ANALYSIS AND DESIGN OF A 25-METRE-TALL STEEL TRANSMISSION TOWER USING STAAD.PRO

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WAKNAGHAT

CERTIFICATE

This is to certify that the work entitled, **"ANALYSIS AND DESIGN OF A 25-METRE TALL STEEL TRANSMISSION TOWER USING STAAD.pro"** submitted by **ANKUSH CHAUHAN, CHETAN DHAWAN, DHEERAJ KANNA, PIYUSH AGGARWAL** and **RAGHAV BINDAL** in partial fulfillment for the award of degree of Bachelor of Technology in Civil Engineering of Jaypee University of Information Technology has been carried out under my supervision. This work has not been submitted partially or wholly to any other University or Institute for the award of this or any other degree or diploma.

25/5/07

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Certified the above mentioned project work has been carried out by the said group of students.

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LIST OF ABBREVIATIONS AND SYMBOLS

Abbreviations

(1) ASCE - American Society of Civil Engineering

(2) DL - Dead load

(3) EIA - Environmental Impact Assesment

(4) IS- Indian Standard

(5) ISA - Indian Standard Angles

(6) L/C - Load combinations

(7) LL - Live load

(8) STAAD.PRO - Structural Advanced Analysis and Design. Processing

(9) WL - wind load

Symbols

(1) A_y - Sectional Area

(2) B_f - Flange width

(3) C_f = Net Wind force Coefficient

(4) D_w = Depth of web

(5) I_z - Moment of Inertia

(6) k_1 = probability factor (or risk coefficient)

(7) k_2 = terrain, height and structure size factor

(8) k_3 = topography factor

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

(10) V_b = basic wind speed in m/s

(11) V_z = Design wind speed

(12) ρ = Density of Steel

(13) ϕ - Solidity ratio

(14) σ_a = Allowable stress

ABSTRACT

In this project, the analysis and design of a self designed steel lattice tower employed for electricity transmission system under various categories of gravity and lateral loads is done. The tower is designed using IS 800:1984 and then the tower is analyzed under various load-combinations.

Before the design process appropriate site investigation data as well as Environmental impact assessment data are collected through appropriate electronic and print media in order to plan the design process most accurately. Keeping in consideration the hilly slope terrain of location (Shimla) appropriate safety design factors are considered during the design. The non-linear irregularities both environmental as well as structural material are also considered during the design. The steel angles joined through riveting were selected according to varying functions and load impacts. The foundation detailing is chosen keeping in consideration the geotechnical investigation data. The software tool used in the process is STAAD.Pro 2005. The load calculations were performed manually but the analysis and design results were obtained through STAAD.Pro 2005. At all stages, the effort is to provide optimally safe design along with keeping the economic considerations.

Key Words: Transmission Tower, STAAD.Pro 2005, Non-linear irregularities.

SECTION 1
INTRODUCTION

1.1 Objective

The objective of this project is to propose a steel lattice tower for electricity transmission system and analyze it under various loads thereby designing and checking the proposed members for failures. The tower is to be located in the city of Shimla, Himachal Pradesh.

1.2 Definition of Problem

Safe and economic design of steel transmission tower using the software tool STAAD.pro 2004. The height of the tower is 25 m. The number of cables supported by this tower is 7.

1.3 Methodology

The analysis and design were carried as per the recommendations given in IS: 800-1984 The software tool used in the design and analysis of the tower is STAAD.pro 2005.

1.4 STAAD-designed Transmission Tower Example

Figure 1.1 shows Wattana Transmission Tower. Some details are as follows:

Location: Outside of Bangkok, Thailand

Designed by: PBP Steel Co., Ltd.

Managing Director: Capt Nattapong Buapli Rtn.

Senior Engineering Consultant: Mr. Sompoch Tiangwan

Software Tool Used: STAAD.Pro

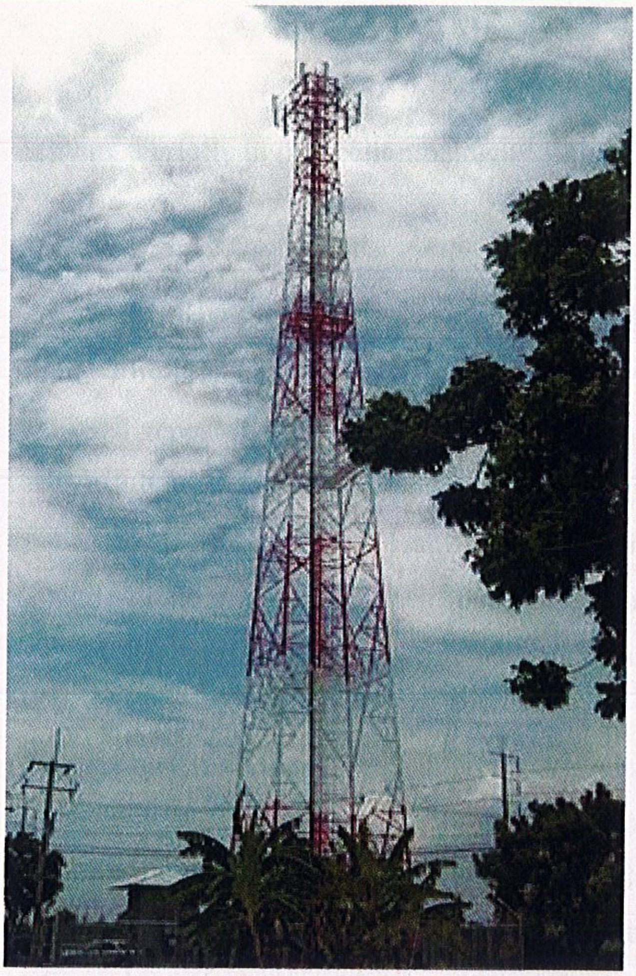


Fig. 1.1: Wattana Transmission Tower

The Wattana Transmission tower is 67.5 m high and is located outside of Bangkok, Thailand. It was designed to survive 130 km/hr wind gusts as well as minimial seismic activity. STAAD.Pro was used to analyze the steel structure. STAAD's advanced wind and seismic loader were used to distribute the forces on the tower. About 3 man weeks of calculations were saved with the automatic load generators. The tower was designed using the EIA-222C Transmission Tower code which was externally developed and linked to STAAD.Pro

1.5 Introduction to STAAD.pro

The STAAD.pro is explained briefly in the section below.

1.5.1 Introduction

Before the availability of computers using 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.

1.5.2 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

1.5.3 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, Prestress and Fixed-end Loads

SECTION 2
PROBLEM FORMULATION

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 45m 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.

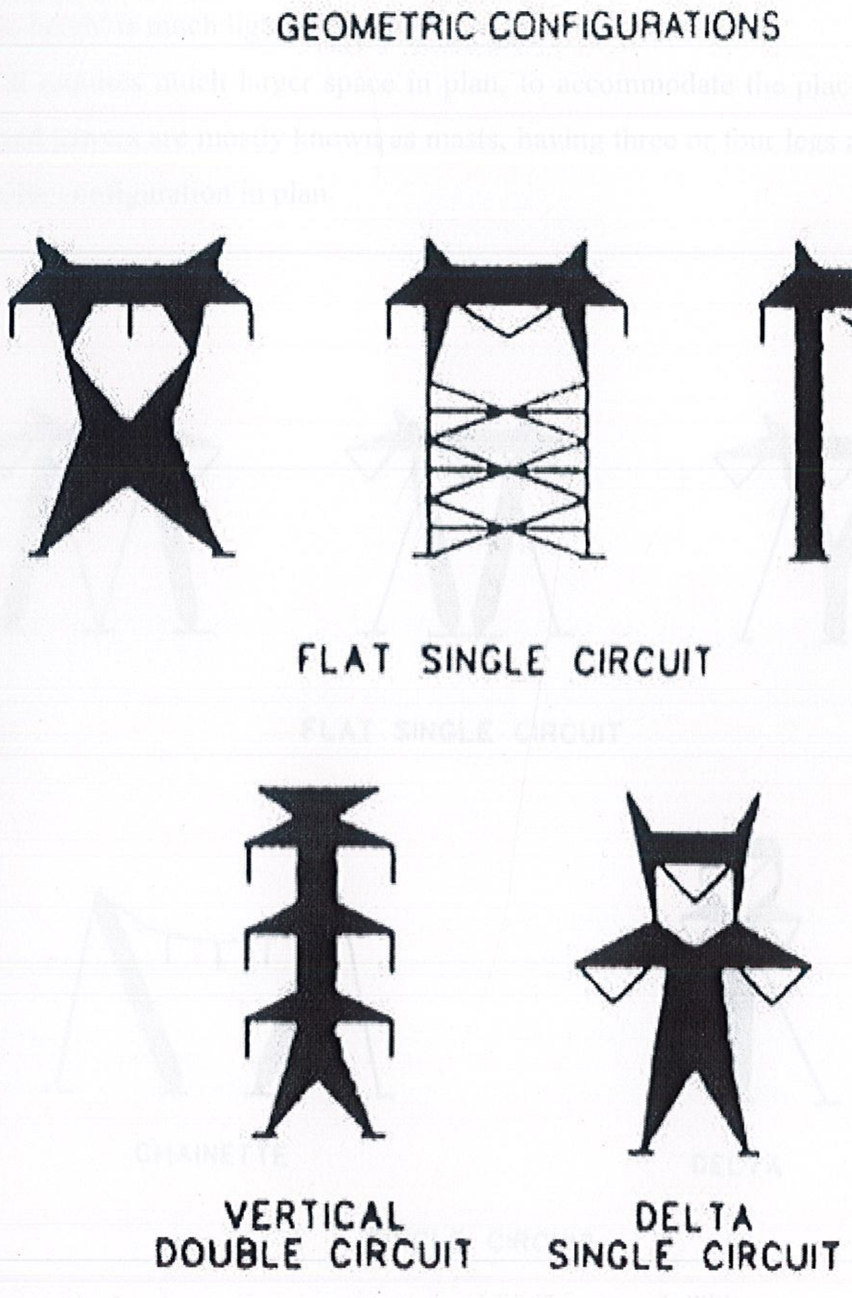


Fig. 2.1: Self Supporting Towers

(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.

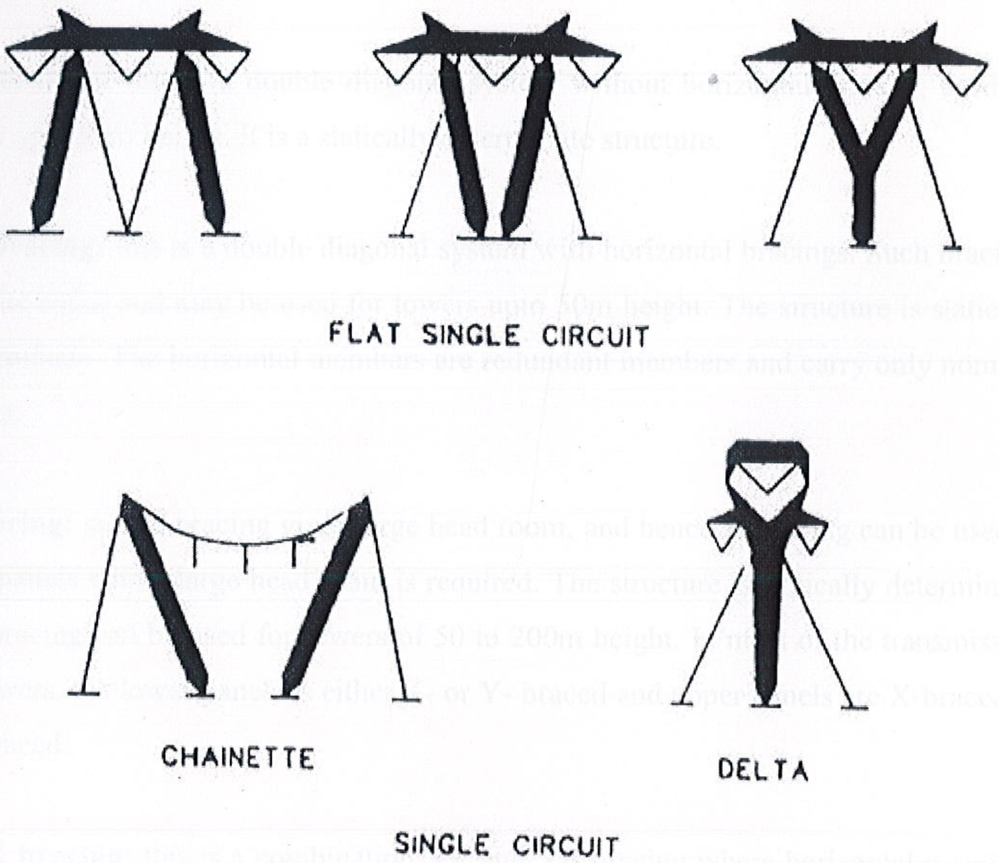


Fig. 2.2: Guyed Towers

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 double diagonal 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-section.

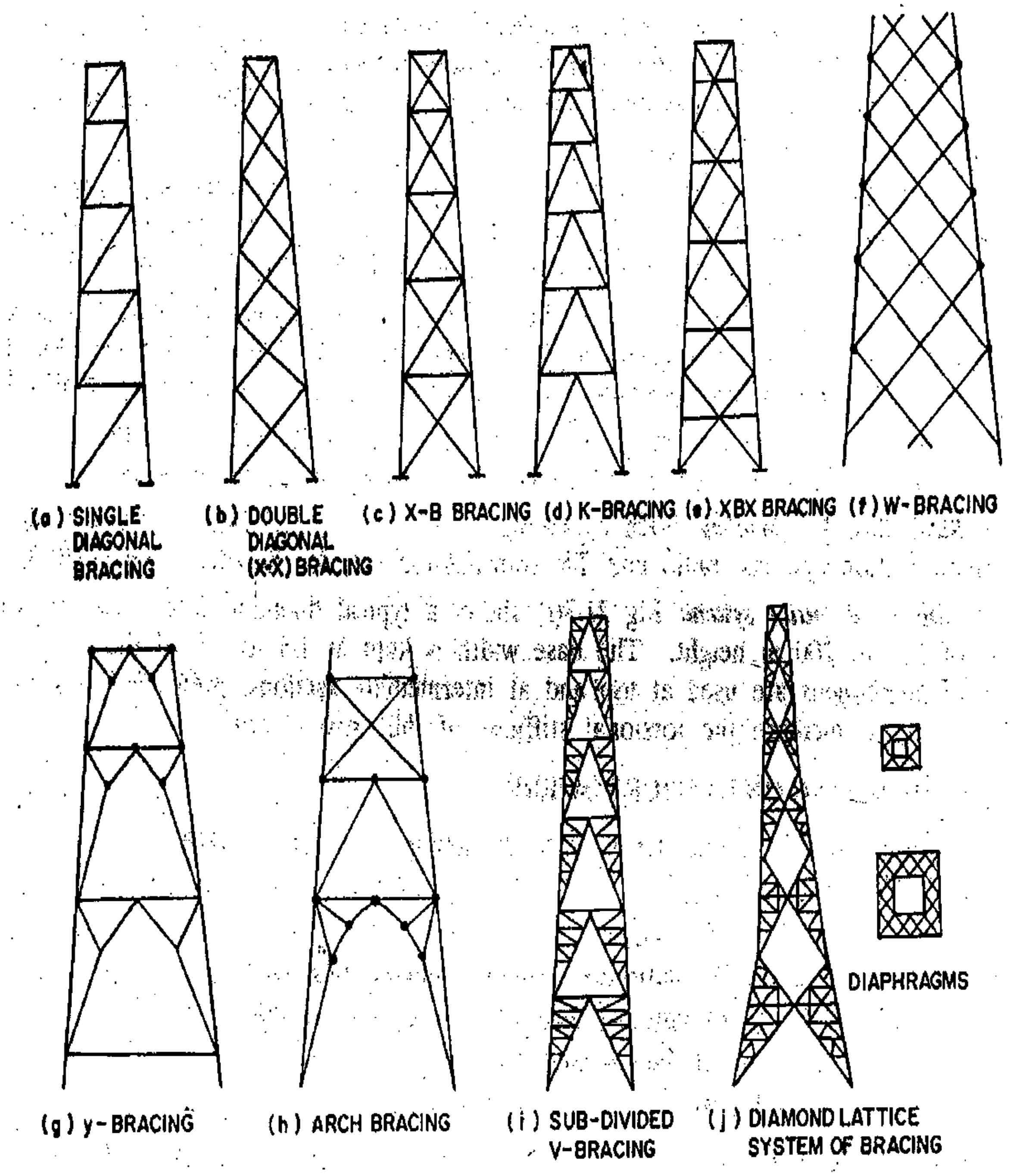


Fig. 2.3: Lattice tower configurations with Bracing systems.

2.1.3 Components of the tower

1. Cables
2. Rolled Steel long leg unequal angles back to back
3. Rolled Steel long leg equal angles back to back
4. Concrete Base
5. Footing

2.1.4 Parameters of the tower

1. The building lies in Seismic Zone IV
2. The factor of safety of the tower is 1.2
3. The height of the tower is 25.25m.
4. The base width of the tower is 3.52m.
5. The top width of the tower is 1.52m.
6. The Flange width in the tower is 2.7m.
7. The bearing capacity of the soil assumed to be 250 kN/m^2.

2.1.5 Analysis model for tower

Number of members:	492
Number of joints:	151
Loading:	Self weight, Wind load, Cable load
Analysis:	UsingSTAAD.Pro

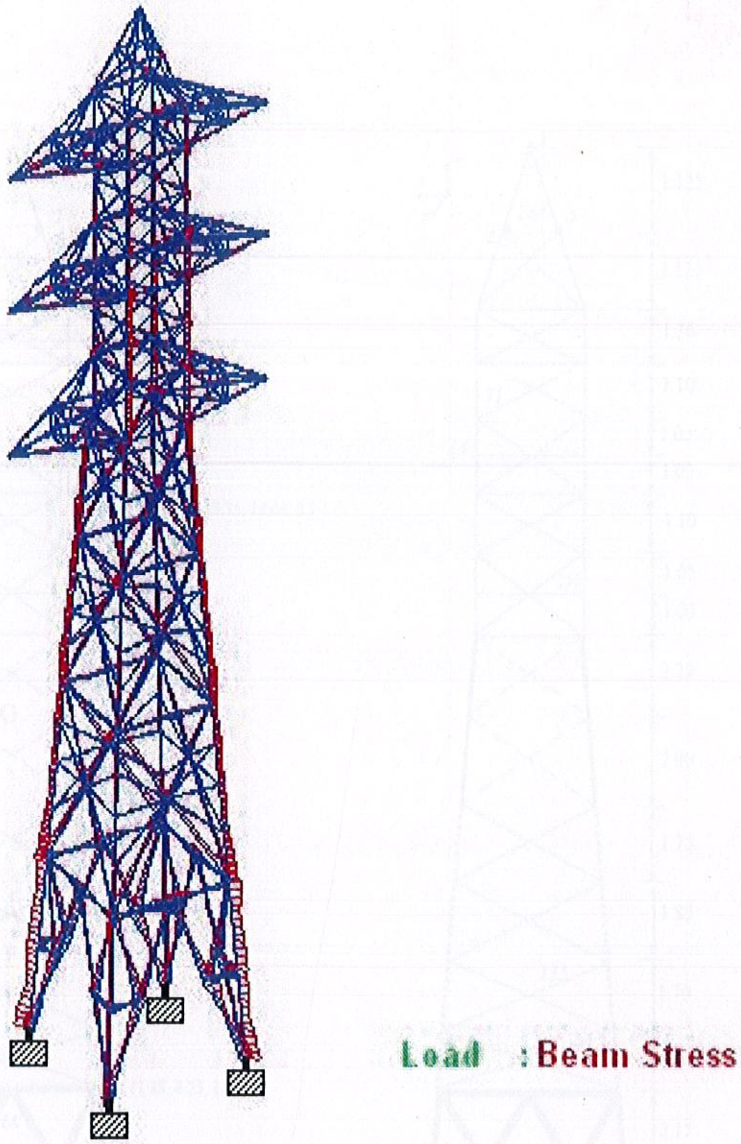
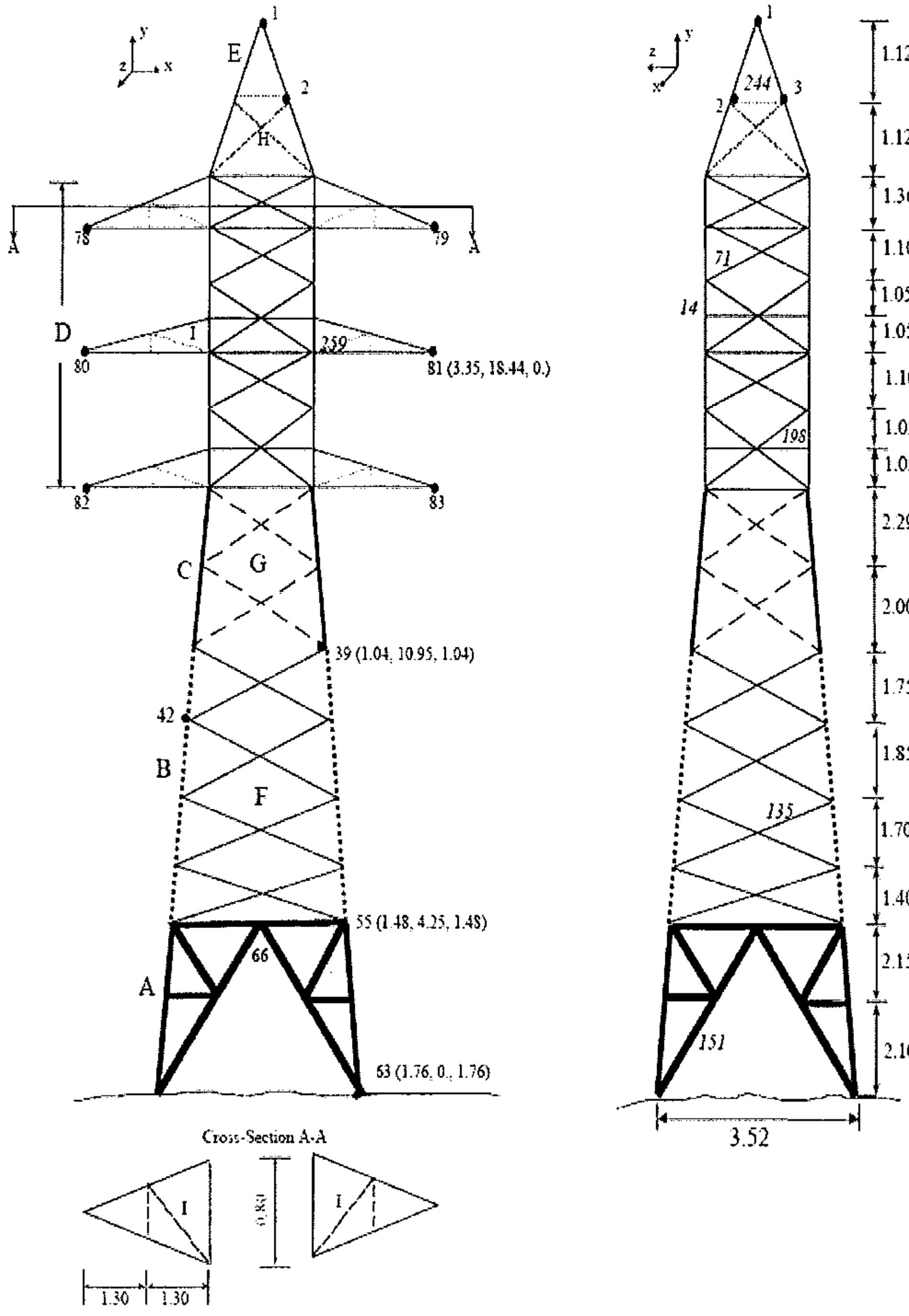


Fig. 2.4: Isometric View of Steel Transmission Tower showing stresses



a. Front View b. Side View

Fig. 2.5 Front view and side view of Transmission Tower

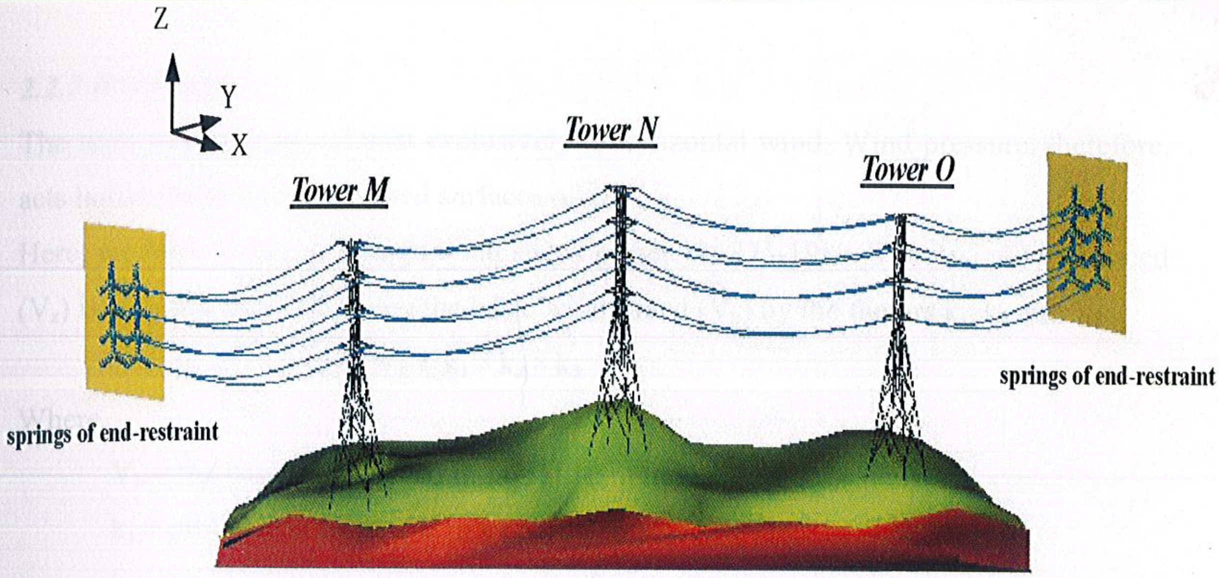


Fig. 2.6 Analytical model of tower system

2.2 Estimation of Loads for Analysis and Design

For the Transmission tower, analysis was performed and the design done for the following loads:

- Self Weight
- Wind load and
- Cable load

2.2.1 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.

2.2.2 Wind load

The term 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 2.1 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 centres.

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 2.2 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 as 1.0) otherwise

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

C depends upon slopes as:

SLOPE	VALUE OF C
$> 17^o$	0.36
$3^o < \theta < 17^o$	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

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

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.

ϕ = 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.

Table 2.3 Values of net wind force coefficient

Solidity ratio ϕ	C_f for	
	Square towers	Equilateral triangular towers
0.05	4	3.3
0.1	3.8	3.1
0.2	3.3	2.7
0.3	2.8	2.3
0.4	2.3	1.9
0.5	2.1	1.5

Wind load on the tower

Force coefficient for the tower of square or equilateral triangle section with flat sided members for wind blowing against any face shall be taken as given in table below. Here solidity ratio (ψ) is equal to the effective area (i.e. projected area is equal of all the individual elements) of a frame normal to the wind direction divided by the area enclosed by the boundary of the frame normal to the wind direction.

For square lattice towers with flat sided members, the maximum load which occurs when the wind blows into a corner shall be taken as 1.2 times the load for the wind blowing against a face.

Factor of safety

When the applied stresses on a structure reach their yield point the member suddenly elongates by large.Such yielding of the member will cause detrimental deformations of the structure of which it is part. It is necessary, therefore, at design loads, that is under service conditions, to keep the applied stress below the yield point by certain margin.

Hence allowable stress in a tension member is obtained by dividing the yield stress by a constant referred to as safety factor or factor of safety (F):

$$\text{Allowable stress } (\sigma_a) = f_y/F$$

In order to find the minimum value of factor of safety (F_{min}), let us define it in a rational method. The factor of safety (F) may be defined as the ratio of computed strength (S) of the structure or the structural member to the respective computed force p carried by it:

$$F = S/P$$

2.2.3 Cable load

The metal cables reaching out from the transmission tower imposes axial pull on the tower creating tensile and compressive stresses in the angle members of the tower. The length of cable between two consecutive towers can generally vary from anything between 50m to 500m. We have ignored the wind pressure on cables in our design calculations.

In our design transmission tower in all seven cables reach out from the tower with six from horizontal flanges with three on each side and one at the top. We have assumed the diameter of transmission tower has 20mm.

Procedure for determination of cable loads

Load = Area × Density × length of cable

Where,

Load = cable load on the transmission tower in kN

Density = Density of steel in kN/m^3

Length = Length of cable in m

Formulation of cable load:

$$\text{Area of cable} = \frac{\pi}{4} D^2$$

Where,

D = Diameter of the cable wire

Load/metre on the cable $= \rho$ (kN/m^3) × area (m^2)

= load (kN/m)

Total force due to cable = load (kN/m) × length of cable (m)

= force (kN)

Load Combinations

A judicious combination of all the working loads, specified in all the preceding articles, keeping in view the probability of:

(a) their acting together

(b) their disposition in relation to other loads

(c) the severity of stresses or deformations caused by the combination of the various loads.

It is necessary to ensure the required safety and economy in the design of a structure.

The following load combinations were adopted for steel as per IS-875: 1987 (part 5):

(1) 1×WL in X+ 1×DL

(2) 1.2×DL + 1.2×LL + 1.2×WL in X

(3) WL in X + LL

(4) 1×WLin Z+ 1×DL

(5) 1.2×DL + 1.2×LL + 1.2×WL in Z

(6) WL in Z + LL

2.3 Site data

The chosen site for construction of transmission tower lies in the outskirts of shimla. The geotechnical and environmental factors of the vicinity are as follows:

1. The bearing capacity of the soil in 250 kN/m^2.

2. The basic wind speed in shimla is 39m/sec.

3. The probability factor k_1 is taken from the table 2.1 as 1.06.

4. The Terrain, height and structure size factor k_2 is varying at different levels of the tower and is taken from the table 2.2 as follows:

k_2 at 10m height = 0.98

k_2 at 15m height = 1.02

k_2 at 20m height = 1.05

k_2 at 25m height = 1.75

5. The Topography factor k_3 is assumed to be 1.25 for hilly terrain of shimla.

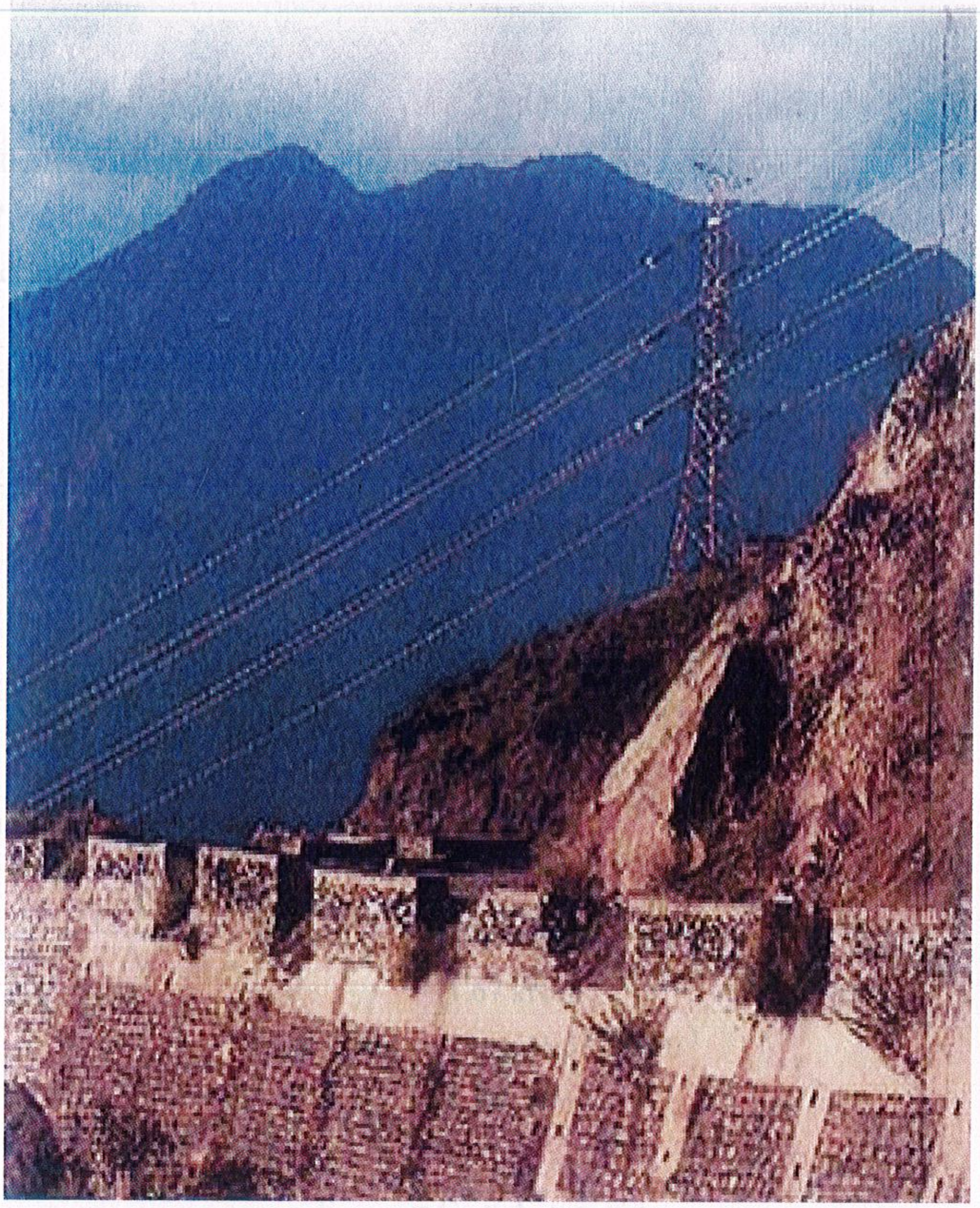


Fig. 2.7 Transmission Tower in Hill Side Area

2.4 Design calculations

The design calculation for wind load and cable load are as follows.

2.4.1 Calculation of wind load

The design wind speed is calculated as:

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

$$V_z \text{ at } 10m = 39 \times 1.06 \times 0.98 \times 1.25$$

$$= 50.64 \text{ m/sec}$$

$$V_z \text{ at } 15m = 39 \times 1.06 \times 1.02 \times 1.25$$

$$= 52.7 \text{ m/sec}$$

$$V_z \text{ at } 20m = 39 \times 1.06 \times 1.05 \times 1.25$$

$$= 54.25 \text{ m/sec}$$

$$V_z \text{ at } 25m = 39 \times 1.06 \times 1.075 \times 1.25$$

$$= 55.55 \text{ m/sec}$$

Design Wind Pressure

$$p_z = 0.6\ V_z^2$$

$$p_z \text{ at } 15 \text{ m} = 0.6 \times (52.7)^2 \times 10^{-3}$$

$$= 1.67 \text{ kN/m}^2$$

$$p_z \text{ at } 25 \text{ m} = 0.6 \times (55.55)^2 \times 10^{-3}$$

$$= 1.85 \text{ kN/m}^2$$

Design wind force

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

Calculation of area

$$\text{Area of segment I} = \left[\frac{3.52 + 1.52}{2}\right] \times 15.24$$

$$= 38.4 \text{ m}^2$$

$$\text{Area of segment II} = 1.52 \times 7.72 + 6 \times 0.5 \times 2.70 \times 1.0$$

$$= 2.25 \times 0.5 \times 1.5 + 2$$

$$= 24.50 \text{ m}^2$$

Now, we calculate wind force using the above area

$$F = A \times C_f \times P_z \times \phi$$

Put $C_f = 3.15$ from table 2.3

$$F_{15} = 38.40 \times 3.15 \times 1.667 \times 0.23 \ [C_f]$$

$$F_{15} = 46.74 \text{ kN}$$

again from table 2.3 $C_f = 3.05$

$$F_{25} = 24.50 \times 3.05 \times 1.851 \times 0.25$$

$$F_{25} = 34.59 \text{ kN}$$

2.4.2 Calculation of cable load

Unit Load of the cable $= \frac{\pi}{4} D^2 \times \rho$

$$= \frac{\pi}{4} \times (20 \times 10^{-3})^2 \times 76.81$$

$$= 0.024 \text{ kN/m}$$

Cable load = Unit load × c/c distance of one cable from the other cable

= 0 .024 × 225

= 5.4 kN

Total load of the cable = 1.5 cable load + Weight of man with loads + Weight of earth wire attachement

= 1.5 (5.4) + 1.5 + 0.5

= 10.162 kN

SECTION 3
ANALYSIS OF TOWER

3.1 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. Supports
4. Assigning type and properties of members
5. Assignment of loads due to wind and cables
6. Grouping of members

Following data were inserted as text:

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

3.2 Summary of Member End Forces

The following table has been obtained from STAAD.pro results. It is obvious that the load cases containing Wind Load in Z direction are most critical.

Table 3.1 Summary of Member end forces

	Beam	L/C	Node	Fx (kN)	Fy (kN)	Fz (kN)	Mx (kNm)	My (kNm)	Mz (kNm)
Max Fx	198	9	2	3408.192	-21.358	-3.827	-0.051	-4.671	23.157
Min Fx	9	9	9	-3185.505	-12.366	3.644	0.05	-4.772	-8.188
Max Fy	3	9	5	-527.761	22.05	-8.13	0.016	5.769	20.552
Min Fy	2	9	5	-533.144	-22.32	7.696	-0.029	5.014	20.984
Max Fz	218	9	78	-68.797	0.716	40.754	0.057	-20.732	-3.614
Min Fz	220	9	78	-58.811	1.091	-42.135	-0.045	20.879	-2.505
Max Mx	8	9	8	199.356	-7.982	4.382	0.109	-1.838	-6.22
Min Mx	5	9	9	207.204	-6.159	-4.971	-0.103	2.583	-5.243
Max My	204	9	85	180.207	-20.673	-21.725	0.009	25.864	-24.64
Min My	204	9	1	180.998	-21.005	-21.725	0.009	-24.196	23.378
Max Mz	197	9	1	3251.431	-20.85	3.491	0.048	4.437	23.955
Min Mz	204	9	85	180.207	-20.673	-21.725	0.009	25.864	-24.64

Note: Load Case no. 9 is 1.2×DL+1.2 ×LL+1.2×WL IN Z

3.3 Summary of Nodal Displacements

The following table has been obtained from STAAD.pro results. It is obvious that the load cases containing Wind Load in X and Z directions are most critical.

Table 3.2 Summary of Nodal displacement

	A Node	Horz L/C	HorZ. X (mm)	VERT. Y (mm)	HORZ. Z (mm)	Res. (mm)	Rot. rX (rad)	H rY (rad)	I rZ (rad)
Max X	19	6	623.93	-2.328	8.78	623.996	0	0	-0.04
Min X	85	9	-26.219	-12.804	-21.259	36.102	0.002	-0.001	-0.002
Max Y	122	6	494.549	127.997	7.528	510.9	0	0	-0.039
Min Y	121	9	494.001	-134.505	7.287	512.037	0	0	-0.04
Max Z	19	6	9.588	-2.426	682.04	682.111	0.043	0	0
Min Z	86	9	-19.392	-11.725	-24.02	33.023	0.002	0.001	-0.002
Max rX	19	6	9.588	-2.426	682.04	682.111	0.043	0	0
Min rX	8	9	7.782	-15.59	-0.954	17.45	-0.009	0.001	-0.013
Max rY	83	6	14.112	-10.188	-17.887	24.957	0.003	0.012	-0.001
Min rY	86	9	-16.824	-11.61	-20.929	29.255	0.003	-0.012	0.001
Max rZ	4	6	-1.043	-17.029	8.347	18.993	0.014	-0.001	0.01
Min rZ	121	9	494.001	-134.505	7.287	512.037	0	0	-0.04
MaxRst	19	6	9.588	-2.426	682.04	682.111	0.043	0	0

Note: (a) Load Case no. 6:1.2 × DL+1.2 × LL+1.2 × WL IN X

(b) Load Case no. 9:1.2×DL+1.2 ×LL+1.2×WL IN Z

3.4 Summary of Support reactions

Table 3.3 Support reactions

	A	Horiz.	Horiz.	Vert.	Horiz.	Moment	G	H
	Node	L/C	Fx (kN)	Fy (kN)	Fz (kN)	Mx (kNm)	My (kNm)	Mz (kNm)
Max Fx	2	9	282.232	4151.24	-423.769	50.236	-1.16	56.29
Min Fx	6	6	-391.953	3811.905	259.198	-51.6	1.022	-45.797
Max Fy	2	9	282.232	4151.24	-423.769	50.236	-1.16	56.29
Min Fy	7	9	-263.19	-3886.22	-405.477	45.733	-0.929	-52.301
Max Fz	6	6	-391.953	3811.905	259.198	-51.6	1.022	-45.797
Min Fz	2	9	282.232	4151.24	-423.769	50.236	-1.16	56.29
Max Mx	1	6	-376.455	3658.338	-243.011	56.64	-0.856	-50.708
Min Mx	6	6	-391.953	3811.905	259.198	-51.6	1.022	-45.797
Max My	6	9	245.59	-3714.7	-387.108	44.226	1.138	50.386
Min My	2	9	282.232	4151.24	-423.769	50.236	-1.16	56.29
Max Mz	2	9	282.232	4151.24	-423.769	50.236	-1.16	56.29
Min Mz	1	9	-264.632	3983.763	-406.922	55.59	0.979	-61.785

Note: (a) Load Case no. 6:1.2×DL+1.2×LL+1.2WL IN X

(b) Load Case no. 9:1.2×DL+1.2 ×LL+1.2×WL IN Z

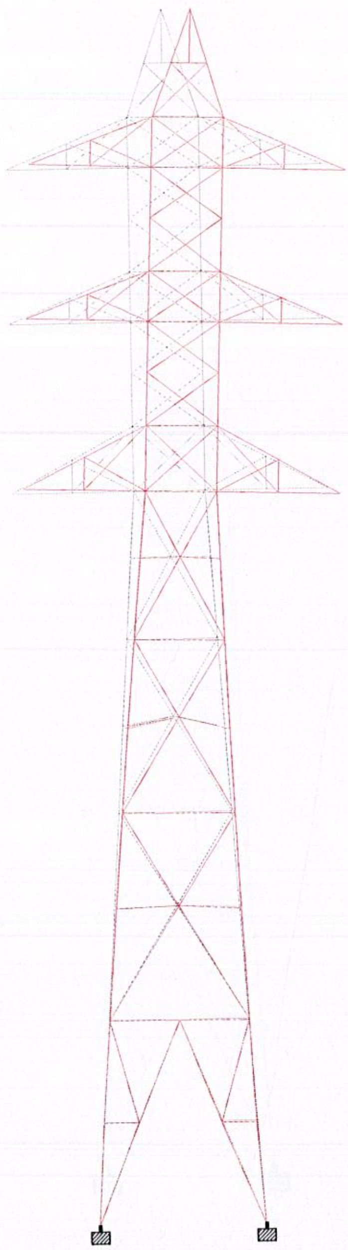


Fig. 3.1 Displacement of the tower under Worst load combination i.e. [1.2×DL + 1.2×LL + 1.2×WL] in X dir.

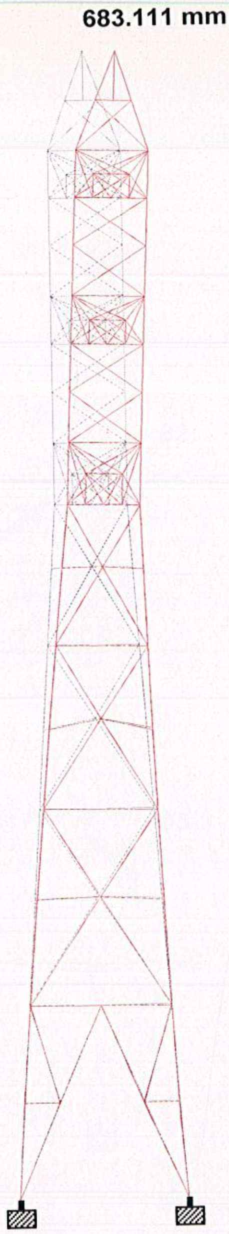


Fig. 3.2 Displacement of the tower under Worst load combination i.e. [1.2×DL + 1.2×LL + 1.2×WL] in Z dir.

3.5 Variation of axial forces

Figure 3.3 shows the representative members whose axial and shear forces diagrams were plotted by STAAD.pro and shown in figures 3.4 to 3.8.

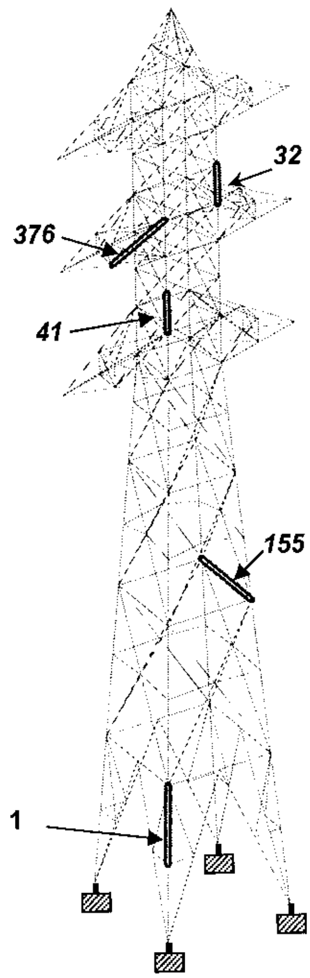
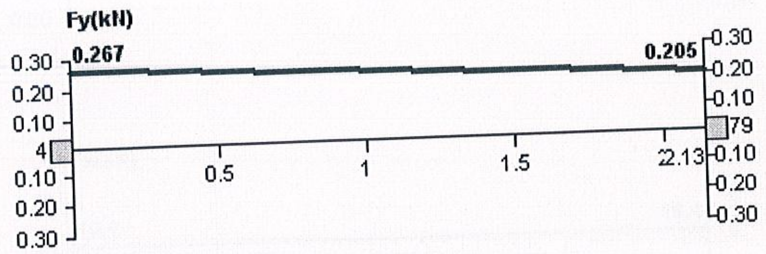


Fig. 3.3: Highlighted members whose force-diagrams are plotted

Following are the graphs showing variation of axial forces along some typical representative members.

Member No. 1



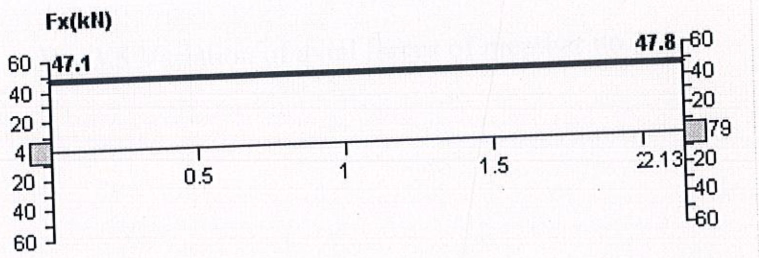


Fig 3.4 Variation of axial forces of member no.1

Member No. 376

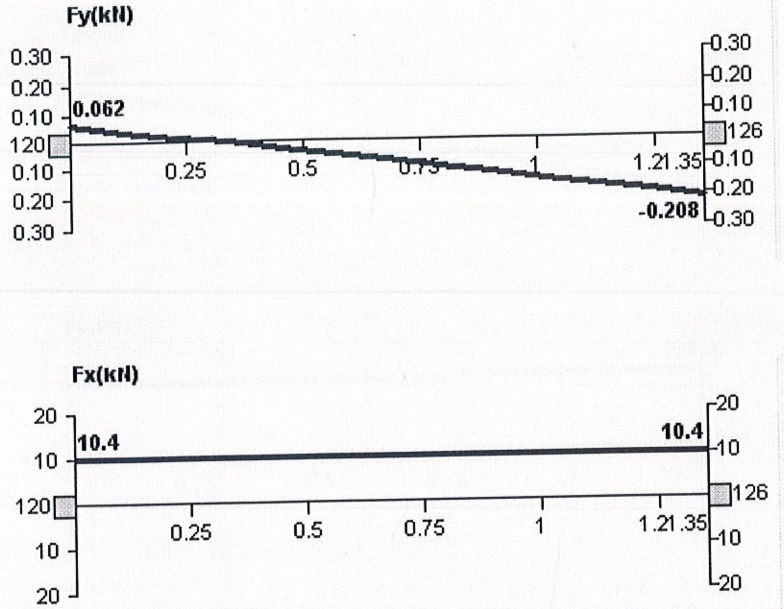


Fig 3.5 Variation of axial forces of member no.376

Member No. 41

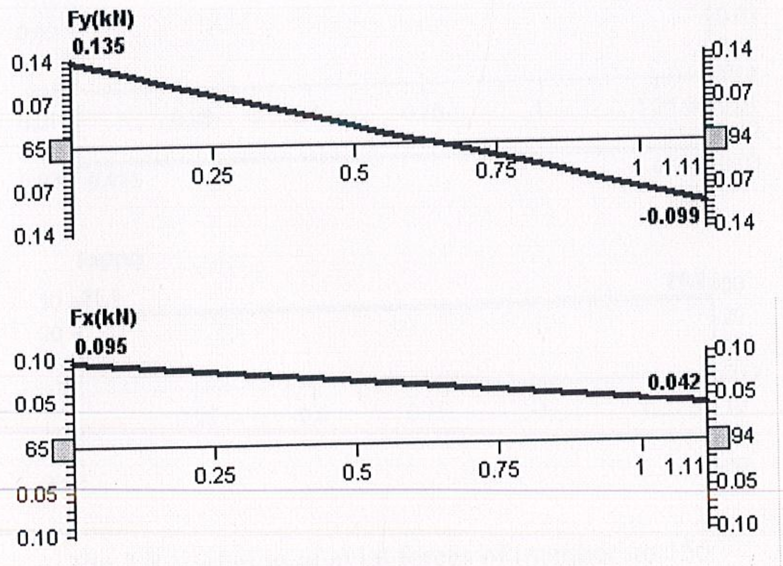


Fig 3.6 Variation of axial forces of member no.41

Member No. 32

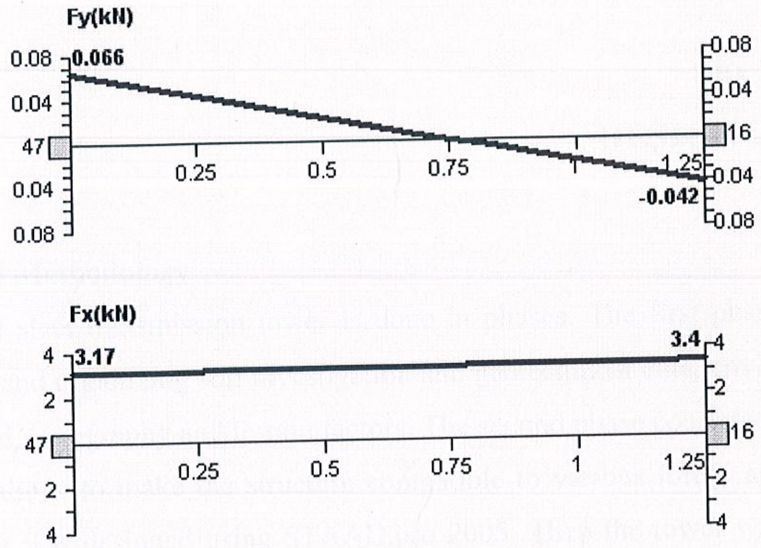


Fig 3.7 Variation of axial forces of member no.32

Member No. 155

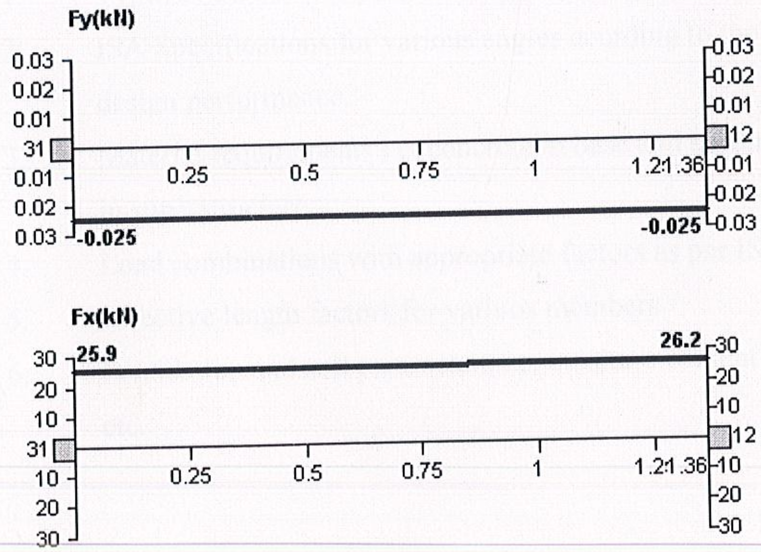


Fig 3.8 Variation of axial forces of member no.155

SECTION 4
DESIGN OF TOWER

4.1 Design Methodology

The design of steel transmission tower is done in phases. The first phase consisted of accumulating and organizing soil investigation and geotechnical data, environmental data i.e. wind speed, topography and terrain factors. The second phase consisted of performing design calculations to make the structure compatible to various forces and loads. After then the tower was designed using STAAD.pro 2005. Then the tower was analyzed for being compatible with various loads. Ultimately the tower design was considered for optimum safety consideration on most economical cost.

4.2 Data Input for Design with STAAD.pro

1. Types of sections of all member groups
2. ISA Specifications for various angles acording to their expected design performance.
3. Material requirements i.e. concrete in base and substructure, steel in superstructure.
4. Load combinations with appropriate factors as per IS-875: 1987-V
5. Effective length factors for variuos members
6. Foundation and soil parameters i.e. mositure content and plasticity etc.

4.3 Design Results For Superstructure

The design was finally performed by STAAD.pro and the results obtained are tabulated as below:

Table 4.1 Design results

Beam	New Property	Ratio	Ay (cm2)	Az (cm2)	Ax (cm2)	Dw (cm)	Bf (cm)	Iz (cm4)	Iy (cm4)	Ix (cm4)
1	ISA90X90X12	0.141	14.4	14.4	40.38	9	9	300.582	591.753	19.382
2	ISA80X80X10	0.192	10.667	10.667	30.1	8	8	177.969	345.444	10.033
3	ISA90X90X12	0.035	14.4	14.4	40.38	9	9	300.582	591.753	19.382
4	ISA90X90X12	0.037	14.4	14.4	40.38	9	9	300.582	591.753	19.382
5	ISA90X90X12	0.025	14.4	14.4	40.38	9	9	300.582	591.753	19.382
6	ISA90X90X10	0.042	12	12	34.06	9	9	258.363	490.924	11.353
7	ISA70X70X10	0.02	9.333	9.333	26.04	7	7	116.321	232.488	8.68
8	ISA90X90X10	0.038	12	12	34.06	9	9	258.363	490.924	11.353
9	ISA90X90X10	0.049	12	12	34.06	9	9	258.363	490.924	11.353
10	ISA90X90X10	0.055	12	12	34.06	9	9	258.363	490.924	11.353
11	ISA90X90X10	0.061	12	12	34.06	9	9	258.363	490.924	11.353
12	ISA90X90X10	0.08	12	12	34.06	9	9	258.363	490.924	11.353
13	ISA90X90X10	0.064	12	12	34.06	9	9	258.363	490.924	11.353
14	ISA90X90X10	0.043	12	12	34.06	9	9	258.363	490.924	11.353
15	ISA90X90X10	0.046	12	12	34.06	9	9	258.363	490.924	11.353
16	ISA90X90X10	0.068	12	12	34.06	9	9	258.363	490.924	11.353
17	ISA90X90X10	0.077	12	12	34.06	9	9	258.363	490.924	11.353
18	ISA90X90X10	0.065	12	12	34.06	9	9	258.363	490.924	11.353
19	ISA90X90X10	0.066	12	12	34.06	9	9	258.363	490.924	11.353
20	ISA90X90X10	0.038	12	12	34.06	9	9	258.363	490.924	11.353
21	ISA90X90X10	0.049	12	12	34.06	9	9	258.363	490.924	11.353
22	ISA90X90X10	0.055	12	12	34.06	9	9	258.363	490.924	11.353
23	ISA70X70X10	0.023	9.333	9.333	26.04	7	7	116.321	232.488	8.68
24	ISA70X70X10	0.032	9.333	9.333	26.04	7	7	116.321	232.488	8.68
25	ISA70X70X10	0.021	9.333	9.333	26.04	7	7	116.321	232.488	8.68
26	ISA60X60X10	0.035	8	8	22	6	6	70.924	147.333	7.333
27	ISA60X60X10	0.03	8	8	22	6	6	70.924	147.333	7.333
28	ISA60X60X10	0.019	8	8	22	6	6	70.924	147.333	7.333
29	ISA60x60x10	0.06	8	8	22	6	6	70.924	147.333	7.333
30	ISA60X60X10	0.02	8	8	22	6	6	70.924	147.333	7.333
31	ISA70X70X10	0.014	9.333	9.333	26.04	7	7	116.321	232.488	8.68
32	ISA60X60X10	0.036	8	8	22	6	6	70.924	147.333	7.333
33	ISA60X60X10	0.014	8	8	22	6	6	70.924	147.333	7.333
34	ISA60X60X10	0.059	8	8	22	6	6	70.924	147.333	7.333
35	ISA60X60X10	0.06	8	8	22	6	6	70.924	147.333	7.333
36	ISA60X60X10	0.029	8	8	22	6	6	70.924	147.333	7.333

37	ISA60X60X10	0.013	8	8	22	6	6	70.924	147.333	7.333
38	ISA60X60X10	0.035	8	8	22	6	6	70.924	147.333	7.333
39	ISA60X60X10	0.02	8	8	22	6	6	70.924	147.333	7.333
40	ISA70X70X10	0.032	9.333	9.333	26.04	7	7	116.321	232.488	8.68
41	ISA70X70X10	0.021	9.333	9.333	26.04	7	7	116.321	232.488	8.68
42	ISA60X60X10	0.035	8	8	22	6	6	70.924	147.333	7.333
43	ISA60X60X10	0.03	8	8	22	6	6	70.924	147.333	7.333
44	ISA60X60X10	0.019	8	8	22	6	6	70.924	147.333	7.333
45	ISA60X60X10	0.06	8	8	22	6	6	70.924	147.333	7.333
46	ISA70X70X10	0.023	9.333	9.333	26.04	7	7	116.321	232.488	8.68
47	ISA60X60X10	0.036	8	8	22	6	6	70.924	147.333	7.333
48	ISA60X60X10	0.059	8	8	22	6	6	70.924	147.333	7.333
49	ISA60X60X10	0.029	8	8	22	6	6	70.924	147.333	7.333
50	ISA60X60X10	0.014	8	8	22	6	6	70.924	147.333	7.333
51	ISA60X60X10	0.06	8	8	22	6	6	70.924	147.333	7.333
52	ISA60X60X10	0.03	8	8	22	6	6	70.924	147.333	7.333
53	ISA60X60X10	0.013	8	8	22	6	6	70.924	147.333	7.333
54	ISA70X70X10	0.014	9.333	9.333	26.04	7	7	116.321	232.488	8.68
55	ISA90X90X10	0.023	12	12	34.06	9	9	258.363	490.924	11.353
56	ISA90X90X10	0.033	12	12	34.06	9	9	258.363	490.924	11.353
57	ISA90X90X10	0.005	12	12	34.06	9	9	258.363	490.924	11.353
58	ISA90X90X10	0.032	12	12	34.06	9	9	258.363	490.924	11.353
59	ISA70X70X10	0.023	9.333	9.333	26.04	7	7	116.321	232.488	8.68
60	ISA70X70X10	0.017	9.333	9.333	26.04	7	7	116.321	232.488	8.68
61	ISA70X70X10	0.008	9.333	9.333	26.04	7	7	116.321	232.488	8.68
62	ISA70X70X10	0.018	9.333	9.333	26.04	7	7	116.321	232.488	8.68
63	ISA90X90X12	0.039	14.4	14.4	40.38	9	9	300.582	591.753	19.382
64	ISA90X90X12	0.05	14.4	14.4	40.38	9	9	300.582	591.753	19.382
65	ISA90X90X12	0.044	14.4	14.4	40.38	9	9	300.582	591.753	19.382
66	ISA90X90X12	0.06	14.4	14.4	40.38	9	9	300.582	591.753	19.382
67	ISA90X90X12	0.055	14.4	14.4	40.38	9	9	300.582	591.753	19.382
68	ISA90X90X12	0.049	14.4	14.4	40.38	9	9	300.582	591.753	19.382
69	ISA90X90X12	0.057	14.4	14.4	40.38	9	9	300.582	591.753	19.382
70	ISA90X90X12	0.052	14.4	14.4	40.38	9	9	300.582	591.753	19.382
71	ISA90X90X12	0.053	14.4	14.4	40.38	9	9	300.582	591.753	19.382
72	ISA90X90X12	0.025	14.4	14.4	40.38	9	9	300.582	591.753	19.382
73	ISA90X90X12	0.024	14.4	14.4	40.38	9	9	300.582	591.753	19.382
74	ISA90X90X12	0.031	14.4	14.4	40.38	9	9	300.582	591.753	19.382
75	ISA75X75X10	0.041	10	10	28.04	7.5	7.5	144.956	285.383	9.347
76	ISA75X75X10	0.052	10	10	28.04	7.5	7.5	144.956	285.383	9.347
77	ISA75X75X10	0.053	10	10	28.04	7.5	7.5	144.956	285.383	9.347
78	ISA80X80X10	0.069	10.667	10.667	30.1	8	8	177.969	345.444	10.033
79	ISA80X80X10	0.07	10.667	10.667	30.1	8	8	177.969	345.444	10.033
80	ISA75X75X10	0.063	10	10	28.04	7.5	7.5	144.956	285.383	9.347
81	ISA75X75X10	0.061	10	10	28.04	7.5	7.5	144.956	285.383	9.347
82	ISA80X80X10	0.07	10.667	10.667	30.1	8	8	177.969	345.444	10.033
83	ISA70X70X10	0.039	9.333	9.333	26.04	7	7	116.321	232.488	8.68

84	ISA70X70X10	0.054	9.333	9.333	26.04	7	7	116.321	232.488	8.68
85	ISA70X70X10	0.05	9.333	9.333	26.04	7	7	116.321	232.488	8.68
86	ISA70X70X10	0.078	9.333	9.333	26.04	7	7	116.321	232.488	8.68
87	ISA90X90X12	0.037	14.4	14.4	40.38	9	9	300.582	591.753	19.382
88	ISA90X90X12	0.035	14.4	14.4	40.38	9	9	300.582	591.753	19.382
89	ISA90X90X12	0.048	14.4	14.4	40.38	9	9	300.582	591.753	19.382
90	ISA90X90X12	0.044	14.4	14.4	40.38	9	9	300.582	591.753	19.382
91	ISA90X90X12	0.043	14.4	14.4	40.38	9	9	300.582	591.753	19.382
92	ISA90X90X12	0.163	14.4	14.4	40.38	9	9	300.582	591.753	19.382
93	ISA90X90X12	0.164	14.4	14.4	40.38	9	9	300.582	591.753	19.382
94	ISA90X90X12	0.169	14.4	14.4	40.38	9	9	300.582	591.753	19.382
95	ISA90X90X12	0.086	14.4	14.4	40.38	9	9	300.582	591.753	19.382
96	ISA90X90X12	0.088	14.4	14.4	40.38	9	9	300.582	591.753	19.382
97	ISA90X90X12	0.089	14.4	14.4	40.38	9	9	300.582	591.753	19.382
98	ISA90X90X12	0.097	14.4	14.4	40.38	9	9	300.582	591.753	19.382
99	ISA80X80X10	0.032	10.667	10.667	30.1	8	8	177.969	345.444	10.033
100	ISA80X80X10	0.056	10.667	10.667	30.1	8	8	177.969	345.444	10.033
101	ISA80X80X10	0.031	10.667	10.667	30.1	8	8	177.969	345.444	10.033
102	ISA80X80X10	0.054	10.667	10.667	30.1	8	8	177.969	345.444	10.033
103	ISA80X80X10	0.031	10.667	10.667	30.1	8	8	177.969	345.444	10.033
104	ISA80X80X10	0.054	10.667	10.667	30.1	8	8	177.969	345.444	10.033
105	ISA80X80X10	0.041	10.667	10.667	30.1	8	8	177.969	345.444	10.033
106	ISA80X80X10	0.063	10.667	10.667	30.1	8	8	177.969	345.444	10.033
107	ISA70X70X10	0.023	9.333	9.333	26.04	7	7	116.321	232.488	8.68
108	ISA70X70X10	0.008	9.333	9.333	26.04	7	7	116.321	232.488	8.68
109	ISA70X70X10	0.017	9.333	9.333	26.04	7	7	116.321	232.488	8.68
110	ISA70X70X10	0.018	9.333	9.333	26.04	7	7	116.321	232.488	8.68
111	ISA70X70X10	0.014	9.333	9.333	26.04	7	7	116.321	232.488	8.68
112	ISA75X75X10	0.052	10	10	28.04	7.5	7.5	144.956	285.383	9.347
113	ISA75X75X10	0.051	10	10	28.04	7.5	7.5	144.956	285.383	9.347
114	ISA75X75X10	0.046	10	10	28.04	7.5	7.5	144.956	285.383	9.347
115	ISA75X75X10	0.047	10	10	28.04	7.5	7.5	144.956	285.383	9.347
116	ISA75X75X10	0.062	10	10	28.04	7.5	7.5	144.956	285.383	9.347
117	ISA75X75X10	0.063	10	10	28.04	7.5	7.5	144.956	285.383	9.347
118	ISA75X75X10	0.061	10	10	28.04	7.5	7.5	144.956	285.383	9.347
119	ISA75X75X10	0.052	10	10	28.04	7.5	7.5	144.956	285.383	9.347
120	ISA80X80X10	0.116	10.667	10.667	30.1	8	8	177.969	345.444	10.033
121	ISA80X80X10	0.113	10.667	10.667	30.1	8	8	177.969	345.444	10.033
122	ISA80X80X10	0.115	10.667	10.667	30.1	8	8	177.969	345.444	10.033
123	ISA75X75X10	0.004	10	10	28.04	7.5	7.5	144.956	285.383	9.347
124	ISA75X75X10	0.041	10	10	28.04	7.5	7.5	144.956	285.383	9.347
125	ISA75X75X10	0.047	10	10	28.04	7.5	7.5	144.956	285.383	9.347
126	ISA90X90X12	0.038	14.4	14.4	40.38	9	9	300.582	591.753	19.382
127	ISA75X75X10	0.04	10	10	28.04	7.5	7.5	144.956	285.383	9.347
128	ISA90X90X12	0.042	14.4	14.4	40.38	9	9	300.582	591.753	19.382
129	ISA75X75X10	0.01	10	10	28.04	7.5	7.5	144.956	285.383	9.347
130	ISA90X90X12	0.044	14.4	14.4	40.38	9	9	300.582	591.753	19.382

131	ISA90X90X12	0.05	14.4	14.4	40.38	9	9	300.582	591.753	19.382
132	ISA90X90X12	0.078	14.4	14.4	40.38	9	9	300.582	591.753	19.382
133	ISA80X80X10	0.008	10.667	10.667	30.1	8	8	177.969	345.444	10.033
134	ISA70X70X10	0.008	9.333	9.333	26.04	7	7	116.321	232.488	8.68
135	ISA70X70X10	0.017	9.333	9.333	26.04	7	7	116.321	232.488	8.68
136	ISA70X70X10	0.003	9.333	9.333	26.04	7	7	116.321	232.488	8.68
137	ISA70X70X10	0.001	9.333	9.333	26.04	7	7	116.321	232.488	8.68
138	ISA70X70X10	0.018	9.333	9.333	26.04	7	7	116.321	232.488	8.68
139	ISA70X70X10	0.041	9.333	9.333	26.04	7	7	116.321	232.488	8.68
140	ISA70X70X10	0.022	9.333	9.333	26.04	7	7	116.321	232.488	8.68
141	ISA70X70X10	0.05	9.333	9.333	26.04	7	7	116.321	232.488	8.68
142	ISA70X70X10	0.054	9.333	9.333	26.04	7	7	116.321	232.488	8.68
143	ISA70X70X10	0.038	9.333	9.333	26.04	7	7	116.321	232.488	8.68
144	ISA70X70X10	0.078	9.333	9.333	26.04	7	7	116.321	232.488	8.68
145	ISA70X70X10	0.05	9.333	9.333	26.04	7	7	116.321	232.488	8.68
146	ISA70X70X10	0.033	9.333	9.333	26.04	7	7	116.321	232.488	8.68
147	ISA70X70X10	0.041	9.333	9.333	26.04	7	7	116.321	232.488	8.68
148	ISA70X70X10	0.061	9.333	9.333	26.04	7	7	116.321	232.488	8.68
149	ISA70X70X10	0.06	9.333	9.333	26.04	7	7	116.321	232.488	8.68
150	ISA70X70X10	0.046	9.333	9.333	26.04	7	7	116.321	232.488	8.68
151	ISA70X70X10	0.044	9.333	9.333	26.04	7	7	116.321	232.488	8.68
152	ISA60X60X10	0.015	8	8	22	6	6	70.924	147.333	7.333
153	ISA60X60X10	0.018	8	8	22	6	6	70.924	147.333	7.333
154	ISA60X60X10	0.012	8	8	22	6	6	70.924	147.333	7.333
155	ISA60X60X10	0.025	8	8	22	6	6	70.924	147.333	7.333
156	ISA60X60X10	0.032	8	8	22	6	6	70.924	147.333	7.333
157	ISA60X60X10	0.026	8	8	22	6	6	70.924	147.333	7.333
158	ISA60X60X10	0.037	8	8	22	6	6	70.924	147.333	7.333
159	ISA60X60X10	0.038	8	8	22	6	6	70.924	147.333	7.333
160	ISA60X60X10	0.005	8	8	22	6	6	70.924	147.333	7.333
161	ISA70X70X10	0.054	9.333	9.333	26.04	7	7	116.321	232.488	8.68
162	ISA70X70X10	0.039	9.333	9.333	26.04	7	7	116.321	232.488	8.68
163	ISA60X60X10	0.014	8	8	22	6	6	70.924	147.333	7.333
164	ISA70X70X10	0.05	9.333	9.333	26.04	7	7	116.321	232.488	8.68
165	ISA60X60X10	0.018	8	8	22	6	6	70.924	147.333	7.333
166	ISA60X60X10	0.017	8	8	22	6	6	70.924	147.333	7.333
167	ISA60X60X10	0.009	8	8	22	6	6	70.924	147.333	7.333
168	ISA60X60X10	0.029	8	8	22	6	6	70.924	147.333	7.333
169	ISA60X60X10	0.028	8	8	22	6	6	70.924	147.333	7.333
170	ISA60X60X10	0.003	8	8	22	6	6	70.924	147.333	7.333
171	ISA60X60X10	0.005	8	8	22	6	6	70.924	147.333	7.333
172	ISA60X60X10	0.045	8	8	22	6	6	70.924	147.333	7.333
173	ISA70X70X10	0.078	9.333	9.333	26.04	7	7	116.321	232.488	8.68
174	ISA70X70X10	0.05	9.333	9.333	26.04	7	7	116.321	232.488	8.68
175	ISA60X60X10	0.009	8	8	22	6	6	70.924	147.333	7.333
176	ISA60X60X10	0.029	8	8	22	6	6	70.924	147.333	7.333
177	ISA70X70X10	0.054	9.333	9.333	26.04	7	7	116.321	232.488	8.68

178	ISA70X70X10	0.038	9.333	9.333	26.04	7	7	116.321	232.488	8.68
179	ISA60X60X10	0.018	8	8	22	6	6	70.924	147.333	7.333
180	ISA60X60X10	0.011	8	8	22	6	6	70.924	147.333	7.333
181	ISA60X60X10	0.017	8	8	22	6	6	70.924	147.333	7.333
182	ISA60X60X10	0.026	8	8	22	6	6	70.924	147.333	7.333
183	ISA60X60X10	0.028	8	8	22	6	6	70.924	147.333	7.333
184	ISA60X60X10	0.013	8	8	22	6	6	70.924	147.333	7.333
185	ISA60X60X10	0.046	8	8	22	6	6	70.924	147.333	7.333
186	ISA90X90X12	0.038	14.4	14.4	40.38	9	9	300.582	591.753	19.382
187	ISA75X75X10	0.005	10	10	28.04	7.5	7.5	144.956	285.383	9.347
188	ISA75X75X10	0.006	10	10	28.04	7.5	7.5	144.956	285.383	9.347
189	ISA75X75X10	0.004	10	10	28.04	7.5	7.5	144.956	285.383	9.347
190	ISA90X90X12	0.043	14.4	14.4	40.38	9	9	300.582	591.753	19.382
191	ISA90X90X12	0.045	14.4	14.4	40.38	9	9	300.582	591.753	19.382
192	ISA75X75X10	0.008	10	10	28.04	7.5	7.5	144.956	285.383	9.347
193	ISA90X90X12	0.044	14.4	14.4	40.38	9	9	300.582	591.753	19.382
194	ISA75X75X10	0.007	10	10	28.04	7.5	7.5	144.956	285.383	9.347
195	ISA90X90X12	0.047	14.4	14.4	40.38	9	9	300.582	591.753	19.382
196	ISA90X90X12	0.074	14.4	14.4	40.38	9	9	300.582	591.753	19.382
197	ISA80X80X10	0.008	10.667	10.667	30.1	8	8	177.969	345.444	10.033
198	ISA90X90X12	0.073	14.4	14.4	40.38	9	9	300.582	591.753	19.382

4.4 Design of Foundation

The table given below gives the foudation detailing while the diagram below gives the pictorial representation of foundation.

4.4.1 Design Results of Foundation

The foundation has been designed for the worst loads coming on it. The forces for which the foundation has been designed are given in Table-3.3 (Support reactions)

Table 4.2 Foundation Details

Geometry	Geometry	Geometry	Geometry	Geometry	Geometry
Dim.of Foundation along X-dirn. (m)	Dim.of Foundation along X-dirn. (m)	Dim.of Foundation along Y-dirn. (m)	Dim.of Foundation along Y-dirn. (m)	Overall Thickness of Foundation (mm)	Overall Thickness of Foundation (mm)
Dim.of Foundation along X-dirn. (m)	Dim.of Foundation along X-dirn. (m)	Dim.of Foundation along Y-dirn.	Dim.of Foundation along Y-dirn. (m) 5	Overall Thickness of Foundation (mm) 500	Overall Thickness of Foundation(mm) 500

5	5	(m) 5			
Width of Beam	Width of Beam	Width of Beam	Depth of Beam	Depth of Beam	Depth of Beam
(mm) 300	(mm) 300	(mm) 300	(mm) 500	(mm) 500	(mm) 500
Depth of Foundation from Top of soil (m)	Depth of Foundation from Top of soil (m)	Water Table Considered	Water Table Considered	Depth of the Water Table (m)	Depth of the Water Table (m)
Depth of Foundation from Top of soil (m) 2.7	Depth of Foundation from Top of soil (m) 2.7	Water Table Considered	Water Table Considered	Depth of the Water Table (m)	Depth of the Water Table (m)
Stability	**Stability**	**Stability**	**Stability**	**Stability**	**Stability**
Allowable Gross Brg Capacity of soil (KN/m2) 250	Allowable Gross Brg Capacity of soil (KN/m2) 250	Actual Gross Pressure (KN/m2) 81.92	Actual Gross Pressure (KN/m2) 81.92	Tension Criteria	Tension Criteria
Allowable Gross Brg Capacity of soil (KN/m2) 250	Allowable Gross Brg Capacity of soil (KN/m2) 250	Actual Gross Pressure (KN/m2) 81.92	Actual Gross Pressure (KN/m2) 81.92	Tension Criteria	Tension Criteria
Allowable FOS aganist Overturning	Allowable FOS aganist Overturning	Actual FOS against Overturning about x-axis	Actual FOS against Overturning about x-axis	Actual FOS aganist Overturning about Y-axis	Actual FOS aganist Overturning about Y-axis
Allowable FOS aganist Overturning 1	Allowable FOS aganist Overturning 1	Actual FOS against Overturning about x-axis	Actual FOS against Overturning about x-axis	Actual FOS aganist Overturning about Y-axis	Actual FOS aganist Overturning about Y-axis
Minimum Allowable Percentage of Contact Area 70	Minimum Allowable Percentage of Contact Area 70	Minimum Allowable Percentage of Contact Area 70	Actual Percentage of Contact Area 100	Actual Percentage of Contact Area 100	Actual Percentage of Contact Area 100
Reinforcement Details of Beam	**Reinforcement Details of Beam**	**Reinforcement Details of Beam**	**Reinforcement Details of Beam**	**Reinforcement Details of Beam**	**Reinforcement Details of Beam**
Reinforcement Detail of Left Part of Beam	Reinforcement Detail of Left Part of Beam	Reinforcement Detail of Left Part of Beam	Reinforcement Detail of Left Part of Beam	Reinforcement Detail of Left Part of Beam	Reinforcement Detail of Left Part of Beam
At Bottom	At Bottom	At Bottom	At Top	At Top	At Top
Provided Reinforcement	Required Area (mm2) 286.95	Provided Area (mm2) 402.12	Provided Reinforcement	Required Area (mm2) 286.95	Provided Area (mm2) 402.12
Provided	Required Area	Provided Area	Provided	Required Area (mm2)	Provided Area

Reinforcement	(mm2) 286.95	(mm2) 402.12	Reinforcement	286.95	(mm2) 402.12
2 Nos 16mm dia bar			2 Nos 16mm dia bar		
2 Nos 16mm dia bar			2 Nos 16mm dia bar		
Reinforcement Detail of Mid Part(Span) of Beam	Reinforcement Detail of Mid Part(Span) of Beam	Reinforcement Detail of Mid Part(Span) of Beam	Reinforcement Detail of Mid Part(Span) of Beam	Reinforcement Detail of Mid Part(Span) of Beam	Reinforcement Detail of Mid Part(Span) of Beam
At Bottom	At Bottom	At Bottom	At Top	At Top	At Top
Provided Reinforcement	Required Area (mm2) 286.95	Provided Area (mm2) 402.12	Provided Reinforcement	Required Area (mm2) 1338.28	Provided Area (mm2) 1407.43
Provided Reinforcement	Required Area (mm2) 286.95	Provided Area (mm2) 402.12	Provided Reinforcement	Required Area (mm2) 1338.28	Provided Area (mm2) 1407.43
2 Nos 16mm dia bar			7 Nos 16mm dia bar		
2 Nos 16mm dia bar			7 Nos 16mm dia bar		
Reinforcement Detail of Right Part of Beam	Reinforcement Detail of Right Part of Beam	Reinforcement Detail of Right Part of Beam	Reinforcement Detail of Right Part of Beam	Reinforcement Detail of Right Part of Beam	Reinforcement Detail of Right Part of Beam
At Bottom	At Bottom	At Bottom	At Top	At Top	At Top
Provided Reinforcement	Required Area (mm2) 286.95	Provided Area (mm2) 402.12	Provided Reinforcement	Required Area (mm2) 286.95	Provided Area (mm2) 402.12
Provided Reinforcement	Required Area 286.95	Provided Area (mm2) 402.12	Provided Reinforcement	Required Area (mm2) 286.95	Provided Area (mm2) 402.12
2 Nos 16mm dia bar			2 Nos 16mm dia bar		
2 Nos 16mm dia bar			2 Nos 16mm dia bar		
Shear Reinforcement Detail	**Shear Reinforcement Detail**	**Shear Reinforcement Detail**	**Shear Reinforcement Detail**	**Shear Reinforcement Detail**	**Shear Reinforcement Detail**
At Left Column	At Left Column	At Left Column	At Right Column	At Right Column	At Right Column
8 mm 2 legged stirrups @ 50.00mm c/c	8 mm 2 legged stirrups @ 50.00mm c/c	8 mm 2 legged stirrups @ 50.00mm c/c	8 mm 2 legged stirrups @ 50.00mm c/c	8 mm 2 legged stirrups @ 50.00mm c/c	8 mm 2 legged stirrups @ 50.00mm c/c
Reinforcement Details of Slab	Reinforcement Details of Slab	Reinforcement Details of Slab	Reinforcement Details of Slab	Reinforcement Details of Slab	Reinforcement Details of Slab
Bottom	Bottom	Bottom	Bottom	Bottom	Bottom

Reinforcement Along X-dirn.	Reinforcement Along X-dirn.	Reinforcement Along X-dirn 506.4	Reinforcement Along X-dirn. 506.4	Reinforcement Along X-dirn. 514.08	Reinforcement Along X-dirn. 514.08
Provided Reinf.	Provided Reinf.	Reqd. Reinf.(mm2/mt length) 506.4	Reqd. Reinf.(mm2/mt length) 506.4	Provided Reinf.Area(mm2/mt length) 514.08	Provided Reinf.Area(mm2/mt length) 514.08
Provide 12 mm dia @ 220.00 mm c/c	Provide 12 mm dia @ 220.00 mm c/c				
Provide 12 mm dia @ 220.00 mm c/c	Provide 12 mm dia @ 220.00 mm c/c				
Bottom Reinforcement Along Y-dirn.	Bottom Reinforcement Along Y-dirn.	Bottom Reinforcement Along Y-dirn. 923.96	Bottom Reinforcement Along Y-dirn. 923.96	Bottom Reinforcement Along Y-dirn. 942.48	Bottom Reinforcement Along Y-dirn. 942.48
Provided Reinf.	Provided Reinf.	Reqd. Reinf.(mm2/mt length) 923.96	Reqd. Reinf.(mm2/mt length) 923.96	Provided Reinf.Area(mm2/mt length) 942.48	Provided Reinf.Area(mm2/mt length) 942.48
Provide 12 mm dia @ 120.00 mm c/c	**Provide 12 mm dia @ 120.00 mm c/c**				
Provide 12 mm dia @ 120.00 mm c/c	**Provide 12 mm dia @ 120.00 mm c/c**				
Calculation of Concrete Volume	Calculation of Concrete Volume	Calculation of Concrete Volume	Calculation of Concrete Volume	Calculation of Concrete Volume	Calculation of Concrete Volume 12.5

4.4.2 Calculations for Foundation Design

Calculation of Footing Weight & Soil Weight

Dimension of Footing in X-dirn.(B_x)

= **5000.00 mm**

Dimension of Footing in Y-dirn.(B_y)

= **5000.00 mm**

Steel Provided along Y-direction at bottom (Ast_{by})

= **0.00 mm^2/m length**

Dimension of Left Column in X-dirn.(B_{cx1})

= **400.00 mm**

Dimension of Left Column in Y-dirn.(B_{cy1})

= **400.00 mm**

Distance of left column centre from left edge (Lcolf)

= **500.00 mm**

Dimension of Right Column in X-dirn.(B_{cx2})

= **400.00 mm**

Dimension of Right Column in Y-dirn.(B_{cy2})

= **400.00 mm**

Distance of right column centre from right edge (Rcolr)

= **500.00 mm**

Total thickness of footing (D)

= **500.00 mm**

Area of Foundation (A_f)

= B_x x B_y = **25000000.00 mm^2**

Depth of foundation from top of soil (D_f)

= **2000.000 mm**

Effect of water table is not considered

Total Weight of soil on footing (W_s)

= **652105.57 N**

Total Weight of Foundation (W_f)

= **305815.16 N**

Total Dead load Surcharge on foundation (W_{SDL})

= **870957.20 N**

Total Live load Surcharge on foundation (W_{SLL})

Calculation of Loads for Stability Checking

Total vertical Load from column

Dead Load case (P_d)

= **218570.00 N**

Dead+Live Load case (P_{dl})

= **218570.00 N**

Dead+Wind or Seismic Load case (P_{dws})

= **218570.00 N**

Dead+Live+Wind or Seismic Load case (P_{dlws})

= **218570.00 N**

Dead+Live+Wind or Seismic + Other Load case (P_{dlwso})

= **218570.00 N**

Dead+Other Load case (P_{do})

= **218570.00 N**

Dead+Live+Other Load case (P_{dlo})

= **218570.00 N**

Stability Calculation in Dead Load case

Total vertical load (P)

= **2047447.92 N**

Total Moment along X dirn. (M_{xd})

= **280000.00 Nmm**

Total Moment along Y dirn. (M_{yd})

= **100000.00 Nmm**

FOS against overturning about Y-axis (FOS_{ovrxd})

= **18280.79**

FOS against overturning about X-axis (FOS_{ovryd})

= **51186.20**

Contact Area ($A_{contact\text{-}d}$)

= **25000000.00 sq.mm**

Tension does not occur.

Pressure on foundation (Pr_d)

= **0.08 N/sq.mm**

Stability Calculation in Dead + Live Load case

Total vertical load (P)

= **2047447.92 N**

Total Moment along X dirn. (M_{xdl})

= **280000.00 Nmm**

Total Moment along Y dirn. (M_{ydl})

= **100000.00 Nmm**

FOS against overturning about Y-axis (FOS_{ovrxdl})

= **18280.79**

FOS against overturning about X-axis (FOS_{ovrydl})

= **51186.20**

Contact Area ($A_{contact\text{-}dl}$)

= **25000000.00 sq.mm**

Stability Calculation in Dead + Wind or Seismic Load case

Total vertical load (P)

= **2047447.92 N**

Total Moment along X dirn. (M_{xdws})

= **280000.00 Nmm**

Total Moment along Y dirn. (M_{ydws})

= **100000.00 Nmm**

FOS against overturning about Y-axis ($FOS_{ovrxdws}$)

= **18280.79**

FOS against overturning about X-axis ($FOS_{ovrydws}$)

= **51186.20**

Contact Area ($A_{contact\text{-}dws}$)

= **25000000.00 sq.mm**

Tension does not occur.

Pressure on foundation (Pr_{dws})

Calculation of Shear and Moments (Beam)

UDL on Beam

= 261.60 N/mm

Distance of critical Section for shear from Column Face

= 422.00 mm

Shear force at the critical section on left of Left column (S_{x11})

= 0.00 N

Shear force at the critical section on right of Left column (S_{x21})

= 348707.43 N

Shear force at the critical section on right of Right column (S_{x12})

= 0.00 N

Shear force at the critical section on left of Right column (S_{x22})

= 348707.43 N

Moment at section at left face of Left column (M_{bx11})

= 11771818.56 N-mm

Moment at section at right face of Left column (M_{bx21})

= -66706971.84 N-mm

Moment at section at right face of Right column (M_{bx12})

= 11771818.56 N-mm

Moment at section at left face of Right column (M_{bx22})

= -66706971.84 N-mm

Calculation of Bottom Reinforcement of the footing

Design of the Beam

Limiting Moment (M_u / bd^2)	= **2.76 N/mm²**
$M_{u/bd}^2$ on Left bottom of Beam	= **0.12 N/mm²**
$M_{u/bd}^2$ on Middle bottom of Beam	= **0.00 N/mm²**
$M_{u/bd}^2$ on Right top of Beam	= **0.12 N/mm²**
$M_{u/bd}^2$ on Left top of Beam	= **0.00 N/mm²**
$M_{u/bd}^2$ on Right top of Beam	= **0.00 N/mm²**
$M_{u/bd}^2$ on Middle top of Beam	= **4.90 N/mm²**
Effective Depth of Beam at bottom	= **467.00 mm**
Effective Depth of Beam at top	= **467.00 mm**
Steel Required at Left bottom (Ast_{bx})	= **382.60 mm²**
Steel Required at Letf top (Ast_{tx})	= **382.60 mm²**
Steel Required at Right bottom (Ast_{by})	= **382.60 mm²**
Steel Required at Right top (Ast_{ty})	= **382.60 mm²**
Steel Required at Mid Span bottom (Ast_{bm})	= **382.60 mm²**
Steel Required at Mid Span top (Ast_{tm})	= **1782.42 mm²**
Steel Provided at Left bottom (Ast_{bx})	= **402.12 mm²**
Steel Provided at Left top (Ast_{tx})	= **402.12 mm²**
Steel Provided at Right bottom (Ast_{by})	= **402.12 mm²**
Steel Provided at Right top (Ast_{ty})	= **402.12 mm²**
Steel Provided at Mid Span bottom (Ast_{bm})	= **402.12 mm²**
Steel Provided at Mid Span top (Ast_{tm})	= **1809.56 mm²**

Steel Provided at Left bottom (Ast_{bx})

= 402.12 mm^2

Steel Provided at Left top (Ast_{tx})

= 402.12 mm^2

Steel Provided at Right bottom (Ast_{by})

= 402.12 mm^2

Steel Provided at Right top (Ast_{ty})

= 402.12 mm^2

Steel Provided at Mid Span bottom (Ast_{bm})

= 402.12 mm^2

Steel Provided at Mid Span top (Ast_{tm})

= 1809.56 mm^2

Steel Required along X-direction at bottom (Ast_{bx})

= 506.40 mm^2/m length

Steel Required along Y-direction at bottom (Ast_{by})

= 923.96 mm^2/m length

Spacing provided along X-direction at bottom

= 220.00 mm

Spacing provided along Y-direction at bottom

= 120.00 mm

Steel Provided along X-direction at bottom (Ast_{bx})

= 514.08 mm^2/m length

Steel Provided along Y-direction at bottom (Ast_{by})

= 942.48 mm^2/m length

Steel Percentage Provided along X-direction at bottom

= 0.12 mm

Steel Percentage Provided along Y-direction at bottom

= 0.22 mm

Shear Calculation of Beam

Effective Depth bottom(d)

= 467.00 mm

Effective Depth top (d)

= 467.00 mm

Steel Percentage Provided at Left bottom

= 0.22

Steel Percentage Provided at Right bottom

= 0.22

Nominal Shear Stress on Left (τ_{vx1})

= 1.87 N/mm ^{2}

Nominal Shear Stress on Right (τ_{vx2})

= 1.87 N/mm ^{2}

β_{x1} Left

= 10.79

β_{x2} Right

= 10.79

Design Shear Strength on Left (τ_{cx1})

= 0.34 N/mm ^{2}

Design Shear Strength on Right (τ_{cx2})

= 0.34 N/mm ^{2}

Shear Calculation of Slab

Nominal Shear Stress (τ_{vx})

= 0.00 N/mm ^{2}

Nominal Shear Stress (τ_{vy})

= 0.23 N/mm ^{2}

β_x

= 19.06

β_y

= 10.69

Design Shear Strength (τ_{cx})

= 0.26 N/mm ^{2}

Design Shear Strength (τ_{cy})

= 0.34 N/mm ^{2}

SECTION 5
CONCLUSIONS

The assimilation of field investigation data is necessary for the accurate planning and faster implimentation of the project

The present project presented the idea for using the advanced structural tool STAAD.pro to solve complicated engineering problems involving beam and nodes with great ease and in very less time.

It has been revealed that the load combinations involving wind-forces were critical amongst all combinations. Hence the design was carried out for those combinations. The wind force normal to cables was found to the worst of all

The design given by STAAD.pro has been found to be complying with IS-800: 1984 and all the members were safe.

No matter how sophisticated the software be, it is always the scheme and the specifications of the human engineer, which has to be fed in to get desired and applicable solutions. Thus, it is necessary that the person using the computer applications must be an expert in his area. Henceforth during our compilation of the project we tried to contain the combination of safe design and optimal cost.

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2) Duggal, S.K. *Design of steel structures*. Tata McGraw Hill. New Delhi Second Edition ninth reprint 2005

3) IS: 456 – 2000 (For RCC footing Design)

4) IS:800-1984 (For steel members design)

5) IS:875-1987- part III and part-V (For Wind Loads and Load combinations)

6) IS:1911-1967 (For density of steel)

7) SP-6 (Part-I) (For ISA sections)

8) www.google.com

9) www.altavista.com

10) www.wikipedia.com

11) www.ci-net.co.za/englogic/staadpro.htm

12) www.staadpro.co.uk/product/pro/pro.asp

13) www.MSSTEEL.com

14) www.MSTOWER.com

15) REI STAAD.pro manuals

APPENDIX-A

LOCATION OF MEMBERS AND THEIR NUMBERING IN THE STEEL TRANSMISSION TOWER

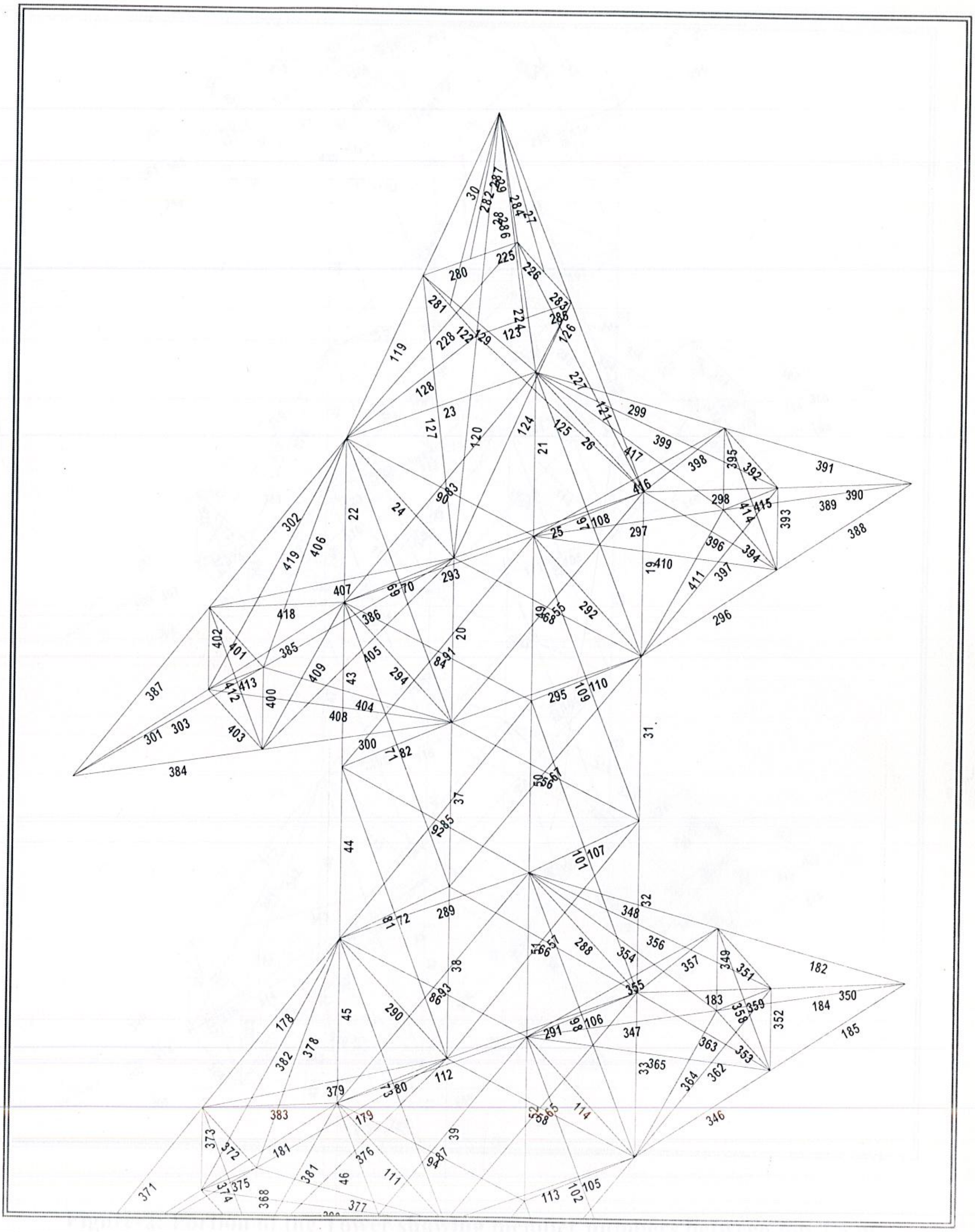

Figure-1: Top 7.5 m of the Tower showing member numbers

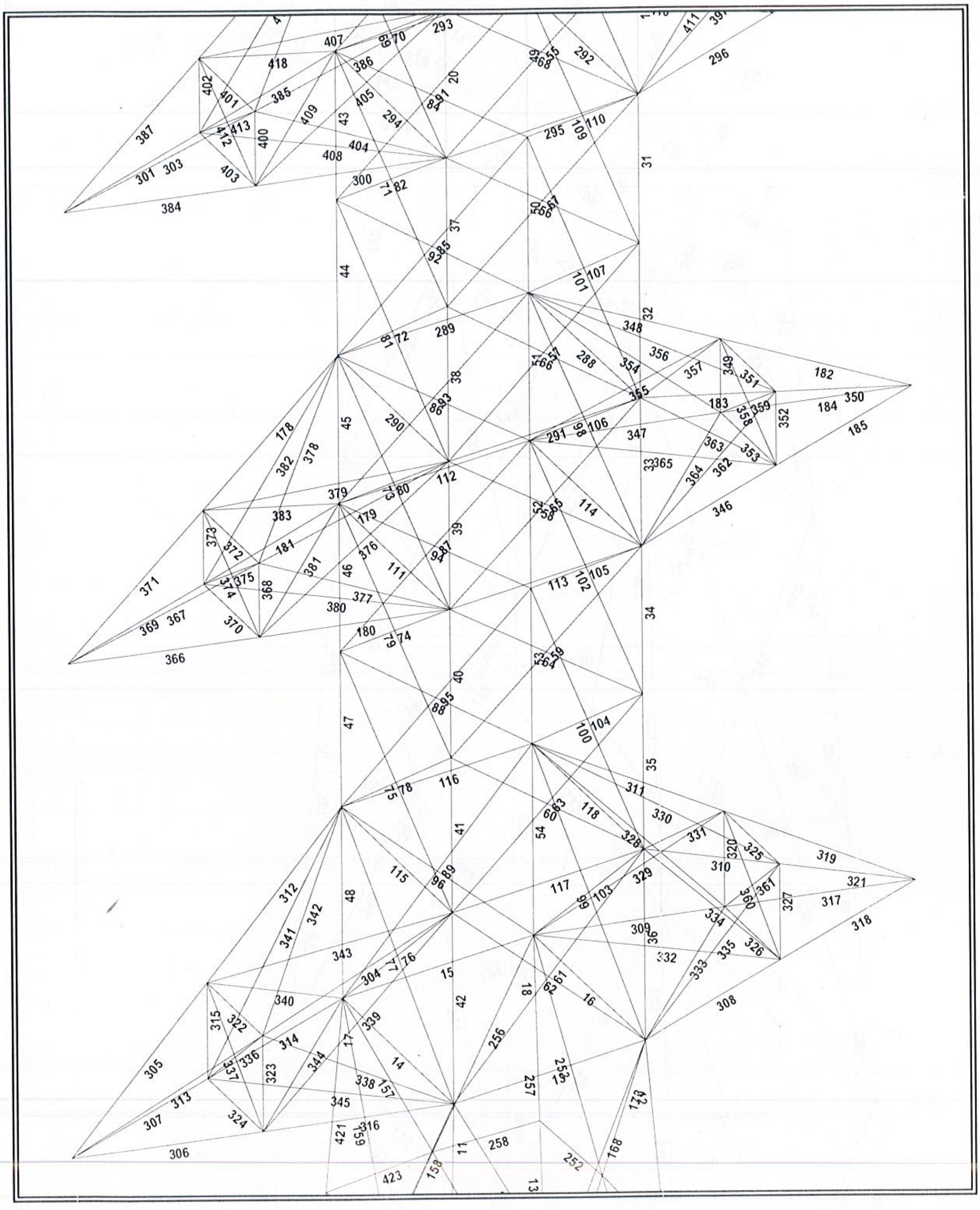

Figure-2: Portion of the Tower showing member numbers between top 7.5 m and 15 m.

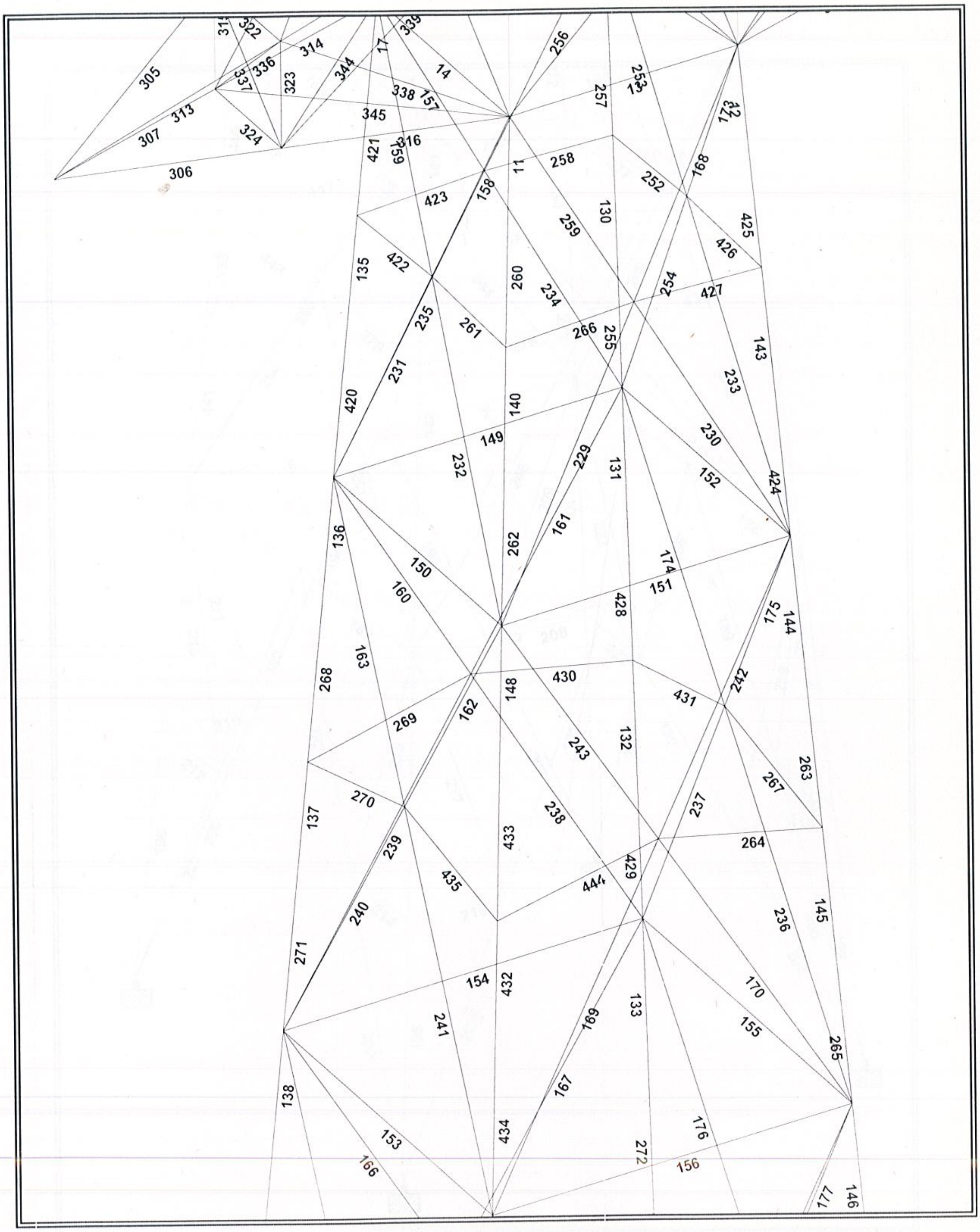

Figure-3: Portion of the Tower between bottom 10 m and 15 m showing member numbers

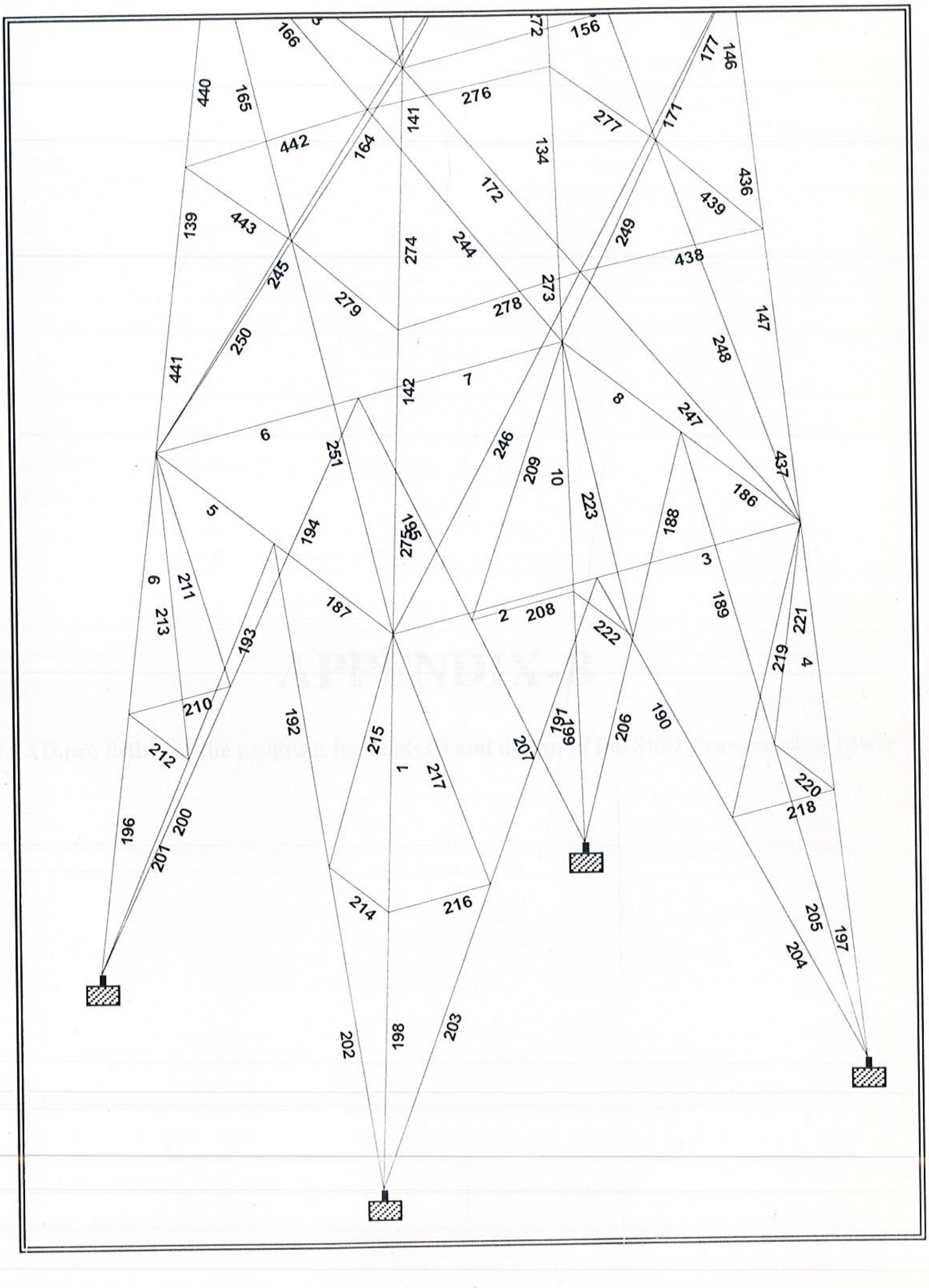

Figure-4: Bottom 10m portion of the Tower showing member numbers.

APPENDIX-B

STAAD.pro listing of the program for analysis and design of the Steel Transmission Tower

STAAD listing for the 25m Transmission Tower

```
STAAD SPACE
START JOB INFORMATION
ENGINEER DATE 03-May-07
END JOB INFORMATION
UNIT METER KN
JOINT COORDINATES
1 1.76 0 1.76; 2 -1.76 0 1.76; 3 1.48 4.25 1.48; 4 -1.48 4.25 1.48;
5 0 4.25 1.48; 6 1.76 0 -1.76; 7 -1.76 0 -1.76; 8 1.48 4.25 -1.48;
9 -1.48 4.25 -1.48; 10 0 4.25 -1.48; 11 0.758 15.24 0.758;
12 -0.758 15.24 0.758; 13 0.758 15.24 -0.758; 14 -0.758 15.24 -0.758;
15 -0.758 23 -0.758; 16 0.758 23 0.758; 17 -0.758 23 0.758;
18 0.758 23 -0.758; 19 0 25.25 0; 20 0.758035 21.95 0.758;
21 0.75807 20.9 0.758; 22 0.758107 19.8 0.758; 23 0.758142 18.75 0.758;
24 0.758178 17.7 0.758; 25 0.758214 16.6 0.758; 26 -0.758 21.95 0.758;
27 -0.758 20.9 0.758; 28 -0.758 19.8 0.758; 29 -0.758 18.75 0.758;
30 -0.758 17.7 0.758; 31 -0.758 16.6 0.758; 32 -0.758 21.95 -0.758;
33 -0.758 20.9 -0.758; 34 -0.758 19.8 -0.758; 35 -0.758 18.75 -0.758;
36 -0.758 17.7 -0.758; 37 -0.758 16.6 -0.758; 38 0.758 21.95 -0.758;
39 0.758 20.9 -0.758; 40 0.758 19.8 -0.758; 41 0.758 18.75 -0.758;
42 0.758 17.7 -0.758; 43 0.758 16.6 -0.758; 45 -0.379 24.125 -0.379;
46 -0.379 24.125 0.379; 47 0.379 24.125 0.379;
48 0.84958 13.846 -0.84958; 49 0.960785 12.153 -0.960785;
50 1.0818 10.311 -1.0818; 51 1.19628 8.569 -1.19628;
52 1.32711 6.577 -1.32711; 53 -0.84958 13.846 -0.85;
54 -0.960785 12.153 -0.961; 55 -1.0818 10.311 -1.082;
56 -1.19628 8.569 -1.196; 57 -1.327 6.577 -1.327; 58 -0.85 13.846 0.85;
59 -0.961 12.153 0.961; 61 -1.196 8.569 1.196; 62 -1.327 6.577 1.327;
63 0.85 13.846 0.85; 64 0.961 12.153 0.961; 65 1.082 10.311 1.082;
66 1.196 8.569 1.196; 67 1.327 6.577 1.327; 68 -1.079 10.361 1.079;
71 3.35 18.75 0; 72 -3.35 18.75 0; 75 1.48 4.25 0; 76 -1.48 4.25 0;
77 -1.62 2.125 -1.62; 78 1.62 2.125 1.62; 79 -1.62 2.125 1.62;
80 1.62 2.125 -1.62; 81 -0.88 2.125 -1.62; 82 -1.62 2.125 -0.88;
83 -1.62 2.125 0.88; 84 -0.88 2.125 1.62; 85 0.88 2.125 1.62;
86 1.62 2.125 0.88; 87 1.62 2.125 -0.88; 88 0.88 2.125 -1.62;
89 0.379 24.125 -0.379; 90 7.27414e-005 13.8786 0.847522;
91 -0.847419 13.8788 -1.747e-006; 92 0.847519 13.8787 4.83665e-005;
93 1.7845e-006 13.8786 -0.84743; 94 1.06557 10.5564 2.04383e-006;
95 -4.7953e-006 10.5566 -1.0658; 96 -1.06582 10.5562 4.77739e-006;
97 -4.85618e-008 10.5562 1.0657; 98 3.12115e-006 6.63843 -1.32295;
99 -1.21398e-007 6.63868 1.32293; 100 1.32309 6.63857 -8.05464e-005;
101 -1.32293 6.63868 -3.15194e-006; 103 0.905182 12.9995 -0.905182;
104 0.80379 14.543 -0.80379; 105 -0.804 14.543 0.804;
106 -0.9055 12.9995 0.9055; 107 1.0215 11.232 1.0215;
108 1.139 9.44 1.139; 109 -1.02129 11.232 -1.0215;
110 -1.13904 9.44 -1.139; 111 1.2617 7.573 -1.2617;
112 1.40356 5.4135 -1.40356; 113 -1.2615 7.573 1.2615;
114 -1.4035 5.4135 1.4035; 115 0 24.125 -0.379; 116 -0.379 24.125 0;
117 0.379 24.125 0; 118 0 24.125 0.379; 119 3.35 15.24 0;
120 -3.35 15.24 0; 121 3.35 21.95 0; 122 -3.35 21.95 0;
123 -2.054 15.92 -0.379; 124 -2.054 15.92 0.379;
125 -2.054 15.24 -0.379; 126 -2.054 15.24 0.379; 127 2.054 15.24 -0.379;
128 2.05413 15.24 0.379; 129 2.054 15.92 -0.379;
130 2.05411 15.92 0.379; 131 2.05407 18.75 0.379;
132 2.054 18.75 -0.379; 133 2.054 19.275 -0.379;
134 2.05405 19.275 0.379; 135 -2.054 18.75 0.379;
136 -2.054 19.275 0.379; 137 -2.054 18.75 -0.379;
138 -2.054 19.275 -0.379; 139 -2.054 21.95 0.379;
140 -2.054 21.95 -0.379; 141 -2.054 22.475 0.379;
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142 -2.054 22.475 -0.379; 143 2.05402 21.95 0.379;
144 2.054 21.95 -0.379; 145 2.054 22.475 0.379; 146 2.054 22.475 -0.379;
147 -0.905181 12.9995 -0.905499; 148 -0.803789 14.543 -0.803999;
149 0.905497 12.9995 0.905497; 150 0.804128 14.543 0.803998;
151 1.02129 11.232 -1.02129; 152 1.13904 9.44 -1.13904;
154 -1.02164 11.232 1.02164; 155 -1.13913 9.44001 1.13913;
156 1.2615 7.573 1.2615; 157 1.4035 5.4135 1.4035;
158 -1.26164 7.57301 -1.2615; 159 -1.4035 5.4135 -1.4035;
MEMBER INCIDENCES
1 4 79; 2 4 5; 3 5 3; 4 3 78; 6 9 76; 7 9 10; 8 8 10; 9 8 75; 10 9 77;
14 8 80; 15 12 105; 16 11 150; 17 12 11; 18 14 12; 19 14 13; 20 13 11;
21 14 148; 22 13 104; 23 16 20; 24 17 26; 25 18 38; 26 15 32; 27 18 15;
28 15 17; 29 16 17; 30 18 16; 31 19 47; 32 19 46; 33 19 89; 34 19 45;
35 20 21; 36 21 22; 37 22 23; 38 23 24; 39 24 25; 40 25 11; 41 26 27;
42 27 28; 43 28 29; 44 29 30; 45 30 31; 46 31 12; 47 32 33; 48 33 34;
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91 41 36; 92 36 43; 93 43 14; 94 38 15; 95 38 33; 96 40 33; 97 40 35;
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108 42 25; 110 22 39; 111 41 24; 112 25 13; 113 24 43; 114 23 42;
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247 84 2; 248 85 1; 249 86 1; 250 87 6; 251 88 6; 252 80 88; 253 88 8;
254 77 81; 255 81 9; 256 77 82; 257 82 9; 258 83 79; 259 83 4;
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297 48 92; 298 13 92; 299 92 49; 301 103 49; 302 13 93; 303 104 48;
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322 106 90; 323 107 94; 324 65 94; 325 108 94; 326 109 55; 327 95 109;
328 96 109; 329 95 55; 330 96 55; 331 110 56; 332 95 110; 333 96 110;
334 111 52; 335 112 8; 336 113 62; 337 114 4; 338 111 98; 339 52 98;
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374 31 124; 375 120 123; 376 120 126; 377 120 125; 378 11 128;

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395 129 130; 396 128 127; 397 130 128; 398 43 127; 399 129 13;
400 43 130; 401 25 129; 402 13 128; 403 127 11; 404 25 128; 405 130 11;
406 124 125; 407 123 126; 408 124 12; 409 31 126; 410 123 14;
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417 132 41; 418 133 40; 419 132 133; 420 134 71; 421 134 133;
422 131 134; 423 131 132; 424 40 132; 425 133 41; 426 40 134;
427 22 133; 428 133 131; 429 134 132; 430 129 128; 431 130 127;
432 134 23; 433 22 131; 434 132 23; 435 131 41; 436 135 72; 437 136 72;
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443 138 137; 444 138 135; 445 136 137; 446 28 135; 447 136 29;
448 136 34; 449 138 28; 450 137 29; 451 135 35; 452 34 137; 453 138 35;
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503 150 90; 504 63 90; 505 149 90; 506 151 50; 507 152 51; 508 95 151;
509 94 151; 510 95 50; 511 94 50; 512 95 152; 513 94 152; 514 68 155;
515 154 68; 516 155 61; 517 97 154; 518 96 154; 520 96 68; 521 97 155;
522 96 155; 523 156 67; 524 157 3; 525 99 156; 526 100 156; 527 99 67;
528 67 100; 529 100 157; 530 99 157; 531 158 57; 532 159 9; 533 98 158;
534 101 158; 535 98 57; 536 57 101; 537 101 159; 538 98 159; 539 68 97;
START GROUP DEFINITION
MEMBER
_BOTTOM_7 2 3 6 TO 9 230 TO 239 244 TO 267 289 TO 296 339 340 342 343 -
346 TO 349 527 TO 530 535 TO 538
END GROUP DEFINITION
DEFINE MATERIAL START
ISOTROPIC STEEL
E 2.05e+008
POISSON 0.3
DENSITY 76.8195
ALPHA 1.2e-005
DAMP 0.03
END DEFINE MATERIAL
MEMBER PROPERTY INDIAN
1 10 14 151 152 156 157 161 162 166 167 232 TO 251 334 TO 337 523 524 -
531 532 TABLE LD ISA200X200X12
23 TO 26 35 TO 58 TABLE LD ISA200X150X12
31 TO 34 133 TO 135 268 352 354 356 357 TABLE LD ISA150X115X12
206 207 216 217 222 TO 225 366 TO 384 386 TO 389 391 416 TO 418 420 -
436 437 439 441 454 TO 461 TABLE LD ISA150X150X12
4 186 TO 189 194 195 200 201 252 TO 267 289 TO 296 338 TO 349 -
525 TO 530 533 TO 538 TABLE LD ISA200X150X12
178 180 TO 185 190 192 193 197 TO 199 273 TO 277 279 TO 288 -
297 TO 299 302 304 TO 309 311 312 314 316 317 319 TO 325 327 TO 330 -
332 333 492 TO 497 500 TO 505 508 TO 513 517 518 520 TO 522 -
539 TABLE LD ISA150X150X12
62 TO 69 77 TO 84 90 TO 93 97 TO 100 103 105 108 111 TO 115 385 390 -
393 397 TO 415 419 422 424 TO 435 438 443 TO 453 466 TO 469 -
474 TO 489 TABLE LD ISA200X150X10
27 TO 30 59 TO 61 70 TO 76 85 TO 89 94 TO 96 101 110 116 TO 119 358 -
359 TO 365 TABLE LD ISA200X150X10
137 138 140 141 143 TO 146 269 TO 272 350 351 353 -
355 TABLE LD ISA130X130X12
```

```
2 3 6 TO 9 174 TO 177 230 231 TABLE LD ISA200X150X12
15 16 21 22 148 TO 150 153 TO 155 158 163 TO 165 168 301 303 310 313 -
315 318 326 331 490 491 498 499 506 507 514 TO 515 -
516 TABLE LD ISA150X150X12
17 TO 20 170 TO 173 TABLE LD ISA150X150X12
124 TO 131 TABLE LD ISA200X150X10
392 394 TO 396 421 423 440 442 462 464 471 473 TABLE LD ISA200X150X10
463 465 470 472 TABLE LD ISA200X150X10
CONSTANTS
MATERIAL STEEL MEMB 1 TO 4 6 TO 10 14 TO 101 103 105 108 110 TO 119 -
124 TO 131 133 TO 135 137 138 140 141 143 TO 146 148 TO 158 -
161 TO 168 170 TO 178 180 TO 190 192 TO 195 197 TO 201 206 207 216 -
217 222 TO 225 230 TO 277 279 TO 299 301 TO 518 520 TO 539
SUPPORTS
1 2 6 7 FIXED
LOAD 3 LOADTYPE DEAD  TITLE CABLE LOAD
SELFWEIGHT Y -1
JOINT LOAD
19 71 72 119 TO 122 FY -10.162
LOAD 1 WIND LOAD IN X DIRECTION
JOINT LOAD
12 14 15 17 19 26 28 29 31 32 34 35 37 72 120 122 TO 126 135 TO 141 -
142 FX 34.59
4 9 54 56 59 61 FX 46.74
LOAD 2 WIND LOAD IN Z DIRECTION
JOINT LOAD
13 TO 15 18 19 32 34 35 37 38 40 41 43 71 72 119 TO 123 125 127 129 -
132 133 137 138 140 142 144 146 FZ 34.59
8 9 49 51 54 56 FZ 46.74
LOAD 5 LIVE LOAD
JOINT LOAD
1 TO 43 45 TO 59 61 TO 68 71 72 75 TO 101 103 TO 152 154 TO 159 FY -1.5
LOAD COMB 4 1*WL IN X+1*DL
3 1.0 1 1.0
LOAD COMB 6 1.2*DL+1.2*LL+1.2WL IN X
3 1.2 1 1.2 5 1.2
LOAD COMB 7 WL IN X+LL
1 1.0 5 1.0
LOAD COMB 8 WL IN Z+1*DL
3 1.0 2 1.0
LOAD COMB 9 1.2*DL+1.2 *LL+1.2*WL IN Z
3 1.2 2 1.2 5 1.2
LOAD COMB 10 WL IN Z+ LL
2 1.0 5 1.0
PERFORM ANALYSIS
LOAD LIST 3
PRINT SUPPORT REACTION LIST 1 2 6 7
PRINT MEMBER FORCES LIST 1 TO 4 6 TO 10 14 TO 101 103 105 108 -
110 TO 119 124 TO 131 133 TO 135 137 138 140 141 143 TO 146 -
148 TO 158 161 TO 168 170 TO 178 180 TO 190 192 TO 195 197 TO 201 -
206 207 216 217 222 TO 225 230 TO 277 279 TO 299 301 TO 518 -
520 TO 539
PRINT MAXFORCE ENVELOPE NSECTION 2 LIST 1 TO 4 6 TO 10 14 TO 101 103 -
105 108 110 TO 119 124 TO 131 133 TO 135 137 138 140 141 143 TO 146 -
148 TO 158 161 TO 168 170 TO 178 180 TO 190 192 TO 195 197 TO 201 -
206 207 216 217 222 TO 225 230 TO 277 279 TO 299 301 TO 518 -
520 TO 539
PRINT STORY DRIFT
PARAMETER
CODE INDIAN
STEEL MEMBER TAKE OFF ALL
```

Determination of Depth and Area of Foundation for Transmission Tower

(I) Determination of dimensions of footing:

Ultimate Soil Bearing Capacitym,	$q_u = 250\ KN/m^2$
Soil Cohesion factor,	$c = 10\ KN/m^2$
Angle of internal friction,	$\Phi = 25^o$
Unit weight of soil,	$\gamma = 18\ KN/m^3$
Surcharge on the footing,	$q = 0$ (no surcharge)

Net maximum vertical load on the footing
(for load case no:9 : 1.2*DL+1.2 *LL+1.2*WL IN Z)

$= 4162.541 + 4226 - 3804$
$= 4584.541$ kN

Required Area $= P/ q_u$
$= 4584.541/250$
$= 18.33m^2$

Width of the footing $= \sqrt{A}$
$= \sqrt{18.33}$
$= 4.28$ m

Size of footing adopted = 5m*5m

(II) Determination of depth of footing (As per IS-6403:1981)

Bearing capacity factors are calculated as follows:

$$N_c = (N_q - 1) \cot \Phi$$
$$N_q = (\exp \pi \tan \Phi) \tan^2 (45+ \Phi/2)$$
$$N_\gamma = 2(N_q + 1) \tan \Phi$$

Where, $N_q = 10.7$
$N_c = 20.7$
$N_\gamma = 10.9$

Shape factors:

$S_c = S_q = 1 + 0.2(B/L)$
$= 1+0.2(5/5)$
$= 1.2$

$S_\gamma = 1-0.4(B/L)$

$= 0.6$

Depth factors:

$$D_c = 1+0.2(D_f/b)\tan(45+\Phi/2)$$
$$= 1+0.2(D_f/5)\tan 57.5$$
$$= 1+0.06D_f$$
$$D_q = 1+0.1(D_f/b)\tan(45+\Phi/2)$$
$$= 1+0.03D_f$$
$$D_\gamma = D_q$$

Now by substituting all the above values in the following equation, depth of footing was worked out:

$$q_u = c*N_c*S_c*D_c*I_c+q*(N_q-1)*S_q*D_q*I_q+0.5*B*N_\gamma*S_\gamma*D_\gamma*I_\gamma W$$

Since there is no surcharge occurring in the foundation, $q = 0$

Hence the equation changes to:

$$q_u = c*N_c*S_c*D_c*I_c+0.5*B*N_\gamma*S_\gamma*D_\gamma*I_\gamma W$$

$$250 = 10*20.7*1.2*[1+0.06D_f](0.69)+0.5*18*5*10.9*0.6[1+0.03D_f](0.16)$$

$$250 = 171.39 + 10.28\,D_f + 47.088 + 1.414\,D_f$$

$$250 = 218.478+16.83D_f$$

$$D_f = 2.69 \sim 2.7\text{m}$$

(III) Check for bearing pressure:

Pressure at base of footing =P/A

=4584.54/(5*5)

= 183.38 KN/ m^2

< 250 KN/ m^2 (safe)