done. This task has been achieved using Staad.pro and MS Excel-VBA. Three different bracing systems were compared on the basis of various parameters like deflection, weight, number of joints and cost. Analysis of the tower under various types of loading has been done using STAAD.pro and Excel-VBA interface was used for connections and foundation design. This work has focused on techno-economical analysis and design of transmission line tower structures. As far as the deflection criterion is concerned, the K bracing tower exhibited the least deflection under the given loading conditions cases for both the zones.

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SECTION 1
INTRODUCTION

1.1 General

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. Also, the disposition of the primary resources for electrical power generation viz., coal, hydro potential is quite uneven, thus again adding to the transmission requirements. 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. The supporting structure types used in transmission lines generally fall into one of the three categories: lattice, pole and guyed. The supports of EHV transmission lines are normally steel lattice towers. The cost of towers constitutes about quarter to half of the cost of transmission line and hence optimum tower design will bring in substantial savings. The selection of an optimum outline together with right type of bracing system contributes to a large extent in developing an economical design of transmission line tower. The height of tower is fixed by the user and the structural designer has the task of designing the general configuration and member and joint details. The goal of every designer is to design the best (optimum) systems. But, because of the practical restrictions this has been achieved through intuition, experience and repeated trials, a process that has worked well.

1.2 Objectives of the Present Work

- To design transmission tower with three different configurations (on the basis of different Bracing Systems) for a given scenario and selecting the most economical design.
- Towers in plain and hilly regions will be considered, in two separate stages.

- Parameters for comparison are :

  Weight of Tower

  Various Stresses

  Foundation

  Cost (Member cost, Joint cost, Labour cost)

1.3 Introduction to STAAD.pro

Before the availability of computers and specialized analysis and design programs, towers were often designed by graphical methods. It was considered prudent to test new designs that would be used repeatedly on a transmission line, thereby confirming the design assumptions with a full-scale test. Today's analysis tools allow engineers to refine designs to an unprecedented degree, and as a result, many utilities feel testing is not warranted. However, while great strides have been made in the analysis and design of latticed steel transmission towers, differences between analysis results and full-scale tests still occur.

STAAD.Pro features a state-of-the-art user interface, visualization tools, powerful analysis and design engines with advanced finite element and dynamic analysis capabilities. From model generation, analysis and design to visualization and result verification, STAAD.Pro is the professional's choice for steel, concrete, timber, aluminum and cold-formed steel design of low and high-rise buildings, culverts, petrochemical plants, tunnels, bridges, piles and much more. The following key STAAD.Pro tools help simplify ordinarily tedious tasks:

- The STAAD.Pro Graphical User Interface incorporates Research Engineers' innovative tabbed page layout. By selecting tabs, starting from the top of the screen and heading down, you input all the necessary data for creating, analyzing and designing a model. Utilizing tabs minimizes the learning curve and helps insure you never miss a step.
- The STAAD.Pro Structure Wizard contains a library of trusses and frames. Use the Structure Wizard to quickly generate models by specifying height, width, breadth and number of bays in each direction. Create any customizable parametric structures for repeated use. Ideal for skyscrapers, bridges and roof structures.

1.3.1 *Features of STAAD.Pro*

- "Concurrent Engineering" based user environment for model development, analysis, design, visualization and verification

- Full range of analysis including static, P-delta, pushover, response spectrum, time history, cable (linear and non-linear), buckling and steel, concrete and timber design included with no extra charge
- Object-oriented intuitive 2D/3D graphical model generation
- Pull down menus, floating tool bars, tool tip help
- Quick data input through property sheets and spreadsheets

1.3.2 *Load Types and Generation*

- Categorized load into specific load group types like dead, wind, live, seismic, snow, user-defined, etc. Automatically generate load combinations based on standard loading codes such as ASCE etc.
- One way loading to simulate load distribution on one-way slabs
- Patch and pressure loading on solid (brick) elements
- Element pressure loads can be applied along a global direction on any imaginary surface without having elements located on that surface
- Automatic wind load generator for complex inclined surfaces, irregular panels and multiple levels also taking into consideration user-defined panels
- Loading for Joints, Members/Elements including Concentrated, Uniform Linear, Trapezoidal, Temperature, Strain, Support Displacement, Priestess and Fixed-end Load

1.4 Introduction to Excel VBA

- The Windows version of Excel supports programming through Microsoft's Visual Basic for Applications (VBA), which is a dialect of Visual Basic. Programming with VBA allows spreadsheet manipulation that is awkward or impossible with standard spreadsheet techniques. Programmers may write code directly using the Visual Basic Editor (VBE), which includes a window for writing code, debugging code, and code module organization environment. The user can implement numerical methods as well as automating tasks such as formatting or data organization in VBA and guide the calculation using any desired intermediate results reported back to the spreadsheet.
- A common and easy way to generate VBA code is by using theMacro Recorder. The Macro Recorder records actions of the user and generates VBA code in the form of a macro. These actions can then be repeated automatically by running the macro. The

macros can also be linked to different trigger types like keyboard shortcuts, a command button or a graphic. The actions in the macro can be executed from these trigger types or from the generic toolbar options. The VBA code of the macro can also be edited in the VBE. Certain features such as loop functions and screen prompts by their own properties, and some graphical display items, cannot be recorded, but must be entered into the VBA module directly by the programmer. Advanced users can employ user prompts to create an interactive program, or react to events such as sheets being loaded or changed.

- VBA code interacts with the spreadsheet through the Excel Object Model a vocabulary identifying spreadsheet objects, and a set of supplied functions or methods that enable reading and writing to the spreadsheet and interaction with its users (for example, through custom toolbars or command bars and message boxes). User-created VBA subroutines execute these actions and operate like macros generated using the macro recorder, but are more flexible and efficient.

SECTION 2
TRANSMISSION TOWERS

2.1 Details of Tower

In the present section, the tower has been detailed for its location, type and kind of constituent members.

2.1.1 *Introduction to Tower*

A tower or mast is a tall skeleton structure with a relatively small cross-section, which has a large ratio between height and maximum width. A tower is a freely standing self supporting structure fixed to the base or foundation.

In developed countries the environmental impact of the traditional transmission towers is no longer accepted. Currently available design solutions with acceptable appearance are not employed in the developing countries, mainly for cost reasons. In the developing countries the use of the traditional lattice transmission towers will continue employing steel angles. A comparison of the available design specifications for steel angles in transmission towers is presented.

Generally towers are made up of a material called steel. Steel towers (short, medium and tall) are normally used for the following purposes:

(i) Electric power transmission
(ii) Microwave transmission for communication
(iii) Radio transmission (short and medium wave wireless)
(iv) Television transmission
(v) Satellite reception
(vi) Air traffic control
(vii) Flood light stand
(viii) Metrological measurements
(ix) Derrick and crawler cranes
(x) Oil drilling masts
(xi) Over head tanks

Further classification of towers depending upon their heights is as follows:

The height of towers for electric power transmission may vary from 10 to 45 m while those for flood lights in stadiums and large flyover intersections may vary from 15 to 50m. The height of television towers may vary from 100 m to 300 m while for those for radio transmission and communication networks the height may vary from 50 to 200m.

Depending upon the size and type of loading, towers are grouped into two heads:

(a) Towers with large vertical loads

(b) Towers with mainly horizontal wind loads

Towers with large vertical loads (such as those of over head water tanks, oil tanks, metrological instrumentation towers etc.) have their sides made up of vertical or inclined trusses.

The towers, falling under the second category and subjected predominantly to wind loads, may be classified in to two types:

(1) Self-supporting towers

(2) Guyed towers

(1) Self-supporting towers

Self-supporting towers or free standing towers are known as lattice towers. These are generally square in plan and are supported by four legs, fixed to the base.

These towers act as vertical cantilever trusses, subjected to wind and/or seismic loads. Free standing towers are commonly used for T.V., microwave transmission, power transmission, flood light holding.

The free standing towers for power transmission have arms to both the sides of the centre line, to carry power transmission lines.

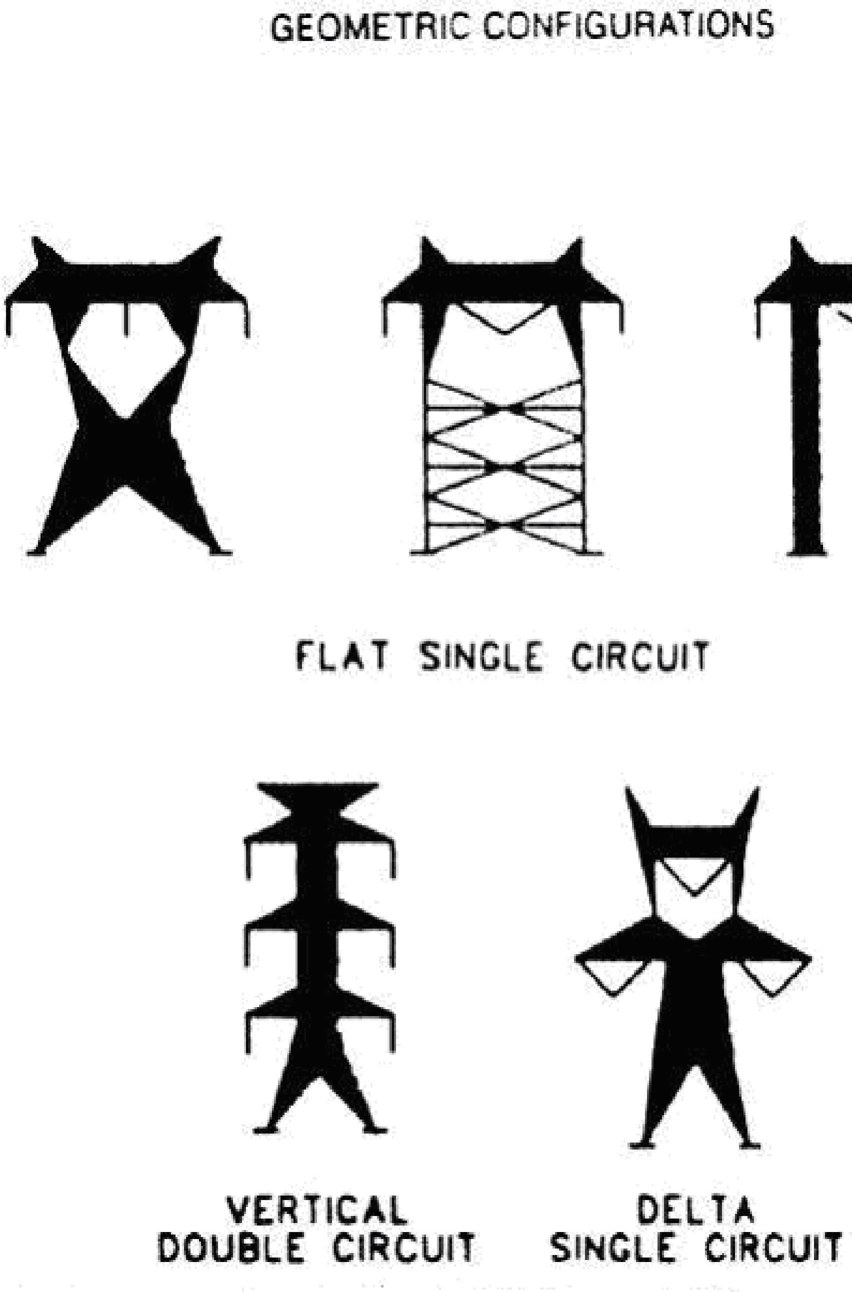

Figure 1: Self Supporting Towers

(2) Guyed towers

Guyed towers are hinged to the base**,** and are supported by guy wires attached to it at various levels, to transmit the wind forces to the ground. Due to this reason, guyed tower of the same height is much lighter than a self- supporting tower. However, it requires much larger space in plan, to accommodate the placement of guy ropes. Guyed towers are mostly known as masts, having three or four legs and triangular or rectangular configuration in plan.

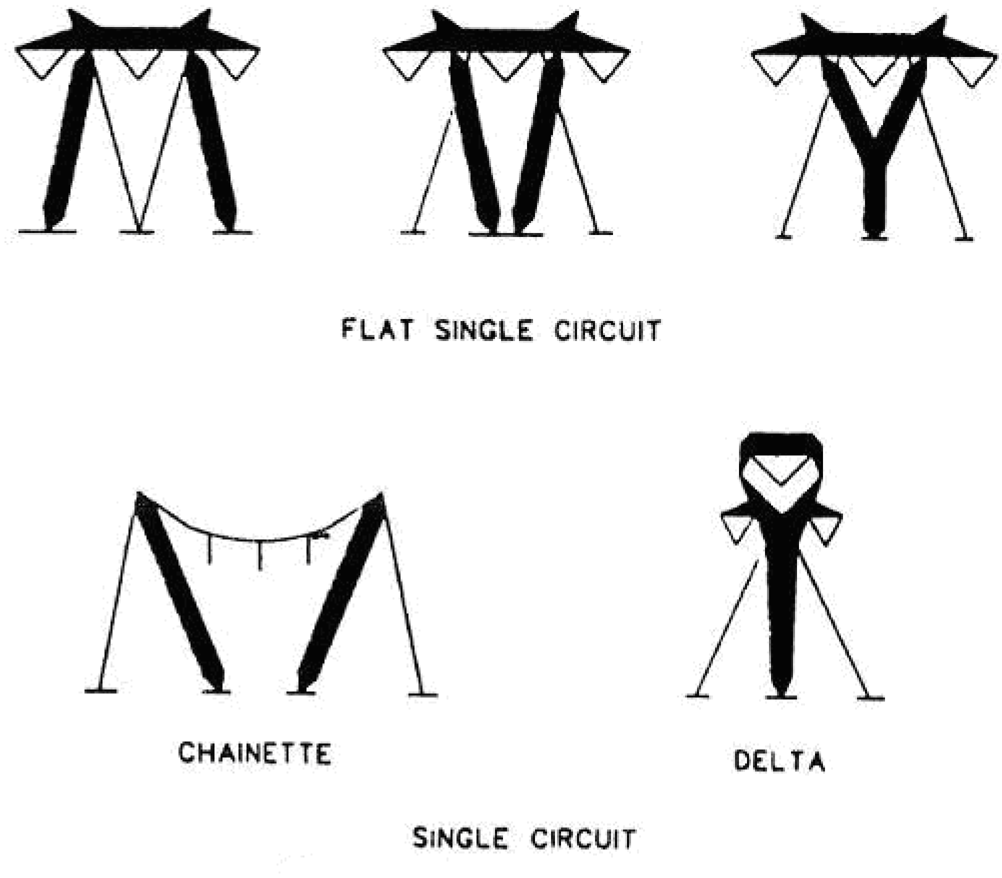

Figure 2: Guyed Towers

2.1.2 *Lattice tower*

The self supporting towers, subjected predominantly to wind loads, are called lattice towers. Such towers are square or rectangular in plan. The width b of the side face at the base may vary between 1/8 to 1/12 of the height H of the tower. The top width of towers is kept between 1.5 to 3m or more, depending upon the requirement.

There are ten types of bracing systems for a lattice tower configuration. Those ten types are as follows:

1.Single diagonal bracings: this is the simplest form of bracing. The wind shear at any level is shared by the single diagonal of the panel. Such bracing is used for towers upto 30m height.

2.X-X bracing: this is a doublediagonal system without horizontal bracing, used for towers upto 50m height. It is a statically determinate structure.

3. X-B bracing: this is a double diagonal system with horizontal bracings. Such bracings are quite rigid, and may be used for towers upto 50m height. The structure is statically indeterminate. The horizontal members are redundant members and carry only nominal stresses.

4. K-bracing: such a bracing gives large head room, and hence K-bracing can be used in lower panels where large head room is required. The structure is statically determinate. Such bracing can be used for towers of 50 to 200m height. In most of the transmission line towers, the lower panels is either K- or Y- braced and upper panels are X-braced or XB-braced.

5. X B X bracing: this is a combination XX and XB bracing where horizontal members are provided only at the level of crossing of diagonals. The structure is statically indeterminate. However, the length of the diagonal is reduced. The system is suitable for towers 50 to 200m height.

6. W-bracing: this system uses a number of overlapping diagonals. The system is statically indeterminate. However, the effective length of diagonals is reduced the system is quite rigid and may be used for towers of 50 to 20m height.

7. Y-bracing: this system gives larger head room can be used for lower panels. The system is statically determinate. In most of the transmission line towers, lower panels are either Y-braced on k-braced and upper panels are X-B braced or X-braced.

8. Arch bracing: such a bracing can be adopted for wider panels. This system also provides greater head room. The system is statically determinate.

9. Subdivided V-bracing: such a bracing are used for tall towers of communication systems, radio and TV transmission etc; for heights between 50 to 200m.

10. Diamond lattice system: A typical diamond lattice system is used for towers of 100 to 200m height. The base width is kept at 1/5 to 1/6 of the height. Rigid horizontal diaphragms are used at top and at intermediate sections, preferably at intervals of 25 to 30m, to increase the torsional stiffness of the cross-arm.

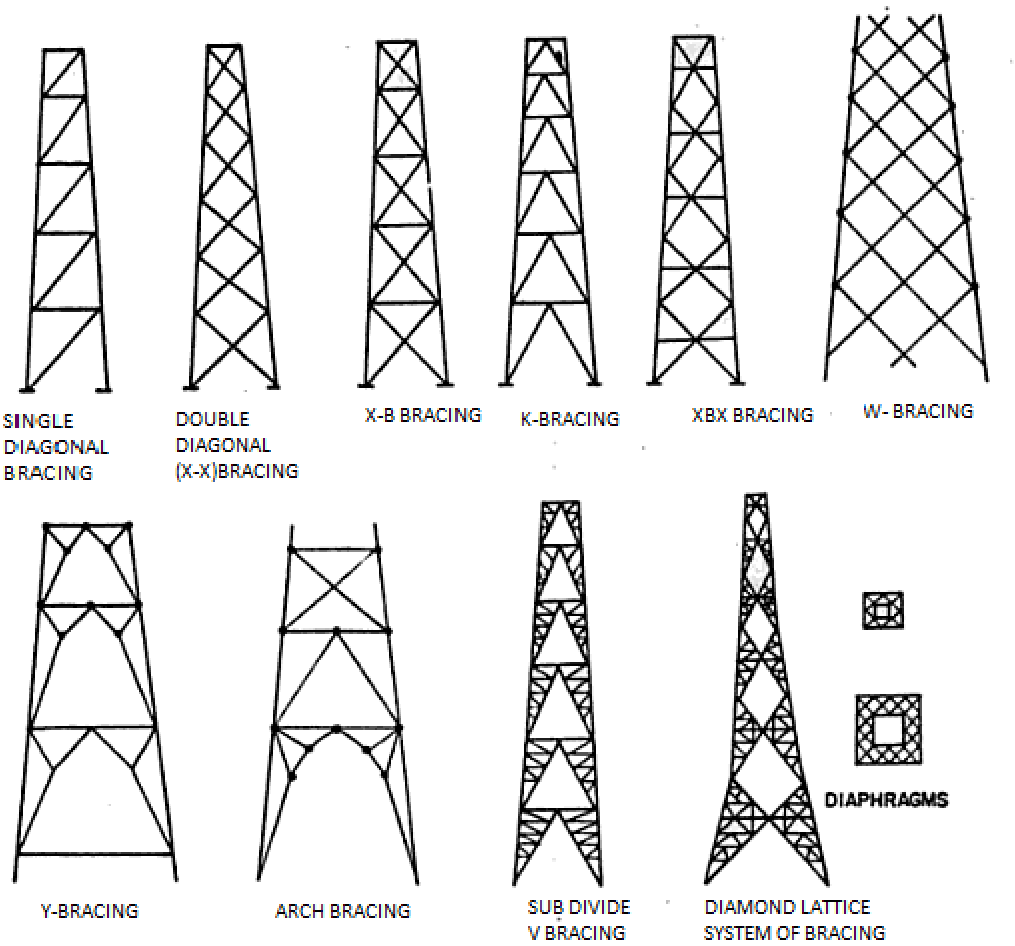

Figure 3: Lattice tower configurations with Bracing systems.

SECTION 3
PROBLEM DEFINITION AND METHODOLOGY

3.1 Problem Definition

In the problem three different towers in two different wind zones, i.e, Himachal Pradesh (39 m/s) and Haryana (47 m/s) have been considered. Different loads considered to be acting on these towers are:

1. Self-weight of tower
2. Weight of conductor
3. Wind load (x and z directions)
4. Wind load on conductor and ground wire
5. Broken wire load (security considerations)
6. Linemen with tools (safety considerations).

Analysis and optimum design of towers has been done for the following requirements and configuration:

- Transmission tower for 220 kV-3 phase-single-circuit.
- Suspension and Tangent tower (0° – 2°)
- Height = 28.2 m, Base width = 4.72 m
- Batter width = 1.5 m
- Deviation angle= 79° (40°-90°)
- Shielding Angle = 30°
- Sag = 8 m
- Wind speed = 39m/s and 41m/s(IS-802 (Part 1)-1995)
- Conductor Wire ACSR ZEBRA (Properties in Table No. 1)
- Earth wire (Properties in Table No. 2)

Table 1: Conductor wire electrical and mechanical 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 mm2
Overall diameter	28.62 mm
Approx. Weight	1621 Kg/ Km
Calculated D.C resistance at 20 0C	0.06915 ohm/Km
Min.UTS	130.32 kN
Modulus of elasticity	7034 Kg/mm2
Co – efficient of linear expansion	19.30 x 10-6/ 0C
Max. Allowable temperature	750C

Table 2: Earth Wire Electrical and Mechanical 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 mm2
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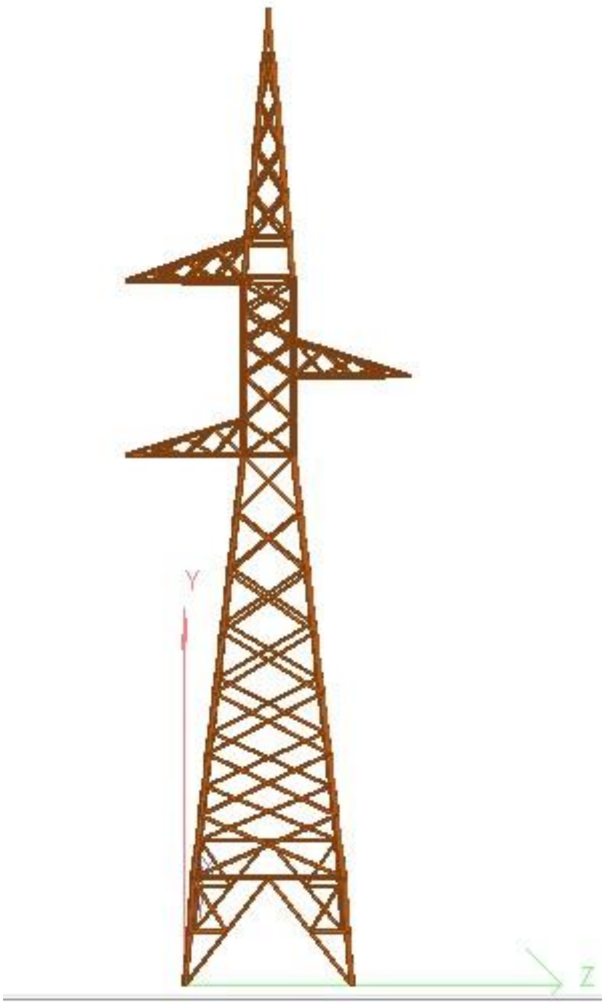


Figure 4: X-X Bracing

Figure 5: X-B Bracing

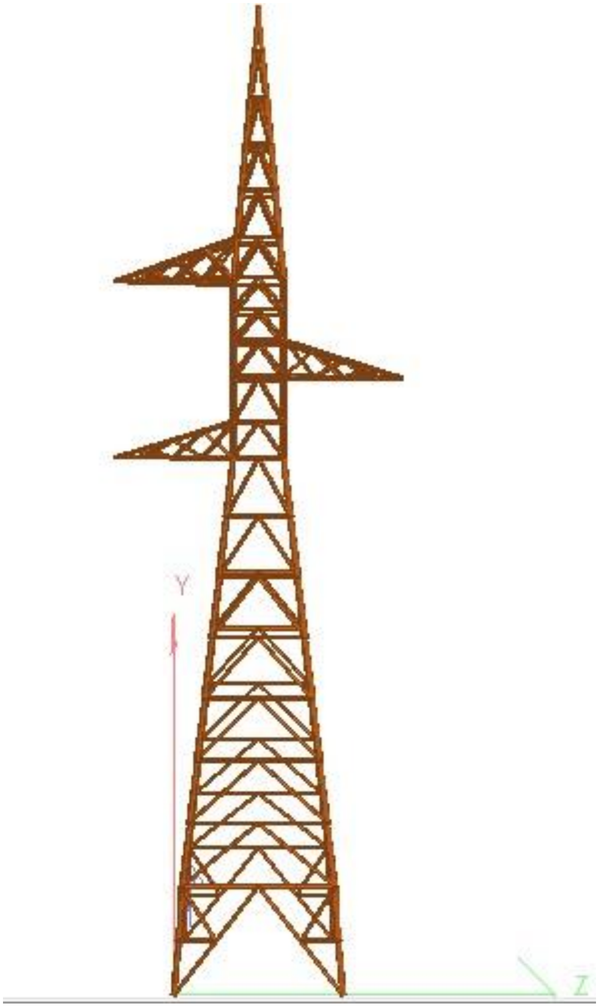


Figure 6 :K Bracing

SECTION 4

LOAD CALCULATIONS AND ANALYSIS

4.1 Load Calculation

4.1.1 *Self weight*

The self weight is precisely considered as the dead load of the structure as these loads ***neither*** change their position ***nor do they*** vary their magnitude. Actually, according to IS 1911:1967, the density of steel is 7850 kg/m^3 but we have assumed the self weight of both super and substructure of the tower as 1 kn/m^2 in downward direction.

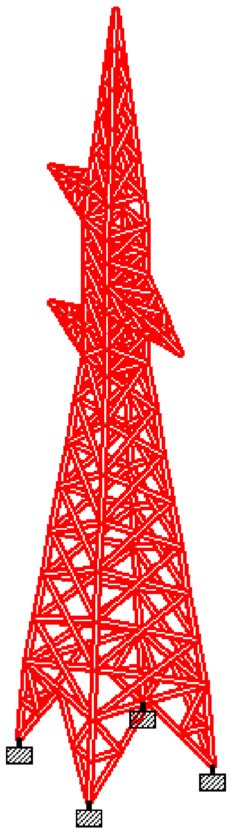


Figure 7: Self Weight

4.1.2 *Wind Load*

Theterm wind denotes almost exclusively to horizontal wind. Wind pressure, therefore, acts horizontally on the exposed surfaces of towers.

Here, we have followed Design wind speed as per IS: 875-1987. The design wind speed (V_z) is obtained by multiplying the basic wind speed (V_b) by the factors k_1, k_2 and k_3

$$V_z = V_b \times k_1 \times k_2 \times k_3$$

where,

V_b = the basic wind speed in m/s at 10 m height

k_1 = probability factor (or risk coefficient)

k_2 = terrain, height and structure size factor

k_3 = topography factor.

The basic wind speed of Shimla is taken as 39 m/s as per IS-875:1987 Part-III.

Probability factor (or risk coefficient) k_1

The factor k_1 is based on statistical concept which take account of degree of reliability required a period of time in years during which there will be exposure to wind. In actual practice the factor $k_1$depends on type and importance of structure, design life of structure and basic wind speed in the region.

Table 3 Values of Factor k_1

Class of structure	Mean probable design life of Structure (years)	k_1 factor for basic design wind speed					
		33	39	44	7	50	55
1. All general buildings and structures	50	1.0	1.0	1.0	1.0	1.0	1.0
2. Temporary sheds and structures Under Construction	5	0.82	0.76	0.73	0.71	0.70	0.67
3. Buildings and structures presenting a low degree of hazard to life and property in event of failure	25	0.94	0.92	0.91	0.90	0.90	0.89
4. Important buildings and structures such as hospitals an communication buildings (tower, power plant structures etc.)	100	1.05	1.06	1.07	1.07	1.08	1.08

Terrain, height and structure size factor k_2

This factor takes into account terrain roughness, height and size of structure for determining k_2. Terrains are classified in to four categories and structures according to their heights into three classes.

Categories of structure

There are mainly four categories of structure for terrain, height and structure size which are as follows:

Category 1:

This represents exposed open terrain with few or no obstructions i.e. open sea coasts and flat treeless plains.

Category 2:

This represents open terrain with well scattered obstructions having height between 1.5 to 10 m., i.e. air fields, under developed built-up outskirts of towns and suburbs.

Category 3:

This represents terrain with numerous closely spaced obstructions. This category includes well wooded areas, shrubs, towns and industrial areas fully or partially developed.

Category 4:

This represents terrain with numerous large high closely spaced obstructions above 25m., i.e. large city centers.

Classes of structure

There are mainly three Classes of structure are as follows:

Class A: Structures having maximum dimension less than 20m.

Class B: Structures having maximum dimension between 20 to 50m.

Class C: Structures having maximum dimension greater than 50m

Table 4 Values of factor k_2.

Height (m)	Terrain Category 1			Terrain Category 2			Terrain Category 3			Terrain Category 4		
	Class			Class			Class			Class		
	A	B	C	A	B	C	A	B	C	A	B	C
10	1.05	1.03	0.99	1.0	0.98	0.93	0.91	0.88	0.82	0.80	0.76	0.67
15	1.09	1.07	1.03	1.05	1.02	0.97	0.97	0.94	0.87	0.80	0.76	0.67

20	1.12	1.10	1.06	1.07	1.05	1.0	1.01	0.98	0.91	0.80	0.76	0.67
30	1.15	1.13	1.09	1.12	1.10	1.04	1.06	1.03	0.96	0.97	0.93	0.83
50	1.20	1.18	1.14	1.17	1.15	1.10	1.12	1.09	1.02	1.10	1.05	0.95
100	1.26	1.24	1.20	1.24	1.22	1.17	1.20	1.17	1.10	1.20	1.15	1.05
150	1.30	1.28	1.24	1.28	1.25	1.21	1.24	1.21	1.15	1.24	1.20	1.10
200	1.32	1.30	1.26	1.30	1.28	1.24	1.27	1.24	1.18	1.27	1.22	1.13
250	1.34	1.32	1.28	1.32	1.31	1.26	1.29	1.26	1.20	1.28	1.24	1.16
300	1.35	1.34	1.30	1.34	1.32	1.28	1.31	1.28	1.22	1.30	1.26	1.17
350	1.37	1.35	1.31	1.36	1.34	1.29	1.32	1.30	1.24	1.31	1.27	1.19
400	1.38	1.36	1.32	1.37	1.35	1.30	1.34	1.31	1.25	1.32	1.28	1.20
450	1.39	1.37	1.33	1.38	1.36	1.31	1.35	1.32	1.26	1.33	1.29	1.21
500	1.40	1.38	1.34	1.39	1.37	1.32	1.36	1.33	1.28	1.34	1.30	1.22

Note: Intermediate values may be obtained by linear interpolation. It is permissible to assume constant wind speed between two heights, for simplicity.

Topography factor k_3

The value of $k_3$is varies from 1 to 1.4, depending upon the topography; for plain lands, k_3=1. Wind speed is affected by local topographic features such as hills, valleys, cliffs escarpments, or ridges. Hence while calculating design wind speed topography of the region is considered especially when the upwind slope (θ) is greater than 3^0 (below that $k_3$is taken as1.0) otherwise

$$k_3 = 1 + C \times s$$

C depends upon slopes as:

SLOPE	VALUE OF C
> 17º	0.36
3º< θ < 17º	1.2 (Z/L)

where,

Z = Height of crest or hill

L = Projected length of upwind zone

Design Wind pressure

The design wind pressure at any height above mean ground level is obtained by the following relationship:

$$p_z = 0.6\ V_z^2$$

where,

p_z = design wind pressure in N/m^2 at height z

V_z = design wind velocity in m/s at height z

Wind load on structure as a whole

The total wind load on a particular structure is given by

$$F = C_f \times A_e \times p_z \times \varphi$$

where ,

F = wind force acting in a direction specified

A_e= effective frontal area of the structure in m^2

p_z= design wind pressure in N/m^2

C_f= Net Wind force Coefficient for the building which depends upon solidity ratio φ of the tower.

$$\varphi = \text{Solidity ratio}$$

$$= \frac{\text{obstruction area of the frontal face}}{\text{gross area of the front face}}$$

For towers φ varies from 0.15 to 0.3 and it assumed in the beginning of the design

4.1.3 *Wind load Cable*

Wind load on conductor and ground wire is calculated on the basis of effective area which is resisting the wind, wind intensity at that height is multiplied with the effective surface area to get the load, which is transferred on the nodes of tower with help of connections.

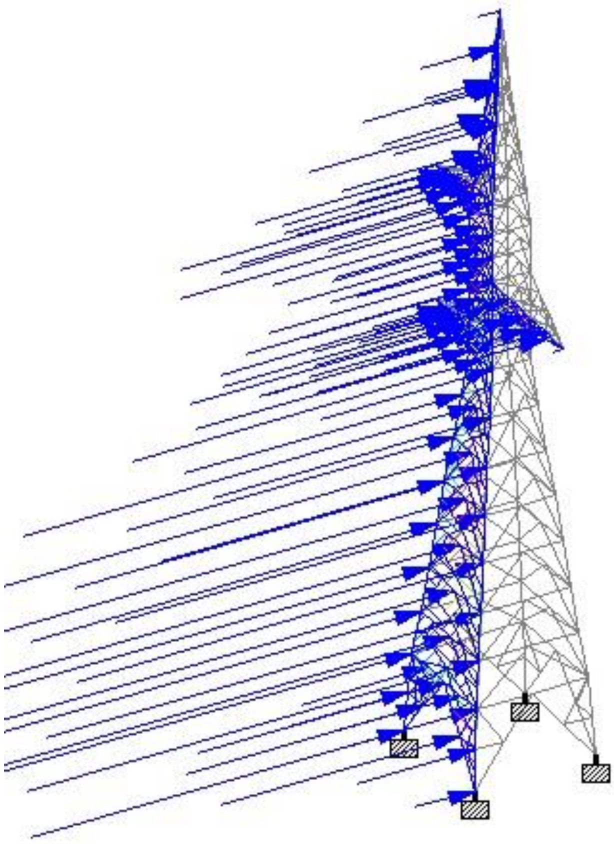


Figure 8: Wind Load

4.1.4 *Others loads*

- Weight of conductor and ground wire
- Line man with tools
- Broken wire Load

4.1.5 *Load Combination*

Load combinations are developed on the basis of the guidelines given in the code IS802 (Part 1/Sec1):1995 considering the reliability, security and safety.

Reliability:

- Self Weight + Wind Load(X Direction) + Weight of Conductors
- Self Weight + Wind Load(Z Direction) + Weight of Conductors + Wind Load on Conductor

Security:

- Self Weight + Reduced Conductor Weight + Broken Wire Load(Middle Conductor)

- Self Weight + Reduced Conductor Weight + Broken Wire Load(Ground Wire)

Safety:

- Self Weight + Conductor Weight + Load of lineman with tools

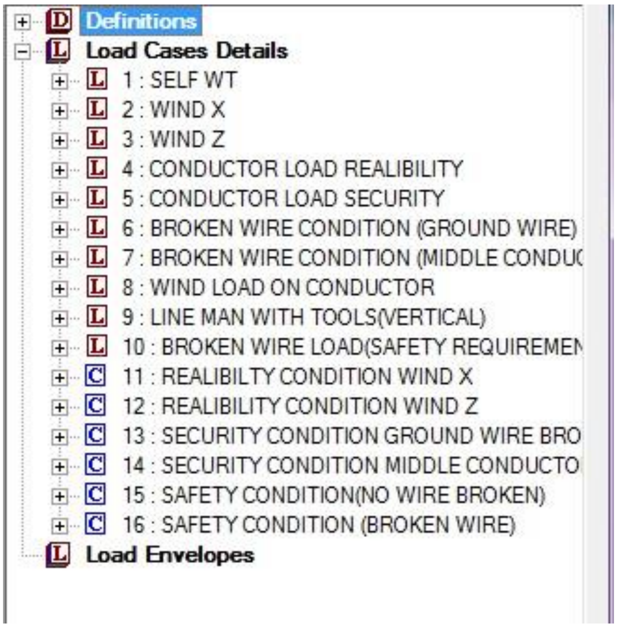


Figure 9: Load combinations

4.2 Structural Analysis

4.2.1 *Data Input for Analysis with STAAD.pro*

STAAD.pro requires data input in some form like graphical or text. The following data was fed to STAAD.pro graphically:

1. Member lengths and locations
2. Mutual Connectivity of members
3. Type of Supports
4. Assigning type and properties of members
5. Assignment of loads

Following data were inserted as text:

1. Load List for Analysis
2. Load Combination
3. Desired analysis results like Nodal displacements, Support reactions etc

4.2.2 *Member forces and nodal displacement values from analysis*

In this section, the analysis results for various cases considered are presented.

Zone 1, Himachal Pradesh (Basic Wind Speed = 39 m/sec)

X-X Bracing

Table 5: Max and min Member Forces (X-X Bracing)

	Beam	L/C	Node	FxkN	FykN	FzkN
Max Fx	9	12REALIBILITY CONDITION WIND Z	3	238.188	0.738	-0.498
Min Fx	35	12REALIBILITY CONDITION WIND Z	41	-193.970	-0.259	-0.190
Max Fy	25	15SAFETY CONDITION(NOWIRE BROKEN)	15	-44.475	4.875	10.266
Min Fy	27	15SAFETYCONDITION(NO WIRE BROKEN)	83	-10.163	-3.752	8.154
Max Fz	25	15SAFETY CONDITION(NOWIRE BROKEN)	15	-44.475	4.875	10.266
Min Fz	26	15SAFETY CONDITION(NOWIRE BROKEN)	14	26.114	4.559	-10.697

Table 6: Nodal Displacements (X-X Bracing)

			Horizontal	Vertical	Horizontal	Resultant
	Node	L/C	X mm	Y mm	Z mm	Mm
Max X	6	2 WIND X	88.693	0.039	0.021	88.693
Min X	60	12 REALIBILITY CONDITION WIND Z	-1.480	-1.271	-0.908	2.152
Max Y	87	12 REALIBILITY CONDITION WIND Z	-0.305	23.527	40.111	46.503
Min Y	20	15 SAFETY CONDITION(NO WIRE BROKEN)	24.778	-33.411	-5.561	41.966
Max Z	6	12 REALIBILITY CONDITION WIND Z	0.004	-1.077	138.470	138.474
Min Z	84	15 SAFETY CONDITION(NO WIRE BROKEN)	33.945	-3.697	-16.641	37.985

Table 7: Support reactions(X-X Bracing)

			Horizontal	Vertical	Horizontal	Moment		
	Node	L/C	FxkN	FykN	FzkN	MxkNm	My kNm	MzkNm
Max Fx	3	12 REALIBILITY CONDITION WIND Z	19.790	275.794	-43.623	0.972	-0.040	1.606
Min Fx	2	11 REALIBILTY CONDITION WIND X	-34.998	206.409	14.235	-1.215	0.031	-0.663
Max Fy	3	12 REALIBILITY CONDITION WIND Z	19.790	275.794	-43.623	0.972	-0.040	1.606
Min Fy	1	12 REALIBILITY CONDITION WIND Z	-15.592	-227.814	-41.010	-0.079	0.847	-1.721
Max Fz	2	11 REALIBILTY CONDITION WIND X	-34.998	206.409	14.235	-1.215	0.031	-0.663
Min Fz	3	12 REALIBILITY CONDITION WIND Z	19.790	275.794	-43.623	0.972	-0.040	1.606
Max Mx	1	2 WIND X	-34.114	-178.645	-12.034	1.469	-0.853	0.238
Min Mx	3	2 WIND X	-32.328	-177.184	12.919	-1.426	0.838	0.184
Max My	1	12 REALIBILITY CONDITION WIND Z	-15.592	-227.814	-41.010	-0.079	0.847	-1.721

X-B Bracing

Table 8: Max and Min Member Forces(X-B Bracing)

	Beam	L/C	Node	FxkN	FykN	FzkN
Max Fx	1	12 REALIBILITY CONDITION WIND Z	1	183.369	0.592	-0.266
Min Fx	25	12 REALIBILITY CONDITION WIND Z	32	-134.960	-0.291	-0.234
Max Fy	194	15 SAFETY CONDITION(NO WIRE BROKEN)	67	34.888	4.768	0.176
Min Fy	332	15 SAFETY CONDITION(NO WIRE BROKEN)	125	48.357	-3.357	0.485
Max Fz	288	12 REALIBILITY CONDITION WIND Z	114	-2.631	-0.446	1.243
Min Fz	381	15 SAFETY CONDITION(NO WIRE BROKEN)	129	-13.459	0.864	-1.733

Table 9: Nodal Displacement(X-B Bracing)

			Horizontal	Vertical	Horizontal	Resultant
	Node	L/C	X mm	Y mm	Z mm	Mm
Max X	99	11 REALIBILTY CONDITION WIND X	52.320	-1.160	1.761	52.362
Min X	46	12 REALIBILITY CONDITION WIND Z	-1.125	-0.955	-0.657	1.615
Max Y	79	12 REALIBILITY CONDITION WIND Z	1.354	21.511	55.887	59.899
Min Y	88	12 REALIBILITY CONDITION WIND Z	-0.451	-23.987	40.481	47.056
Max Z	99	12 REALIBILITY CONDITION WIND Z	1.488	-1.048	99.905	99.922
Min Z	99	1 SELF WT	0.087	-0.860	-1.879	2.068

Table 10: Support Reactions(X-B Bracing)

		Horizontal	Vertical	Horizontal	Moment			
Node	L/C	FxkN	FykN	FzkN	MxkNm	My kNm	MzkNm	Node
1	1 SELF WT	1.793	21.434	-1.900	0.152	0.002	0.156	1
	2 WIND X	-20.932	-107.273	7.837	-0.896	0.616	0.245	
	3 WIND Z	5.473	76.192	-13.781	0.211	-0.031	0.405	
	4 CONDUCTOR LOAD REALIBILITY	0.530	6.071	-0.257	0.046	-0.004	0.032	
	5 CONDUCTOR LOAD SECURITY	0.318	3.643	-0.154	0.028	-0.003	0.019	
	6 BROKEN WIRE CONDITION (GROUND WIRE)	-3.243	-4.364	0.285	-0.032	0.028	0.099	
	7 BROKEN WIRE CONDITION (MIDDLE CONDUCTOR)	-8.604	-37.067	-0.897	-0.340	0.036	-0.027	
	8 WIND LOAD ON CONDUCTOR	7.846	102.763	-12.041	0.483	-0.011	0.586	
	9 LINE MAN WITH TOOLS(VERTICAL)	0.433	5.247	-0.213	0.040	-0.003	0.029	

K Bracing

Table 11: Max and Min forces in members (K bracing)

	Beam	L/C	Node	FxkN	FykN	FzkN
Max Fx	3	12 REALIBILITY CONDITION WIND Z	5	201.807	0.490	1.910
Min Fx	141	12 REALIBILITY CONDITION WIND Z	33	-168.626	0.210	-0.321
Max Fy	194	15 SAFETY CONDITION(NO WIRE BROKEN)	67	44.876	13.499	1.615
Min Fy	340	15 SAFETY CONDITION(NO WIRE BROKEN)	68	-13.529	-4.277	-0.174
Max Fz	151	15 SAFETY CONDITION(NO WIRE BROKEN)	13	60.155	0.557	4.826
Min Fz	3	15 SAFETY CONDITION(NO WIRE BROKEN)	5	71.440	-0.207	-2.738

Table 12: Nodal Displacement (K bracing)

			Horizontal	Vertical	Horizontal	Resultant
	Node	L/C	X mm	Y mm	Z mm	Mm
Max X	99	11 REALIBILTY CONDITION WIND X	44.454	-0.235	4.649	44.697
Min X	82	16 SAFETY CONDITION (BROKEN WIRE)	-10.307	1.068	0.377	10.369
Max Y	79	12 REALIBILITY CONDITION WIND Z	6.948	28.563	55.591	62.885
Min Y	88	12 REALIBILITY CONDITION WIND Z	2.445	-25.189	37.076	44.890
Max Z	99	12 REALIBILITY CONDITION WIND Z	10.848	2.305	107.633	108.203
Min Z	167	2 WIND X	1.233	0.501	-4.225	4.429

Table 13: Support reactions (K Bracing)

			Horizontal	Vertical	Horizontal	Moment		
	Node	L/C	FxkN	FykN	FzkN	MxkNm	My kNm	MzkNm
Max Fx	9	12 REALIBILITY CONDITION WIND Z	13.785	-192.742	-31.737	-0.601	-0.567	0.948
Min Fx	5	11 REALIBILTY CONDITION WIND X	-22.718	152.283	-12.717	1.029	-0.065	0.777
Max Fy	5	12 REALIBILITY CONDITION WIND Z	-16.509	230.147	-36.581	-1.158	-0.003	-1.374
Min Fy	9	12 REALIBILITY CONDITION WIND Z	13.785	-192.742	-31.737	-0.601	-0.567	0.948
Max Fz	1	2 WIND X	-22.392	-130.625	11.197	-1.000	0.715	1.380
Min Fz	5	12 REALIBILITY CONDITION WIND Z	-16.509	230.147	-36.581	-1.158	-0.003	-1.374
Max Mx	5	15 SAFETY CONDITION(NO WIRE BROKEN)	-21.771	86.743	-2.054	1.739	0.309	2.065
Min Mx	1	12 REALIBILITY CONDITION WIND Z	11.940	171.862	-25.773	-1.169	0.123	1.366
Max My	1	2 WIND X	-22.392	-130.625	11.197	-1.000	0.715	1.380

Zone 2, Haryana (Basic Wind Speed = 47 m/sec)

X-X Bracing

Table 14: Max and Min Member Forces(X-X Bracing)

	Beam	L/C	Node	FxkN	FykN	FzkN
Max Fx	11	12 REALIBILITY CONDITION WIND Z	4	281.015	0.924	1.970
Min Fx	152	12 REALIBILITY CONDITION WIND Z	24	-231.711	0.371	-1.548
Max Fy	25	15 SAFETY CONDITION(NO WIRE BROKEN)	15	-43.323	7.347	9.685
Min Fy	27	15 SAFETY CONDITION(NO WIRE BROKEN)	83	-16.480	-6.016	9.551
Max Fz	25	15 SAFETY CONDITION(NO WIRE BROKEN)	15	-43.323	7.347	9.685
Min Fz	28	15 SAFETY CONDITION(NO WIRE BROKEN)	16	55.010	-5.584	-10.725

Table 15: Nodal Displacement (X-X Bracing)

			Horizontal	Vertical	Horizontal	Resultant
	Node	L/C	X mm	Y mm	Z mm	Mm
Max X	6	2 WIND X	65.199	0.499	6.357	65.510
Min X	87	14 SECURITY CONDITION MIDDLE CONDUCTOR BROKEN	-3.849	-3.091	-0.197	4.941
Max Y	20	12 REALIBILITY CONDITION WIND Z	3.527	24.048	54.041	59.255
Min Y	90	12 REALIBILITY CONDITION WIND Z	5.154	-26.295	35.638	44.588
Max Z	6	12 REALIBILITY CONDITION WIND Z	8.381	1.533	113.325	113.644
Min Z	109	15 SAFETY CONDITION(NO WIRE BROKEN)	41.271	-2.406	-11.787	42.989

Table 16: Support Reaction (X-X Bracing)

		Horizontal	Vertical	Horizontal	Moment			
Node	L/C	FxkN	FykN	FzkN	MxkNm	My kNm	MzkNm	Node
1	1 SELF WT	1.298	17.288	1.282	-0.069	0.000	0.068	1
	2 WIND X	-33.453	-141.515	-7.369	0.908	-0.631	0.893	
	3 WIND Z	-7.393	-130.272	-30.154	-0.825	0.617	-0.820	
	4 CONDUCTOR LOAD REALIBILITY	0.332	5.709	0.153	-0.023	0.001	0.015	
	5 CONDUCTOR LOAD SECURITY	0.199	3.425	0.092	-0.014	0.001	0.009	
	6 BROKEN WIRE CONDITION (GROUND WIRE)	-2.074	-25.980	-1.604	0.079	-0.001	-0.059	
	7 BROKEN WIRE CONDITION (MIDDLE CONDUCTOR)	0.568	-30.462	-5.916	-0.080	0.028	-0.218	
	8 WIND LOAD ON CONDUCTOR	-4.995	-90.764	-11.397	0.053	0.027	-0.349	
	9 LINE MAN WITH TOOLS(VERTICAL)	0.278	4.768	0.120	-0.019	0.001	0.012	

X-B Bracing

Table 17: Max and Min Member Forces(X-B Bracing)

	Beam	L/C	Node	FxkN	FykN	FzkN
Max Fx	24	12 REALIBILITY CONDITION WIND Z	29	203.926	-0.325	0.705
Min Fx	141	12 REALIBILITY CONDITION WIND Z	33	-148.769	0.273	-0.281
Max Fy	194	15 SAFETY CONDITION(NO WIRE BROKEN)	67	39.228	6.641	0.485
Min Fy	332	15 SAFETY CONDITION(NO WIRE BROKEN)	125	47.521	-5.098	0.212
Max Fz	151	15 SAFETY CONDITION(NO WIRE BROKEN)	13	48.255	0.508	2.126
Min Fz	3	15 SAFETY CONDITION(NO WIRE BROKEN)	5	86.383	-0.085	-2.777

Table 18: Nodal Displacement (X-B Bracing)

			Horizontal	Vertical	Horizontal	Resultant
	Node	L/C	X mm	Y mm	Z mm	Mm
Max X	99	11 REALIBILTY CONDITION WIND X	55.947	-0.456	2.747	56.016
Min X	82	14 SECURITY CONDITION MIDDLE CONDUCTOR BROKEN	-1.118	-0.607	-0.423	1.341
Max Y	79	12 REALIBILITY CONDITION WIND Z	3.481	28.520	53.759	60.956
Min Y	88	12 REALIBILITY CONDITION WIND Z	2.355	-25.265	35.515	43.649
Max Z	99	12 REALIBILITY CONDITION WIND Z	6.628	1.788	106.917	107.137
Min Z	99	1 SELF WT	-0.508	-0.602	-3.550	3.636

Table 19: Support Reactions (X-B Bracing)

			Horizontal	Vertical	Horizontal	Moment		
	Node	L/C	FxkN	FykN	FzkN	MxkNm	My kNm	MzkNm
Max Fx	1	12 REALIBILITY CONDITION WIND Z	15.103	191.887	-24.058	-0.526	0.116	1.034
Min Fx	5	15 SAFETY CONDITION(NO WIRE BROKEN)	-23.266	102.865	-3.651	1.751	0.284	1.980
Max Fy	5	12 REALIBILITY CONDITION WIND Z	-14.262	219.218	-29.667	-1.057	-0.196	-1.598
Min Fy	9	12 REALIBILITY CONDITION WIND Z	10.106	-161.740	-22.539	-0.118	-0.133	0.640
Max Fz	1	2 WIND X	-19.792	-148.641	12.805	-0.715	0.169	0.562
Min Fz	5	12 REALIBILITY CONDITION WIND Z	-14.262	219.218	-29.667	-1.057	-0.196	-1.598
Max Mx	5	15 SAFETY CONDITION(NO WIRE BROKEN)	-23.266	102.865	-3.651	1.751	0.284	1.980
Min Mx	5	12 REALIBILITY CONDITION WIND Z	-14.262	219.218	-29.667	-1.057	-0.196	-1.598
Max My	5	15 SAFETY CONDITION(NO WIRE BROKEN)	-23.266	102.865	-3.651	1.751	0.284	1.980

K Bracing

Table 20: Max and Min Member Forces(K Bracing)

	Beam	L/C	Node	FxkN	FykN	FzkN
Max Fx	3	12 REALIBILITY CONDITION WIND Z	5	204.771	0.305	2.211
Min Fx	141	12 REALIBILITY CONDITION WIND Z	33	-171.881	0.331	-0.318
Max Fy	194	15 SAFETY CONDITION(NO WIRE BROKEN)	67	44.705	13.488	1.623
Min Fy	340	15 SAFETY CONDITION(NO WIRE BROKEN)	68	-13.357	-4.274	-0.175
Max Fz	151	15 SAFETY CONDITION(NO WIRE BROKEN)	13	59.550	0.556	4.820
Min Fz	3	15 SAFETY CONDITION(NO WIRE BROKEN)	5	72.613	-0.183	-2.840

Table 21: Nodal Displacement (K Bracing)

			Horizontal	Vertical	Horizontal	Resultant
	Node	L/C	X mm	Y mm	Z mm	Mm
Max X	99	11 REALIBILTY CONDITION WIND X	42.085	-0.217	6.860	42.641
Min X	82	14 SECURITY CONDITION MIDDLE CONDUCTOR BROKEN	-10.044	0.394	0.609	10.070
Max Y	79	12 REALIBILITY CONDITION WIND Z	10.262	29.027	57.793	65.482
Min Y	88	12 REALIBILITY CONDITION WIND Z	5.800	-25.480	39.020	46.962
Max Z	99	12 REALIBILITY CONDITION WIND Z	16.471	2.480	110.242	111.493
Min Z	99	1 SELF WT	-0.876	-0.521	-3.442	3.589

Table 22: Support reactions (K Bracing)

			Horizontal	Vertical	Horizontal	Moment		
	Node	L/C	FxkN	FykN	FzkN	MxkNm	My kNm	MzkNm
Max Fx	9	12 REALIBILITY CONDITION WIND Z	15.121	-193.008	-27.888	-0.173	-0.176	0.713
Min Fx	5	15 SAFETY CONDITION(NO WIRE BROKEN)	-22.065	88.335	-2.336	1.759	0.292	2.079
Max Fy	5	12 REALIBILITY CONDITION WIND Z	-17.623	230.073	-33.581	-1.432	-0.212	-1.576
Min Fy	9	12 REALIBILITY CONDITION WIND Z	15.121	-193.008	-27.888	-0.173	-0.176	0.713
Max Fz	1	2 WIND X	-16.444	-116.308	10.595	-0.539	0.206	0.551
Min Fz	5	12 REALIBILITY CONDITION WIND Z	-17.623	230.073	-33.581	-1.432	-0.212	-1.576
Max Mx	5	15 SAFETY CONDITION(NO WIRE BROKEN)	-22.065	88.335	-2.336	1.759	0.292	2.079
Min Mx	5	12 REALIBILITY CONDITION WIND Z	-17.623	230.073	-33.581	-1.432	-0.212	-1.576
Max My	5	15 SAFETY CONDITION(NO WIRE BROKEN)	-22.065	88.335	-2.336	1.759	0.292	2.079

Figure 10: Deflected Shape of Tower

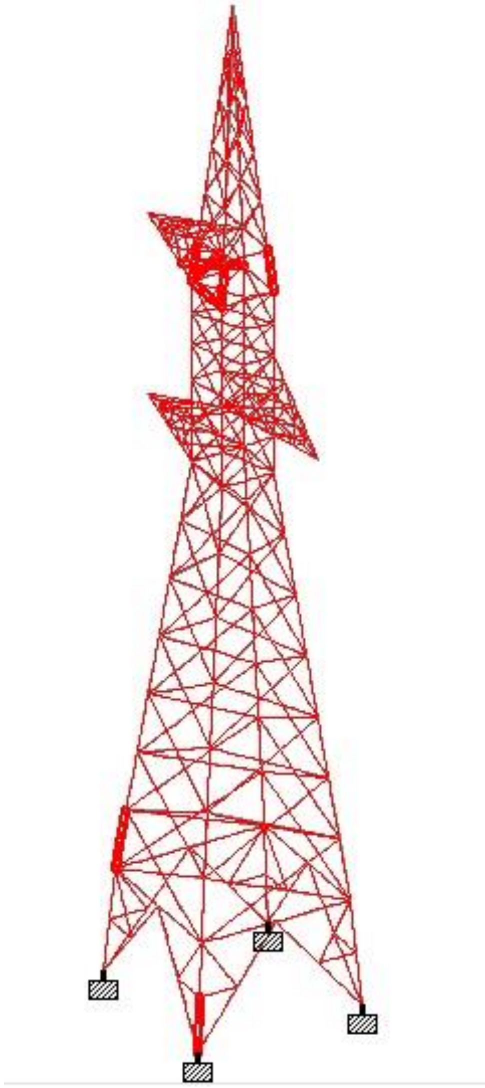


Figure 11: Members with Max and Min Forces(X-X Bracing)

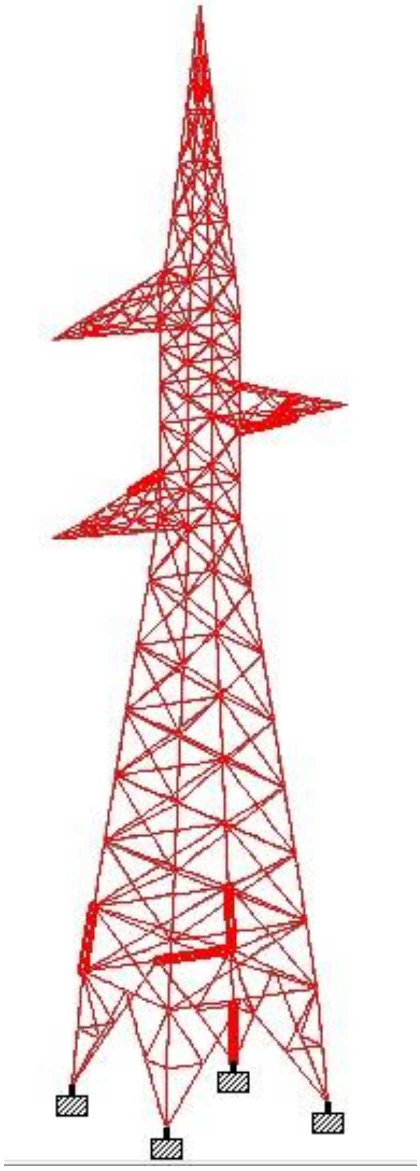


Figure 12: Members with Max and Min Forces(X-B Bracing)

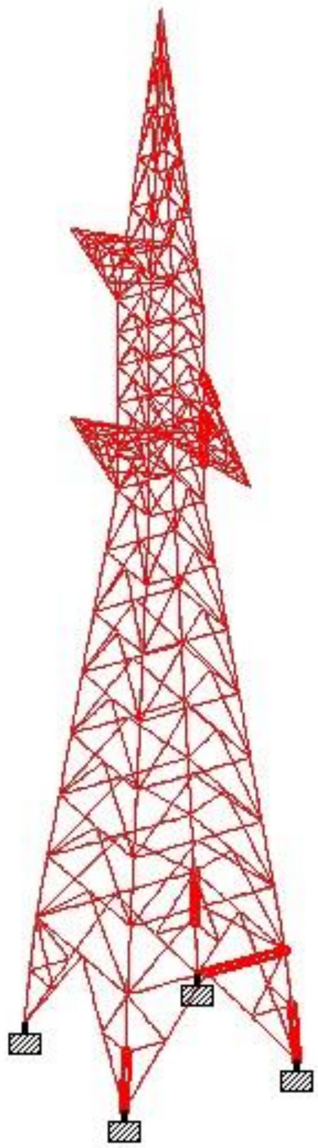


Figure 13: Members With Maximum and Minmum Member forces (K Bracing)

SECTION 5
DESIGN OF TENSION AND COMPRESSION MEMBERS

5.1 Introduction

The various elements of a steel structure like tension member, compression member and flexural member are connected by fasteners. Different types of fasteners available are rivets, bolts, pins and welds. The forces exerted by one member on another are transferred through these fasteners, which should there be adequate to transmit the force safely. Often much attention is not given to the design of connections. If the necessary connections are inadequate, the result will be a poor structure in spite of the most efficiently designed member. Therefore the design of connections must be given due importance. The nature if forces and stress distributions also need to be properly evaluated and established.

A structural member subjected to pulling (tensile) forces applied at its ends is called a tension member. The member and connections are so arranged that eccentricity in the connection and bending stresses on the member are not developed. The stress in such member is assumed to be uniformly distributed over the net section and hence members subjected only to axial tension are supposed to be the most efficient and economical. On the other hand, if some eccentricity in connections, either bending stresses are considered in the design or specifications are provided to account for reduction in the net area.

A compression member is a structural member which is straight and subjected to two equal and opposite compressive forces applied at its ends. Different terms are used for a compression member depending upon its position in structures. Strut is a compression member used the roof truss and bracing. They are of a small span and may be vertical or inclined. Column, stanchion or post is a vertical compression member supporting floors or girders in building. These compression members are subjected to heavy loads. The principal rafter is a top chord member in a roof truss and boom is a principal compression member in a crane.

5.2 VBA Coding

Microsoft Excel VBA program was used to design the tension and compression member by obtaining forces from STAAD Pro., a program was build to give no. of bolts and steel section after user inputs various data’s like force, bolt diameter, bolt grade, thickness of gusset plate. VBA program takes the input and give no. of bolts on the basis of shear and bearing forces, steel section is also selected by the program from the steel section database attached to the excel and program also checks the steel section for gross yielding failure, net section rupture and block shear failure.

5.2.1 Tension member

Hole dia

```
Function holedia(d)
If d = 12 Then
holedia = 13
Else
If d = 14 Then
holedia = 15
Else
If d = 16 Then
holedia = 18
Else
If d = 18 Then
holedia = 20
Else
If d = 20 Then
holedia = 22
Else
If d = 24 Then
holedia = 26
Else
If d = 27 Then
holedia = 30
Else
If d >= 33 Then
```

```
holedia = d + 3
End If
End If
End If
End If
End If
End If
End If
End If
End Function
```

Bolt grade

```
Function boltd(g)
If g = 4.6 Then
boltd = 400
Else
If g = 4.8 Then
boltd = 420
Else
If g = 5.6 Then
boltd = 500
Else
If g = 5.8 Then
boltd = 520
Else
If g = 6.8 Then
boltd = 600
End If
End If
End If
End If
End If
```

```
End Function
```

Pitch

```
Function pitch(f, t)
Dim x As Integer
Dim y As Integer
Dim z As Integer
z = 12 * t
x = 16 * t
y = 200
If f > 0 Then
If y > x Then
pitch = x
Else
pitch = y
End If
End If
If f < 0 Then
If z > y Then
pitch = y
Else
pitch = z
End If
End If
End Function
```

Edge

```
Function edge(a, b, c)
If c > a And c < b Then
edge = c
Else
If c < a Then
```

```
edge = a
Else
If c > b Then
edge = b
End If
End If
End If
End Function
```

Reduction factor

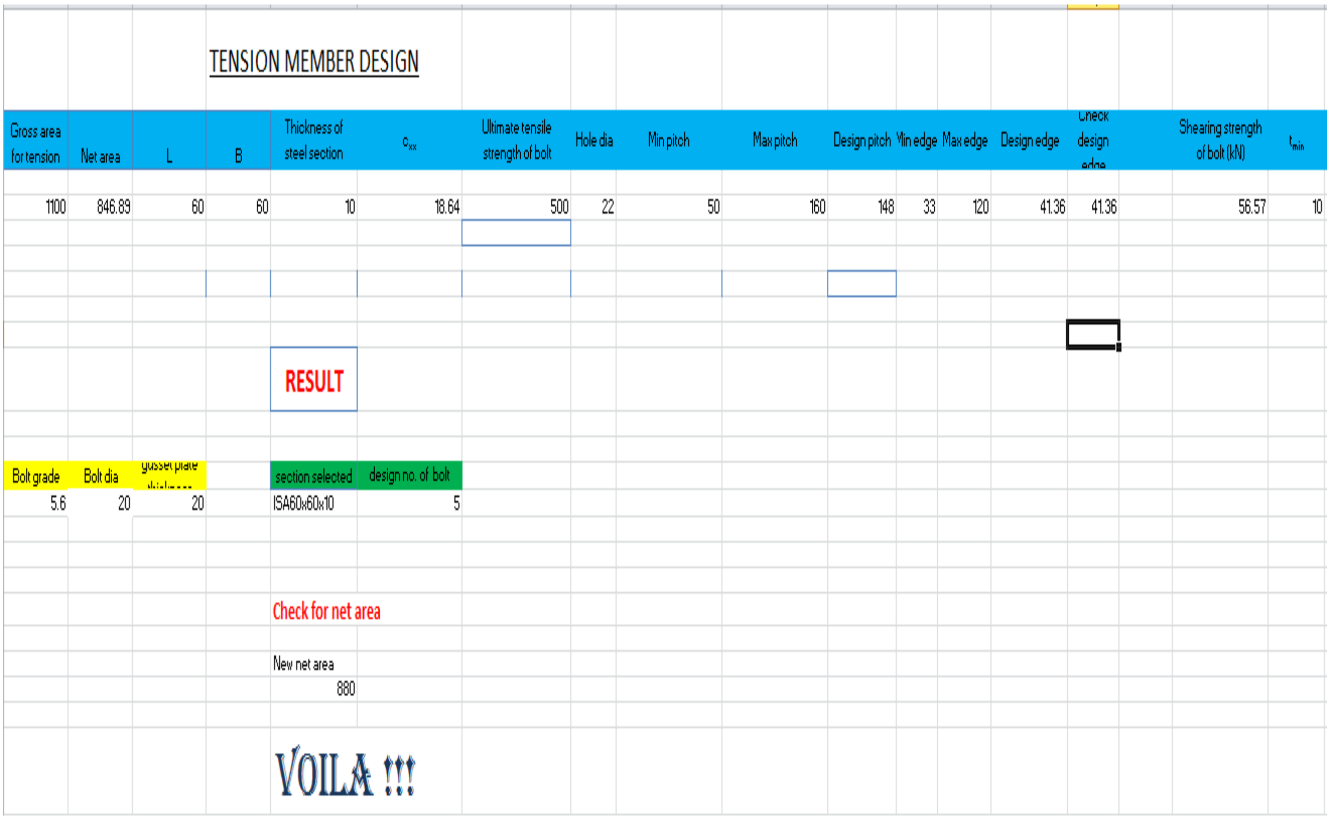
```
Function red(a, b)
If a > 15 * b Then
red = 1.075 - (a / (200 * b))
Else
red = 1
End If
End Function
```

5.2.2 *Compression Member*

```
Private Sub CommandButton1_Click()
Dim i As Integer
Dim j As Integer
    j = 0
    Dim k As Integer
    tom = Cells(2, 2)
    ec = Cells(13, 2)
    bc = Cells(25, 2)
    If tom = "Channel" Then
    Cells(3, 2) = 130
    End If
    If ec = "Fixed" Then
    Cells(14, 2) = 0.7
    End If
```

```
If ec = "Hinged" Then
Cells(14, 2) = 1
End If
If ec = "PR" Then
Cells(14, 2) = 0.85
End If
If bc = "a" Then
Cells(26, 2) = 0.21
End If
If bc = "b" Then
Cells(26, 2) = 0.34
End If
If bc = "c" Then
Cells(26, 2) = 0.49
End If
If bc = "d" Then
Cells(26, 2) = 0.76
End If
For k = 3 To 44
Cells(k, 8) = " "
Next k
For i = 48 To 85
If Cells(i, 16).Value > Range("B6").Value And Not IsEmpty(Cells(i,
16).Value) Then
Cells(7, 2) = Cells(i, 2)
Cells(7, 3) = Cells(i, 4)
Cells(7, 4) = Cells(i, 7)
Cells(9, 2) = Cells(i, 8)
Cells(10, 2) = Cells(i, 9)
Cells(8, 2) = Cells(i, 16)
Cells(3 + j, 8) = Cells(i, 2)
j = j + 1
GoTo end1
End If
```

```
Rev:
If i = 85 Then
MsgBox "Can't Be Designed as Single Channel."
GoTo stop1
End If
Next i
end1:
If Cells(15, 3) = "Ok" And Cells(16, 3) = "Ok" And Cells(28, 4) = "Ok"
And Cells(29, 4) = "Ok" And Cells(30, 4) = "Ok" Then
MsgBox "Slenderness Ratio is OK. Proceed Further."
Else
GoTo Rev
End If
stop1:
End Sub
```



TENSION MEMBER DESIGN

Gross area for tension	Net area	L	B	Thickness of steel section	c_{xx}	Ultimate tensile strength of bolt	Hole dia	Min pitch	Max pitch	Design pitch	Min edge	Max edge	Design edge	Check design edge	Shearing strength of bolt (kN)	t_{min}
1100	846.89	60	60	10	18.64	500	22	50	160	148	33	120	41.36	41.36	56.57	10

RESULT

Bolt grade	Bolt dia	gusset plate thickness	section selected	design no. of bolt
5.6	20	20	ISA60x60x10	5

Check for net area

New net area

880

VOILA !!!

Figure 14: Tension Member Excel Sheet

Design of Compression Member							
Type of Member	Channel						Channel Revision Table
Assumed Initial Stress	130	Mpa					ISLC75
Factored Load	50	kN					ISJC100
Length of the Member	5000	mm					ISMC75
Area Required	384.62	mm2					ISLC100
Section to be Selected	ISMC225	225	6.5		(SP-6_1)		ISJC125
Input the Gross Area	3330	mm2			(SP-6_1)		ISMC100
Moment of Inertia (X-X)	2711	cm4			(SP-6_1)		ISJC150
Moment of Inertia (Y-Y)	186	cm4			(SP-6_1)		ISLC125
Radius of Gyration (X-X)	90.23	mm					ISJC175
Radius of Gyration (Y-Y)	23.63	mm					ISLCP125
End Conditions	PR						ISMC125
Value of K	0.85				(Cl. 7.2.4)		ISMC125H
Slenderness Ratio (X-X)	47.10	Ok			Table-3 (IS		ISJC200
Slenderness Ratio (Y-Y)	179.83	Ok			800:2007)		ISLC150
Critical Slenderness Ratio	179.83						ISPCP 150
							ISMC150
			Design				ISLC175
							ISMC150H
Calculation of Design Compressive Stress							ISMC175
Yield Strength	230	MPa					ISLC200
sqrt(π2*E)	1404.96						ISLCP 200
λ	1.94				(Cl. 7.1.2.1)		ISMC175H
Buckling Class	c				Table-7 (IS 800:2007)		ISMC200
Alpha, α	0.49						ISLC225
ϕ	2.81				(Cl. 7.1.2.1)		ISMC200H
Design Compressive Stress, fcd	43.17	MPa	Ok				ISMC225
Cross Section Classification (d/t	34.62		Ok				
Design Compressive Strength, Pc	143.77	kN	Ok				

Figure 15: Compression Member Excel Sheet

SECTION 6
FOUNDATION DESIGN

6.1 Introduction

For more structures including buildings, bridges, earth fills, earth and concrete dams, it is the earth that provides the ultimate support. The behavior of the supporting ground is invariably a soil (sound rocky stratum being very rare) which is weaker than any construction material like wood, concrete, steel or masonry. Hence, compared to structural members made out of these materials, a large area or mass of soil is necessarily involved in carrying the same load. Structural foundations are the substructure elements which transmit the structural load to the earth in such a way that the supporting soil is not overstressed and not undergo deformations that would cause excessive settlement of the structure. Hence, the properties of the supporting soil must be expected to affect vitally the choice of the type of structural foundation suitable for a structure.

The various types of structural foundations can be broadly grouped into two categories, namely,

- Shallow foundations
- Deep foundations

Due to the presence of large uplift load the only foundation we find suitable for that type of condition is:-

- Under-reamed pile foundations

6.2 Methodology

Microsoft Excel spreadsheets were used for the foundation design of the transmission tower. Foundation design was based on the recommendation of IS, foundation was designed for two main conditions:

- Ultimate Bearing Capacity

- Uplift Load

Spreadsheet takes input from the user in form of Ultimate downward load and Uplift load, Microsoft Excel spread sheet then compare these loads with the various combinations of under-reamed piles. It provides result in the form of pass and fail for both the load cases, and gives opportunity to the user to select best under reamed pile on the basis of least excavation and concreting.

Ultimate bearing capacity calculation

Sr no.	Result	Excavation and concrete	Dia of Bulb in Cm	Dia of Stem in cm	No. of bulbs	Density(Kg/cm3)	N	N_q	Depth of centre of bulb cm	Total depth of pile	Earth constan	Friction Angl	Friction Angle in radians	Depth of centre bulb cm	Ultimate Load carrying Capacity in N	In kn
1	FAIL	0.480813	52.5	35	1	0.0018	22	30	100	125	1.75	30	0.523333333	100	17491.9548	171.596
2	PASS	0.576975	52.5	35	1	0.0018	22	30	125	150	1.75	30	0.523333333	125	21661.33636	212.498
3	PASS	0.7693	52.5	35	1	0.0018	22	30	175	200	1.75	30	0.523333333	175	30749.12535	301.649
4	PASS	0.865463	52.5	35	1	0.0018	22	30	200	225	1.75	30	0.523333333	200	35667.54873	349.899
5	PASS	0.961625	52.5	35	1	0.0018	22	30	225	250	1.75	30	0.523333333	225	40835.65805	400.598
6	PASS	1.057788	52.5	35	1	0.0018	22	30	250	275	1.75	30	0.523333333	250	46253.4533	453.746
7	PASS	1.15395	52.5	35	1	0.0018	22	30	275	300	1.75	30	0.523333333	275	51920.93448	509.344
8	FAIL	0.35325	45	30	1	0.0018	22	30	100	125	1.75	30	0.523333333	100	12959.88145	127.136
9	FAIL	0.4239	45	30	1	0.0018	22	30	125	150	1.75	30	0.523333333	125	16175.95777	158.686
10	PASS	0.5652	45	30	1	0.0018	22	30	175	200	1.75	30	0.523333333	175	23250.15993	228.084
11	PASS	0.63585	45	30	1	0.0018	22	30	200	225	1.75	30	0.523333333	200	27108.28578	265.932
12	PASS	0.7065	45	30	1	0.0018	22	30	225	250	1.75	30	0.523333333	225	31180.42814	305.88
13	PASS	0.77715	45	30	1	0.0018	22	30	250	275	1.75	30	0.523333333	250	35466.58702	347.927
14	PASS	0.8478	45	30	1	0.0018	22	30	275	300	1.75	30	0.523333333	275	39966.7624	392.074
15	FAIL	0.245313	37.5	25	1	0.0018	22	30	100	125	1.75	30	0.523333333	100	9162.410836	89.8833
16	FAIL	0.294375	37.5	25	1	0.0018	22	30	125	150	1.75	30	0.523333333	125	11544.41974	113.251
17	FAIL	0.3925	37.5	25	1	0.0018	22	30	175	200	1.75	30	0.523333333	175	16843.47884	165.235
18	PASS	0.441563	37.5	25	1	0.0018	22	30	200	225	1.75	30	0.523333333	200	19760.52902	193.851
19	PASS	0.490625	37.5	25	1	0.0018	22	30	225	250	1.75	30	0.523333333	225	22855.9263	224.217
20	PASS	0.539688	37.5	25	1	0.0018	22	30	250	275	1.75	30	0.523333333	250	26129.67068	256.332

Figure 16: ultimate load bearing capacity Excel Sheet

Uplift Load Calculation

Uplift Load **150** KN | User Input

Sr no.	Result	Exacavation and concrete	Dia of Bul	Dia of Stem in m	No. of bul	Density(K	N_γ	N_q	Depth of centre of bulb cm	Total dept	Earth cons	Friction Angle	Friction Angle in radians	Depth of centre bulb cm		Uplift load KN
1	FAIL	0.480813	0.525	0.35	1	17.658	22.4	30	1	1.25	1.75	30	0.523333	1		33.91945
2	FAIL	0.576975	0.525	0.35	1	17.658	22.4	30	1.25	1.5	1.75	30	0.523333	1.25		72.51849
3	FAIL	0.7693	0.525	0.35	1	17.658	22.4	30	1.75	2	1.75	30	0.523333	1.75		138.9676
4	PASS	0.865463	0.525	0.35	1	17.658	22.4	30	2	2.25	1.75	30	0.523333	2		180.2154
5	PASS	0.961625	0.525	0.35	1	17.658	22.4	30	2.25	2.5	1.75	30	0.523333	2.25		226.812
6	PASS	1.057788	0.525	0.35	1	17.658	22.4	30	2.5	2.75	1.75	30	0.523333	2.5		278.7574
7	PASS	1.15395	0.525	0.35	1	17.658	22.4	30	2.75	3	1.75	30	0.523333	2.75		336.0517
8	FAIL	0.35325	0.45	0.3	1	17.658	22.4	30	1	1.25	1.75	30	0.523333	1		40.00328
9	FAIL	0.4239	0.45	0.3	1	17.658	22.4	30	1.25	1.5	1.75	30	0.523333	1.25		61.46585
10	FAIL	0.5652	0.45	0.3	1	17.658	22.4	30	1.75	2	1.75	30	0.523333	1.75		118.1451
11	PASS	0.63585	0.45	0.3	1	17.658	22.4	30	2	2.25	1.75	30	0.523333	2		153.3618
12	PASS	0.7065	0.45	0.3	1	17.658	22.4	30	2.25	2.5	1.75	30	0.523333	2.25		193.1632
13	PASS	0.77715	0.45	0.3	1	17.658	22.4	30	2.5	2.75	1.75	30	0.523333	2.5		237.5492
14	PASS	0.8478	0.45	0.3	1	17.658	22.4	30	2.75	3	1.75	30	0.523333	2.75		286.52
15	FAIL	0.245313	0.375	0.25	1	17.658	22.4	30	1	1.25	1.75	30	0.523333	1		32.87417
16	FAIL	0.294375	0.375	0.25	1	17.658	22.4	30	1.25	1.5	1.75	30	0.523333	1.25		50.64417

Figure 17: Uplift load Excel Sheet

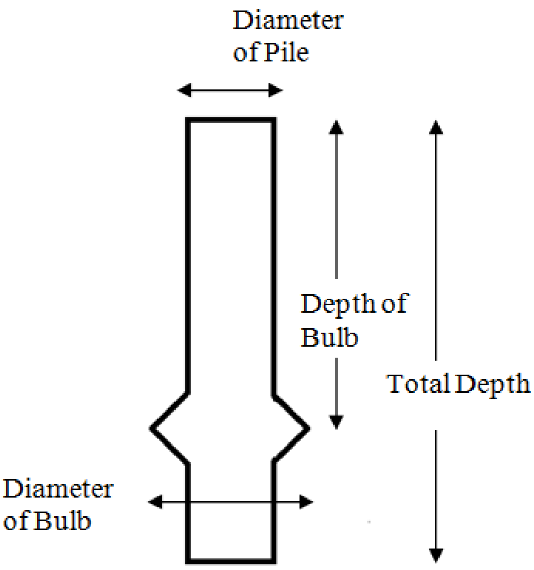


Figure 18: Pile foundation

Table23: Foundation Design (Zone-1)

Type of Bracing system	***Diameter of pile(Cm)***	***Diameter of bulb(Cm)***	***Depth of pile(Cm)***	***Depth of centre of bulb(Cm)***
X-X	30	45	300	275
X-B	25	37.5	300	275
K	30	45	275	250

Table 24 : Foundation Design (Zone-2)

Type of Bracing system	***Diameter of pile(Cm)***	***Diameter of bulb(Cm)***	***Depth of pile(Cm)***	***Depth of centre of bulb(Cm)***
X-X	35	52.5	250	225
X-B	35	52.5	300	275
K	35	52.5	300	275

SECTION 7
RESULTS AND DISCUSSIONS

The results obtained in the previous sections are presented in this section and discussed.

- The parameters of this study are maximum compressive and tensile stresses in the tower members, axial forces in the members and maximum deflection of the nodes in x, y, z directions and the above parameters are compared in zones 1 and 2 with the wind speed 39 m/s and 47 m/s respectively.
- Table 6, 9 and 12 represent the maximum axial deflections of node in x,y and z direction of X-X , X-B , K bracing system in zone 1 and Table 15,18 and 21 represent the maximum axial deflections of node in x,y and z direction of X-X , X-B , K bracing system in zone 2.
- Table 5,8 and 11 represent the maximum and minimum axial forces in X-X, X-B and K bracing system respectively in zone 1 and Table 14,17 and 20 represent the maximum and minimum axial forces in X-X, X-B and K bracing system respectively in zone 2.
- Table 7, 10, 13 represents the support reactions of X-X , X-B and K bracing systems respectively in zone 1 and table 16,19,22 represents the support reactions of X-X , X-B and K bracing systems respectively in zone 2.
- The maximum deflections of top node of different bracing system in different zones are mentioned in Table 23.

Table 25: DEFLECTION

Zone 1		Zone 2	
BRACING SYSTEM	HORIZONTAL DEFLECTION(mm)	BRACING SYSTEM	HORIZONTAL DEFLECTION(mm)
X-X	88.69	X-X	65.19
X-B	52.33	X-B	55.95
K	44.45	K	42.08

Table 26: ZONE 1- X-X Bracing

PROFILE	**LENGTH (m)**	**WEIGHT(N)**
ISA 130x130x16	158.78	47814
ISA 60x60x6	298.60	15690
ISA 100x100x8	196.84	23286
	TOTAL	86790

Table 27: ZONE 1 X-B Bracing

PROFILE	**LENGTH (m)**	**WEIGHT(N)**
ISA 130x130x16	149.64	45061
ISA 60x60x6	404.34	21246
ISA 100x100x8	201.51	23839
	TOTAL	90146

Table 28: ZONE 1 K Bracing

PROFILE	LENGTH (m)	WEIGHT(N)
ISA 130x130x16	10.85	3267
ISA 60x60x6	512.18	26912
ISA 100x100x8	153.04	18104
	TOTAL	48284

Table 29: ZONE 2 X-X Bracing

PROFILE	LENGTH (m)	WEIGHT(N)
ISA 130x130x16	132.14	39792
ISA 60x60x6	342.20	17983
ISA 100x100x8	179.88	21280
	TOTAL	79053

Table 30: ZONE 2 X-B Bracing

PROFILE	LENGTH (m)	WEIGHT(N)
ISA 130x130x16	134.80	40593
ISA 60x60x6	434.17	22813
ISA 100x100x8	186.51	22065
	TOTAL	85472

Table 31: ZONE 2 K Bracing

PROFILE	LENGTH (m)	WEIGHT(N)
ISA 130x130x16	10.85	3267
ISA 60x60x6	518.81	27267
ISA 100x100x8	146.40	17319
	TOTAL	47847

Table 32: No. of Joints

Type of bracing system	Number of Joints
X-X	146
X-B	132
K	203

SECTION 8
CONCLUSIONS

This work attempts to optimize the transmission line tower structure for a 220 KV three phase single circuit, with respect to configuration and different site condition as a variable parameters. Due to multiple loading conditions, each member subjected to maximum stress under any of these loading conditions is assigned an angle size section. This work has focused on techno economical analysis and design of transmission line tower structure. Also the focus is on saving time and cost when optimization of tower for different configurations are considered.

Based upon results and discussions presented in the report, the following are the general observations and conclusions drawn.

- Optimization of tower geometry with respect to member forces. The K-bracing tower with base width 4.72 m is concluded as the optimum tower configuration with respect to geometry for both the zones.
- As far as the deflection criterion is concerned, the K bracing tower has the least deflection under the same load cases for both the zones.
- The tower structure with the least weight is directly associated with the reduction of the foundation cost.
- The cost of the tower is directly proportional to the number of joints required because of increased number of bolts, gusset plates, and man-hours.
- Difference in the foundation parameters is not substantial, therefore this does not affect the total cost to a large extent.

REFERENCES

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2. IS 875(Part 3)-1987: “Code of practice for design loads (other than earthquake) for building and structures”, Part 3, Wind loads, Bureau of Indian Standards code, India
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4. Y. Bhargava Gopi Krishna, et al, “ Analysis and Design of 220kV Transmission Line Tower in Different Zones I & V with Different Base Widths – A comparative Study, International journal of technology enhancements and emerging engineering research.
5. T. Raghavendra et al, “ Computer Aided Analysis and Structural Optimization of Transmission Line Tower” , International Journal of Advanced Engineering Technology
6. IS 4091 (1979) “Code of Practice for Design and Construction of Foundations for Transmission Line and Poles”, Bureau of Indian Standards code, India.

APPENDIX-A

STAAD.pro Code

```
STAAD SPACE

START JOB INFORMATION

ENGINEER DATE 01-Nov-11

END JOB INFORMATION

INPUT WIDTH 79

UNIT METER KN

JOINT COORDINATES

1 0 0 0; 2 4.72 0 0; 3 0 0 4.72; 4 4.72 0 4.72; 6 2.36 28.32 2.36;

10 3.11 15 3.11; 11 1.61 15 3.11; 12 3.11 15 1.61; 13 1.61 15 1.61;

14 3.11 20.2 3.11; 15 1.61 20.2 3.11; 16 3.11 20.2 1.61; 17 1.61 20.2 1.61;

20 2.36 20.2 -1.89; 21 0.212236 2.97735 4.50776; 22 4.50776 2.97735 4.50776;

23 0.212236 2.97735 0.212236; 24 4.50776 2.97735 0.212236;

25 4.50776 2.97735 2.36; 26 2.36 2.97735 0.212236; 27 0.212236 2.97735 2.36;

28 2.36 2.97735 4.50776; 29 0.411916 4.69487 4.30808;

30 0.611597 6.41239 4.1084; 31 0.811277 8.12991 3.90872;

32 1.01096 9.84744 3.70904; 33 1.21064 11.565 3.50936;

34 1.41032 13.2825 3.30968; 35 4.30808 4.69487 4.30808;

36 4.1084 6.41239 4.1084; 37 3.90872 8.12991 3.90872;

38 3.70904 9.84744 3.70904; 39 3.50936 11.565 3.50936;

40 3.30968 13.2825 3.30968; 41 0.411916 4.69487 0.411916;

42 0.611597 6.41239 0.611597; 43 0.811277 8.12991 0.811277;

44 1.01096 9.84744 1.01096; 45 1.21064 11.565 1.21064;

46 1.41032 13.2825 1.41032; 47 4.30808 4.69487 0.411916;

48 4.1084 6.41239 0.611597; 49 3.90872 8.12991 0.811277;
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87 2.36 15 -1.89; 90 2.36 17.35 6.61; 91 3.11 19.295 3.11; 92 1.61 19.295 3.11;

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96 1.97594 24.1619 2.74406; 97 2.10396 25.548 2.61604;

98 2.23198 26.934 2.48802; 99 2.87208 22.7759 2.87208;

100 2.74406 24.1619 2.74406; 101 2.61604 25.548 2.61604;

102 2.48802 26.934 2.48802; 103 1.84792 22.7759 1.84792;

104 1.97594 24.1619 1.97594; 105 2.10396 25.548 2.10396;

106 2.23198 26.934 2.23198; 107 2.87208 22.7759 1.84792;

108 2.74406 24.1619 1.97594; 109 2.61604 25.548 2.10396;

110 2.48802 26.934 2.23198; 111 2.1725 15 -1.015; 112 1.985 15 -0.14;

113 1.7975 15 0.735; 114 2.5475 15 -1.015; 115 2.735 15 -0.14;

116 2.9225 15 0.735; 117 2.1725 15.26 -1.015; 118 1.985 15.52 -0.14;

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132 2.19998 20.4975 -0.987525; 133 2.03995 20.795 -0.08505;

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146 1.7975 18.13 3.985;

MEMBER INCIDENCES

9 3 53; 10 11 10; 11 4 59; 12 1 54; 13 2 61; 14 13 11; 15 10 12; 16 12 13;

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333 119 112; 334 13 119; 335 113 77; 336 120 118; 337 122 118; 338 122 77;

339 73 119; 340 121 119; 341 121 117; 342 114 121; 343 121 116; 344 116 73;

345 120 115; 346 115 122; 347 122 12; 348 114 112; 349 112 116; 350 116 13;

351 111 115; 352 115 113; 353 113 12; 354 111 117; 355 117 120; 356 120 114;

357 114 111; 358 123 124; 359 124 125; 360 125 20; 361 126 127; 362 127 128;

363 128 20; 364 129 130; 365 130 131; 366 131 84; 367 132 133; 368 133 134;

369 134 83; 370 135 136; 371 136 137; 372 137 90; 373 138 139; 374 139 140;

375 140 70; 376 141 142; 377 142 143; 378 143 67; 379 144 145; 380 145 146;

381 146 71; 382 84 134; 383 134 130; 384 130 132; 385 132 129; 386 129 133;

387 133 131; 388 83 131; 389 84 126; 390 126 130; 391 130 128; 392 128 129;

393 129 127; 394 127 131; 395 131 16; 396 125 133; 397 133 123; 398 123 83;

399 132 124; 400 132 125; 401 124 134; 402 134 17; 403 125 128; 404 125 127;

405 127 123; 406 123 16; 407 17 126; 408 126 124; 409 128 124; 410 144 142;

411 142 146; 412 146 67; 413 71 143; 414 143 145; 415 145 141; 416 144 141;

417 141 137; 418 137 142; 419 142 135; 421 141 136; 422 136 143; 423 66 143;

424 144 138; 425 138 145; 426 145 140; 427 140 71; 428 70 146; 429 146 139;

430 139 144; 431 138 137; 432 137 139; 433 139 135; 434 135 70; 435 66 140;

436 136 140; 437 139 137;

DEFINE MATERIAL START

ISOTROPIC STEEL

E 2.05e+008

POISSON 0.3

DENSITY 76.8195

ALPHA 1.2e-005

DAMP 0.03

TYPE STEEL

STRENGTH FY 253200 FU 407800 RY 1.5 RT 1.2

END DEFINE MATERIAL

MEMBER PROPERTY INDIAN

9 TO 28 31 TO 138 140 TO 163 166 167 170 171 174 175 178 TO 180 183 TO 185 -

188 TO 190 193 TO 195 198 TO 200 203 TO 205 208 TO 210 213 TO 215 -

```
218 TO 228 231 TO 258 261 TO 328 330 TO 419 421 TO 437 TABLE ST ISA60x60x6
CONSTANTS
MATERIAL STEEL ALL
SUPPORTS
1 TO 4 FIXED
DEFINE WIND LOAD
TYPE 1 WIND 1
<! STAAD PRO GENERATED DATA DO NOT MODIFY !!!
ASCE-7-2010:PARAMS 39.000 M/SEC 5 1 1 0 0.000 FT 0.000 FT 0.000 FT 1 -
1 30.000 M 8.500 M 30.000 2.000 0.020 -
0 0 0 0 0.701 1.000 1.000 0.850 0 -
0 0 0 0.881 2.590 -0.550
!> END GENERATED DATA BLOCK
INT 1.03943 1.03943 1.06167 1.08281 1.10296 1.12223 1.14071 1.15846 1.17557 -
 1.19207 1.20802 1.22346 1.23843 1.25296 1.26708 1.40036 HEIG  0  4.572 -
4.92369  5.27538  5.62708  5.97877  6.33046  6.68215  7.03385  7.38554 -
7.73723  8.08892  8.44062  8.79231  9.144  9.144
EXP 1 JOINT 1 TO 4 6 10 TO 17 20 TO 67 69 TO 71 73 TO 75 77 TO 79 81 TO 84 -
87 90 TO 146
LOAD 1 LOADTYPE Dead  TITLE SELF WT
SELFWEIGHT Y -1
LOAD 2 LOADTYPE Wind  TITLE WIND X
WIND LOAD X 1 TYPE 1 XR -10 10 YR 0 30 ZR -10 10
LOAD 3 LOADTYPE Wind  TITLE WIND Z
WIND LOAD Z 1 TYPE 1 XR -10 10 YR 0 30 ZR -10 10
LOAD 4 LOADTYPE Dead  TITLE CONDUCTOR LOAD REALIBILITY
JOINT LOAD
```

20 87 90 FY -5.67

6 FY -1.5

LOAD 5 LOADTYPE Dead TITLE CONDUCTOR LOAD SECURITY

JOINT LOAD

20 87 90 FY -3.402

6 FY -0.9

LOAD 6 LOADTYPE Accidental TITLE BROKEN WIRE CONDITION (GROUND WIRE)

JOINT LOAD

6 FX 13

LOAD 7 LOADTYPE Accidental TITLE BROKEN WIRE CONDITION (MIDDLE CONDUCTOR)

JOINT LOAD

90 FX 20

LOAD 8 LOADTYPE Wind TITLE WIND LOAD ON CONDUCTOR

JOINT LOAD

20 90 117 FZ 16.72

6 FZ 5.6

LOAD 9 LOADTYPE Live REDUCIBLE TITLE LINE MAN WITH TOOLS(VERTICAL)

JOINT LOAD

20 87 90 FY -1.5

20 87 90 FY -3.5

LOAD 10 LOADTYPE Live TITLE BROKEN WIRE LOAD(SAFETY REQUIREMENT)

JOINT LOAD

20 87 90 FX 10

6 FX 5

LOAD COMB 11 REALIBILTY CONDITION WIND X

1 1.0 2 1.0 4 1.0

LOAD COMB 12 REALIBILITY CONDITION WIND Z

```
1 1.0 3 1.0 4 1.0 8 1.0

LOAD COMB 13 SECURITY CONDITION GROUND WIRE BROKEN

1 1.0 5 1.0 6 1.0

LOAD COMB 14 SECURITY CONDITION MIDDLE CONDUCTOR BROKEN

1 1.0 5 1.0 7 1.0

LOAD COMB 15 SAFETY CONDITION(NO WIRE BROKEN)

6 1.0 7 1.0 1 1.0 4 2.0 9 1.0

LOAD COMB 16 SAFETY CONDITION (BROKEN WIRE)

6 1.0 7 1.0 5 2.0 1 1.0 9 1.0

PERFORM ANALYSIS

PARAMETER 1

CODE INDIAN

CHECK CODE ALL

PARAMETER 2

CODE INDIAN

STEEL MEMBER TAKE OFF LIST ALL

PARAMETER 4

CODE INDIAN

SELECT OPTIMIZED

PARAMETER 5

CODE INDIAN

STEEL MEMBER TAKE OFF LIST ALL

FINISH
```