ANALYSIS AND ECONOMICAL DESIGN OF TRANSMISSION LINE TOWERS OF DIFFERENT CONFIGURATIONS

A Dissertation Submitted in Partial Fulfillment

For the Award of the Degree of

Master of Engineering

In

Civil Engineering (Structure)

By

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2003 - 2005

<u>CERTIFICATE</u>

This is to declare that the **Major Project** on the topic **"Analysis and Economical Design of Transmission Line Towers of Different Configurations**" is a bonafied research work done by Aman Gupta in partial fulfillment for the requirement of the degree of Master of Structural Engineering (Civil Engineering) from the Delhi College of Engineering, Delhi.

This project has been carried out under the supervision of **Dr. (Mrs.) P.R. Bose** and **Shri G.P. Awadhiya**.

I do hereby state that I have not submitted the matter embodied in this direction for the award of any other degree.

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CERTIFICATE:

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

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ACKNOWLEDGMENT

It is matter of great pleasure to acknowledge a debt of gratitude to **Dr. (Mrs.) P.R. Bose** (Professor & H.O.D.) and **Shri G.P. Awadhiya** (Assistant Professor), Department of Civil Engineering, Delhi College of Engineering, Delhi for their invaluable guidance and generous assistance. Their help, coordination and patience with which they attended my problems and solved them have lead to the completion of the project.

I sincerely express my gratefulness to Mr. **M. Krishna Kumar** (AGM, Engg.-T.L.) and Mr. Nitesh Kumar Sinha. I also thanks Mr. G.K. Sharma, Mr. Patel and Mr. Brijesh and to all the other staff members of The **Power Grid Corporation of India Limited**, Gurgaon without whom completion of this project would have remained just a dream.

I pay my respect to Miss Saloni Priyadarshni (Sr. Dn. Engg., S.D. Engineering Consultants, Delhi) for her extended help in STAAD and AUTO CADD during the execution of the project.

I am also thankful for the corporation extended by the faculty members of the Civil Engineering Department and to all the other staff members of our college.

In the end, I would like to thank all my friends for their cooperation.

(**Aman Gupta**)

ABSTRACT

Transmission Line Towers constitute about 28 to 42 percent of the cost of the Transmission Line. The increasing demand for Electrical Energy can be met more economically by developing different light weight configurations of Transmission Line Towers.

In this thesis, an attempt has been made to make the transmission line more cost effective by changing the geometry (shape) and behavior (type) of transmission line structure. This objective of the research is met by choosing a 220 KV Single Circuit Transmission Line carrying Square Base Self Supporting Towers. With a view to optimize the existing geometry, one of these suspension towers is replaced by Triangular Base Self Supporting Tower. Then, the structural behavior of existing tower is looked upon by developing Square Base Guyed Mast.

Thus, a number of easy to understand excel programs are developed along with AutoCAD for configuring Towers and calculating Loading. Using STAAD, Analysis of each of these three towers has been carried out as a three dimensional structure. Then, the tower members are Design as an Angle Sections.

For optimizing any member section, the entire wind load computations have to be repeated, simultaneously the analysis and again the design. Thus, three successive iterations have been carried out before arriving at the economical designs of square base and triangular base self supporting towers and the square shape guyed mast. Then all these three towers are compared and analyzed.

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1.0 INTRODUCTION

1.0 INTRODUCTION

1.1 BRIEF OF PRESENT STATUS:

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. [Ref. 14]

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. [Ref. 36]

The supports of EHV transmission lines are normally steel lattice towers. The cost of towers constitutes about 28 to 42 percent of the cost of transmission line and hence optimum tower design will bring in substantial savings. [Ref. 15]

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. [Ref. 12]

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. [Ref. 21]

The tower behaves like a single cantilever freely self supporting structure fixed at its base while guyed mast is a structure pin connected to its foundation and braced with guys or other elements. [Ref. 20]

It is seen that guyed towers are cost effective when there is sufficient corridor right of way available and the land value is not at premium. [Ref. 36]

As a 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.

Power Grid Corporations of India Limited has prescribed the following steps to Optimized the Design of Power Transmission Lines:

1. Review of existing system and practices.
2. Selection of clearances.
3. Insulator and insulator string design.
4. Bundle conductor studies.
5. Tower configuration analysis.
6. Tower weight estimation.
7. Foundation volumes estimation.
8. Line cost analysis and span optimization.
9. Economic evaluation of line.

1.2 OBJECTIVES:

In design of tower for weight optimization, below mentioned basic parameters are constrained on the basis for electrical requirements:

1. Base Width
2. Height of the Tower

3. Outline of the Tower

Keeping in mind the above restrictions, an attempt has been made to make the transmission line more cost effective by optimizing the geometry (shape) and behavior (type) of transmission line structure.

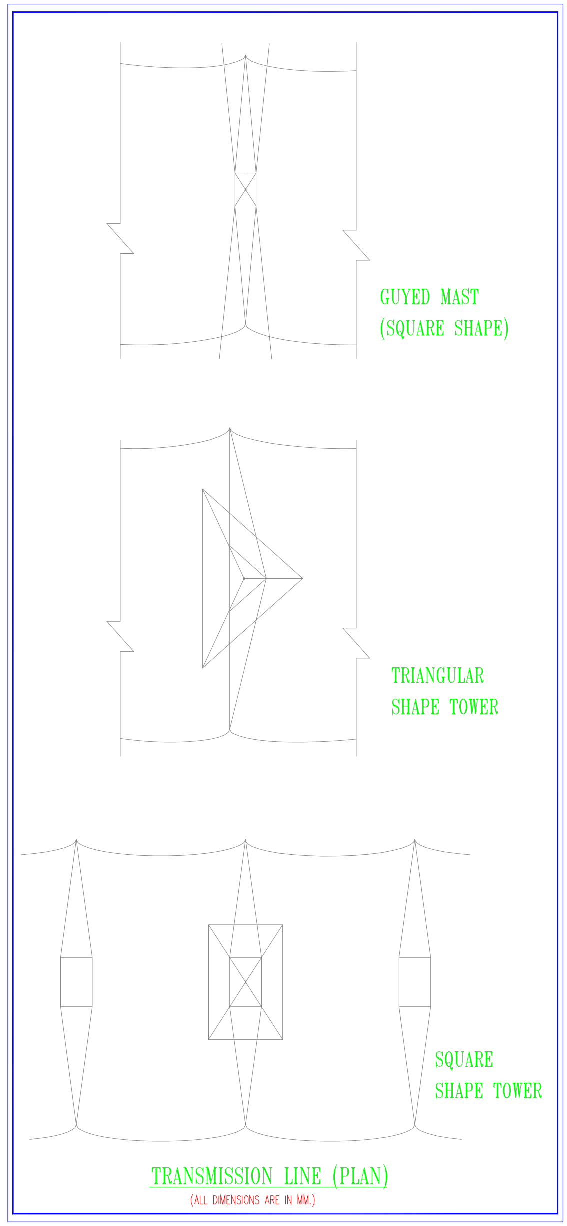
This has been carried out as per the guidelines of Power Grid Corporation of India limited by following the IS Codes and CBIP Manuals with the latest ongoing world wide research.

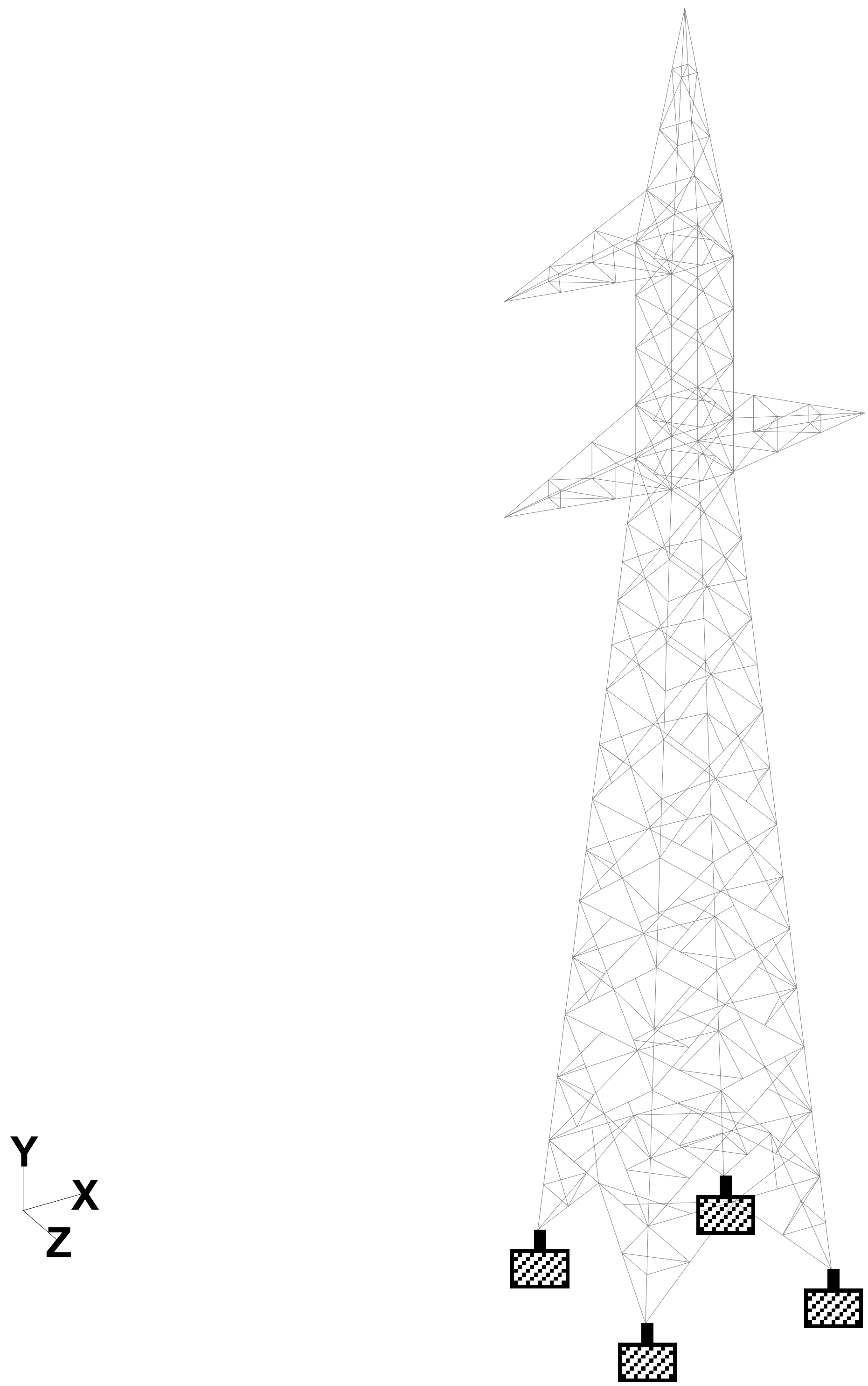
Following research has been carried out for meeting these objectives:

1. Terminology of transmission line and its components have been understood.
2. Literature survey and the on going research work have been studied.
3. Different behaviors of the towers are studied i.e. the self supporting tower and the guyed mast.
4. Methodology for analysis and design of transmission line towers is studied.
5. Finally, worked is done in the direction to find out the most economical configuration or geometry.

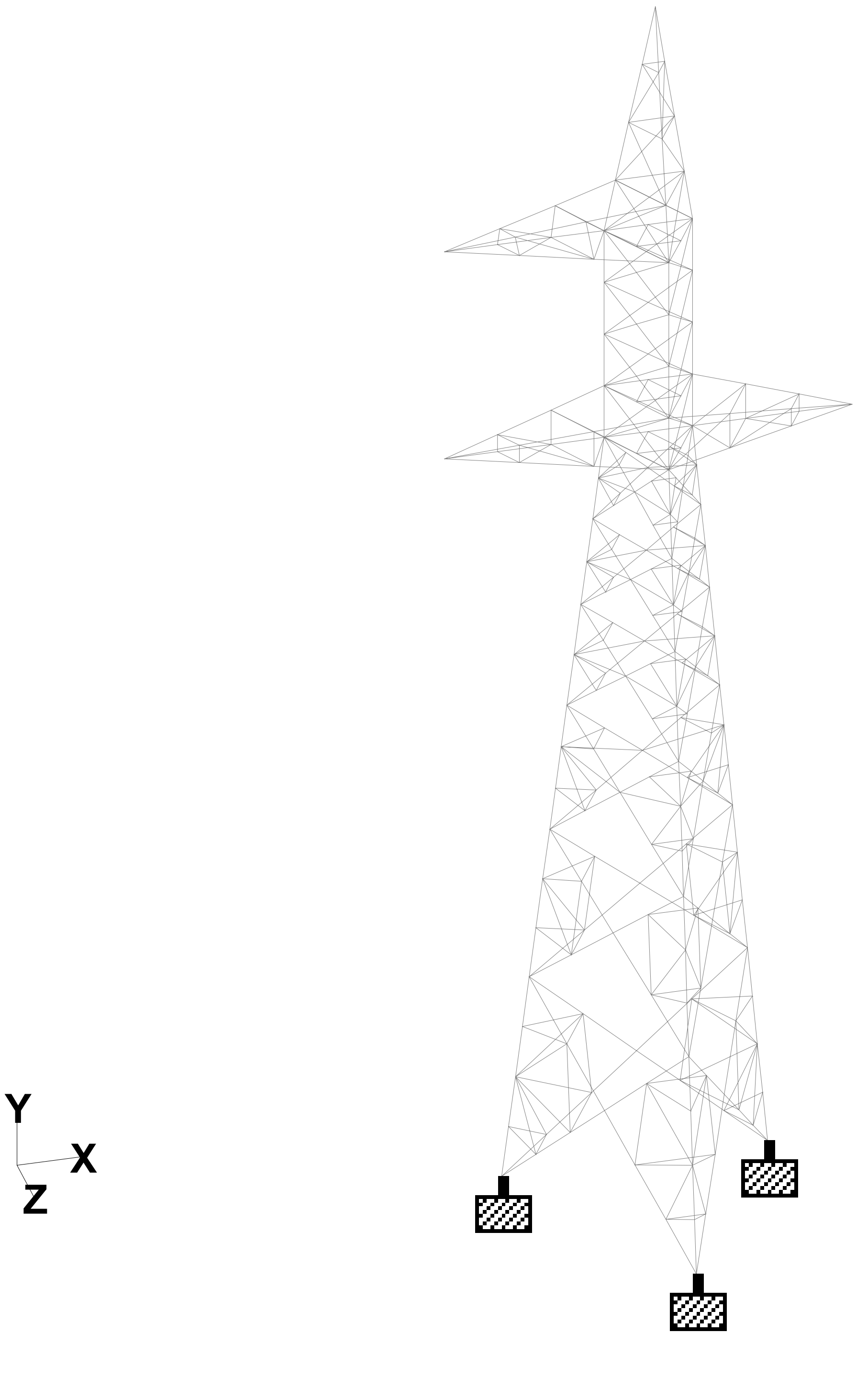
These objectives of the research are met by choosing a 220 KV Single Circuit Transmission Line with Suspension Towers. All the towers are Square Base Self Supporting Type. Thus, for optimizing the existing geometry, one of these suspension towers is replaced by Triangular Base Self Supporting Tower. Further, the structural behavior (type) of existing tower is looked upon by developing Square Base Guyed Mast.

The perception of top view of the towers of different configurations in the transmission line is sketched with the help of AutoCAD (Fig. 1.1). The isometric view of Square Base Tower (Fig. 1.2), Triangular Base Tower (Fig. 1.3) and Square Base Guyed Mast (Fig. 1.4) are shown in detail.

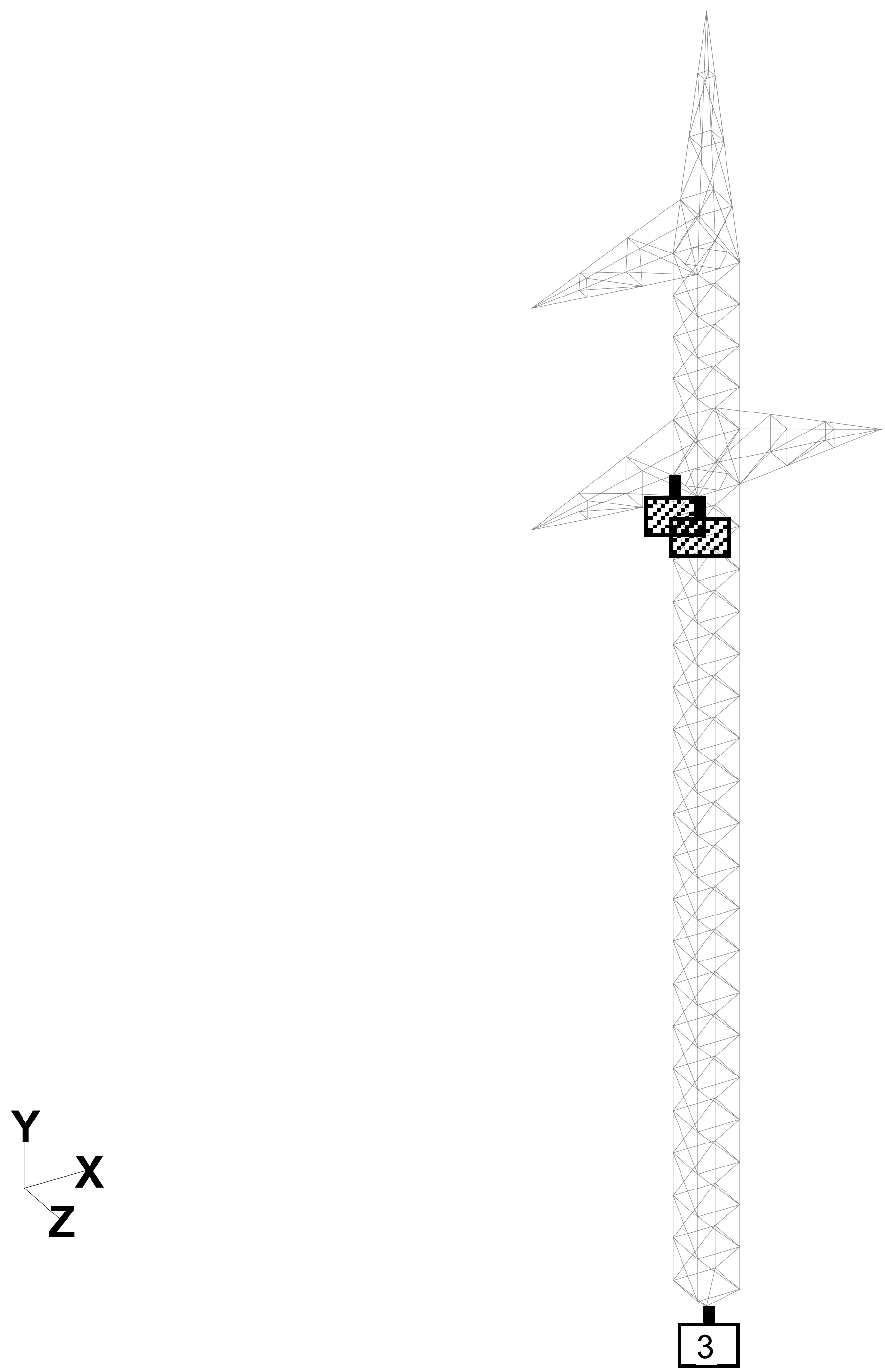

GUYED MAST
(SQUARE SHAPE)
TRIANGULAR
SHAPE TOWER
SQUARE
SHAPE TOWER
TRANSMISSION LINE (PLAN)
(ALL DIMENSIONS ARE IN MM.)



ISOMETRIC VIEW



ISOMETRIC VIEW



ISOMETRIC VIEW

To meet these objectives, the following work has been done:

1. The sag tension calculation for conductor and ground wire is calculated using parabolic equation.
2. Towers are configured with keeping in mind all the electrical and structural constrains on Microsoft Excel and Auto CAD.
3. Loading format including reliability, security and safety pattern is evaluated. Now all the towers are modeled using STAAD.
4. The wind loading is calculated on the longitudinal face of the towers.
5. Then, the towers are analyzed as a three dimensional structure using STAAD.
6. Finally, tower members are designed as an angle sections.

To get the optimum member sections, total of three iterations are carried out. The member sections are required in the wind load calculations, so with every successive design iteration, wind loading on towers is changing, followed by there analysis and design.

1.3 ORGANIZATION OF CHAPTER:

Literature Review consists of research work from the articles of various journals. In this, very precisely the work done in this direction is tried to capture.

Transmission Line starts from the study of basics of the transmission line and the components involve in it. Then, going towards the configuration of towers through meeting the other requirements, like sag tension calculations and finally leading to the loading calculations including the standard format of reliability, security and safety.

Towers include the wind loading on each tower followed by there three dimensional space analysis using some powerful computer tool and finally the economical design of member section.

2.0 LITERATURE REVIEW

2.0 LITERATURE REVIEW

Overhead transmission line plays an important role in the operation of a reliable electrical power system.

The main structural components of transmission line are the conductors, the shield wires, the insulator strings and hardware and the suspension and dead end structures. The response of a line section to cable rupture depends on the interaction between all these components. The conductors are the stranded cables composed of aluminum, galvanized steel or a combination of the two. Shield wires are grounded steel wires placed above the conductors for lightning protection. Conductors are attached to suspension structures via insulators strings that are vertical under the normal operation conditions and are free to swing along the line whenever there is longitudinal unbalanced load. [Ref. 37]

The increase in the demand for electrical energy can be met more economically by increasing the power transmission capacity of the transmission lines. Alternatively, utilizing saving in the cost of transmission lines. In this connection minimizing the cost of transmission line structures is an obvious need. [Ref. 36 & Ref. 40]

Transmission line towers are a vital component and there reliability and the safety should be checked to minimize the risk of disruption to power supply that may result from in-service tower failure. Lattice transmission towers are constructed using angle section members which are eccentrically connected. [Ref. 34]

A high voltage transmission line structure is a complex structure in that its design is characterized by the special requirements to be met from both electrical and structural points of view, the former decides the general shape of the tower in respect of its height and the length of its cross arms that carry electrical conductors. [Ref. 40]

Many older transmission towers are designed based on tension only bracing systems with slender diagonal members. The increased demand in the power supply and changing global weather patterns mean that these towers require upgrading to carry the resultant heavier loading. The failure of single tower can rapidly propagate along the line and result in severe damage that can costs in millions. [Ref. 32]

In India, single standardized sizes and designs are being used because of valid requirements of a fast developing country i.e. speeding up construction activities and early completion of transmission projects, even at a higher cost due to use of non optimized sizes. [Ref. 36]

Static analysis forms the basis of calculations in structural design of overhead power lines. The environmental loads considered in design can be assumed static (icing) or quasi-static (idealized steady wind). They provide a good estimate of the extreme forces that a transmission line is subjected to during its service life. [Ref. 37]

Optimization of transmission structures in weight and shape through mathematical programming methods has attracted wide attention in the past.
Member sectional areas are usually treated as design variables for weight optimization. The joint coordinates are included as decision variables in the case of shape optimization. In combined shape and weight optimization problems, the main objective function, viz. the weight of the structure, is a highly nonlinear function of the design variables because at every stage of iteration, the nodal coordinates and the member lengths get changed. [Ref. 40]

In spite, being the restriction of fixed base width, still there is a scope for the weight minimization and optimum geometry shaping of a transmission line tower. This is apart from the optimum sizing of the members. [Ref. 40]

As the base width, height and outline of the tower is constrained as per the requirement of Indian standards so, geometry (shape) of the tower and its structural behavior are looked upon for the optimization.

3.0 TRANSMISSION LINE

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3.1 SELECTION OF TRANSMISSION LINE AND ITS COMPONENTS:

The transmission line is a function of the line voltage. The overall performance of an overhead transmission line is a function of the performance of various components constituting the transmission line. [Ref. 14]

The transmission line is considered as an integrated system consisting of following subsystems (along with there components):

- Conductor subsystem consisting of conductor and its holding clamps.
- Ground wire subsystem consisting of ground wire and its holding clamps.
- One subsystem for each category of support structure i.e. for a particular lattice structure, the components are angle member, bolts, foundations. [Ref. 9]

The right selection of above mentioned components are highly interrelated to each other. The selection of conductor and ground wire is dependent on the sag characteristics of both and also dependent on the span of the transmission line which in turns relates to the spotting of the towers along the line. Tower spotting is itself a function of tower type. Tower spotting along the line further depend on the angle of line deviation. The span of transmission line and angle of line deviation can further be optimize for getting the best results. Even the footing type is also a function of these two parameters.

The judicious selection in the conductors, insulators and ground wire and design of towers with there spotting and erection can bring the cost effectiveness of the transmission line.

3.2 SAG TENSION CALCULATION:

Proper evaluation of sags and tensions are necessary at the design stage for fixing up the ruling span and structural requirements of line supports.

During erection of the overhead lines, the sags and tensions to be allowed for various spans under the ambient conditions will also have to be properly evaluated, so that the lines may give long and trouble free service. Various methods, analytical and graphical, have been devised to determine the sags and tensions.

Sag tension calculations fix up the conductor and insulator sub system. Sag Tension are required in the decision for fixing up ruling span and in fixing up the outline of the tower, thus, indirectly also decides the tower subsystem.

The spacing required between the ground wires and conductors at null points to ensure that a lightning stroke which hits the ground wire does not flashover to the conductor is called as mid span clearance. Thus, from the protection point of view, the ground wire is strung with a lesser sag (10 to 15%) than the conductor so as to give a mid span separation greater than the supports. [Ref. 17]

Indian standard codes of Practice for Use of Structural Steel in Over Head Transmission Line Towers have prescribed following conditions for the sag tension calculations for the conductor and the ground wire:

- Maximum temperature (75^0 C for ASCR and 53^0 C for ground wire) with design wind pressure (0% & 36%).
- Every day temperature (32^0) and design wind pressure (100%, 75% & 0%).
- Minimum temperature (0^0) with design wind pressure (0% & 36%).

IS 802: part 1:sec 1: 1995 states that Conductor / ground wire tension at every day temperature and without external load should not exceed 25 % (up to 220 KV) for conductors and 20% for ground wires of there ultimate tensile strength.

3.3 CONFIGURATION OF TOWER:

A transmission line tower, like any other exposed structure, has a super structure suitably shaped, dimensioned and designed to sustain the external loads acting on the strung cables (conductors and ground wires) and the super structure itself. The super structure has a trunk and a hamper (cage) to which cables are attached, either through insulators or directly. Suffice it to say, a tower is very much like a tall tree. [Ref. 15]

A.S.C.E manual "Guidelines for Electrical Transmission Line Structural Loading" has distinguished the overall configuration of a transmission line structure on the basis of following requirements:

- Ground clearance requirements
- Electric air gap clearance requirements
- Electric and magnetic field limits
- Insulation requirements
- Structural loading
- Number of circuits
- Right of way requirements
- Aesthetic design criteria

IS 802: Part 1: Sec: 1:1995 states that the configuration of a transmission line tower is dependant on the following parameters:

- The length of the insulator assembly.
- The minimum clearances to be maintained between conductors and between conductor and tower.
- The location of ground wire or wires with respect to the outermost conductor.
- The mid span clearance required from considerations of the dynamic behavior of conductors and lightning protection of the line.
- The minimum clearance of the lowest conductor above ground level.

CBIP in its “Transmission Line Manual” has summed up the total height of a transmission line tower as summation of the following:

1. Minimum permissible ground clearance

   It is the minimum distance from the ground to the lowest point of the bottom conductor. It is fixed as per the requirement of electric air gap clearance and the electric and magnetic field limitations.

2. Maximum sag

   The sag of the conductor is defined as the distance between the point of attachment of the cable to the insulator/ tower and the null point in the cable (earth wire and conductor). It is dependent on the size and type of conductor, climatic conditions (wind temp., snow) and span length.

3. Length of suspension insulator string

   It is an important parameter in deciding the phase to minimum ground metal Clearance, which in turn decides the length of cross arms. It is a function of insulation level, power frequency voltage and service conditions (pollution, altitude, humidity).

4. Vertical spacing between conductors

It is the minimum permissible spacing maintained between two conductors on the basis of electrical requirements.

5. Vertical clearance between ground wire and top conductor

This vertical clearance is decided by the requirement of the peak clearance and the mid span clearance.

Peak clearance is dependant on the angle of shielding made by the ground wire to protect the power conductors against the direct lightning stroke and to conduct the lightning current to the nearest earthed point when contacted by a lightning stroke.

Mid span clearance is the spacing required at the null points between the ground wire and the conductor to safe guard the conductor from flashover during lightning.

3.4 LOADING CALCULATIONS:

CBIP manual “Transmission Line Manual” states that Tower loading is most important part of tower design. The transmission line tower is a pin jointed light structure for which the maximum wind pressure is the chief criterion for design. Further concurrence of earthquake and maximum wind condition is unlikely to place together and seismic stresses are considerably diminished by the flexibility and freedom for vibration of the structure. This assumption is also in the line with the recommendation given in cl. No. 6.2 (b) of IS-1893-1984.

The loadings which are considered during the project are as follows:

1. Dead Load i.e. Self weight of tower members, ground wire, conductor, insulator, line man, equipments used during construction and maintenance.
2. Wind load on tower exposed members, ground wire, conductor and insulator strings.

The Loading Criteria for the transmission line as given by CBIP in “Transmission Line Manual” is as follows:

i. Reliability
ii. Security
iii. Safety

Reliability of a transmission system is the probability that the system would perform its function/ task under the designed load criteria for a specified period. Thus, this covers climatic loads such as wind loads and/or ice loads.

Security of a transmission system is the capacity of the system to protect itself from any major failure arising out of the failure of its components. Thus, this covers unbalanced longitudinal loads and torsional loads due to broken wires

Safety of a transmission system is the ability of the system to provide protection against any injuries or loss of lives to human beings out of the failure of any of its components. Thus, this covers loads imposed on tower during the construction of transmission line and loads imposed on tower during the maintenance of transmission line.

Nature of Loads as given by CBIP in “Transmission Line Manual” is as follows:

1. Transverse loads:

This type of load covers –

- Wind load on tower structure, conductor, ground wire and insulator strings.
- Component of mechanical tension of conductor and ground wire.

2. Vertical loads:

   This type of load covers -

   - Loads due to weight of each conductor, ground wire based on appropriate weight span, weight of insulator strings and fittings.
   - Self weight of the structure.
   - Loads during construction and maintenance.

3. Longitudinal loads:

   This type of load covers –

   - Unbalanced horizontal loads in longitudinal direction due to mechanical tension of conductor and/or ground wire during broken wire condition.

4. Anti Cascading checks:

   - In order to prevent the cascading failure in line, angle towers are checked for anti cascading loads for all conductors and g. wires broken in the same span.

<u>Loading Combinations given by the IS 802: Part 1: Sec: 1:1995 are as follows</u>:

1. Reliability Condition (Normal Condition):

   - Transverse loads
   - Vertical loads
   - Longitudinal loads

2. Security Condition (Broken Wire Condition)

  - Transverse loads
  - Vertical loads
  - Longitudinal loads

3. Safety Condition (Construction and Maintenance):

   Normal Condition:

  - Transverse loads
  - Vertical loads
  - Longitudinal loads

   Broken Wire Condition:

  - Transverse loads
  - Vertical loads
  - Longitudinal loads

4. Anti Cascading loads:

   Broken Wire Condition:

  - Transverse loads
  - Vertical loads
  - Longitudinal loads

4.0 TOWERS

4.0 TOWERS

4.1 WIND LOADING:

CBIP in “Transmission Line Manual” has elaborated that the wind plays a vital role in the load calculation on tower. In order to determine the wind load on tower, the tower is divided into different panels having a height “h”. These panels should normally be taken between the intersections of the legs and bracings. For lattice tower, wind is considered normal to the face of tower acting at the center of gravity of the panel.

Most latticed towers are particularly susceptible to mean wind effects. In the design of lattice towers normally a quasi static approach is adopted with gust response factor included to take into account the dynamic nature of the wind for evaluating the peak stresses in members. It has been recognized that gusts do not envelope the entire span between transmission structures. [Ref. 54]

Gust response factor is the multiplier used for the wind loading to obtain the peak load effect and accounts for the additional loading effects due to wind turbulence and dynamic amplification of flexible structures and cables. [Ref. 9]

Gust response factor for conductor and ground wire depends on the terrain categories, height above the ground and the span. Gust response factor for tower depends upon the terrain categories and the height above the ground. Gust response factor for insulator depends on the ground roughness and height of insulator attachment above ground. [Ref. 12]

Drag coefficients under the wind effect are considered for the conductor, ground wire, tower and the insulator. [Ref. 12]

4.2 ANALYSIS OF TOWER:

Earlier, transmission towers were designed by performing manual calculations based on two dimensional stress analysis / stress diagram method which was time consuming and laborious. The designer has the limitations to try out several permutation and combinations of tower geometry. [Ref. 16 & Ref. 14]

Latter on, the highly sophisticated software have been developed to automate calculation of member forces based on three dimensional finite element analysis / stiffness matrix analysis. Such software finds out critical member force for a number of loading conditions and a variety of possible tower combinations, giving very accurate results. Availability of such software have done great help to designers to understand force distribution and afford to them ample time to concentrate on fine tuning design aspects and at the same time undertake the repetitive calculation and optimization. [Ref. 16]

STAAD Pro 2004 is the next generation of the structural analysis and design software from research engineers. The STAAD engine provides general purpose structural analysis and integrates steel/ concrete/ timber. STAAD Pro 2004 is simple to use and user friendly. The entire input data may be generated either graphically or by typing simple English language based commands. STAAD uses analysis command as Perform Analysis. To ascertain the margin of safety available on the towers, towers are analyzed with the powerful computer software. For this, the towers are idealized as a 3 dimensional pin jointed space truss consisting of nodes and members. Towers are statically indeterminate structure, thus appropriate powerful computer software is essential. [Ref. 16 & Ref. 14]

4.3 DESIGN OF TOWER:

Transmission line towers are designed according to the provisions of Indian national standard codes. Tower designed according to these codes have proved reliable. Adoption of these probabilistic methods of design has not only made us at par with the latest techniques developed in the world but have also lead to optimum and reliable economic designs.

The design criteria of transmission lines shall be such that it should facilitate the transmission lines to fulfill the function to an accepted level of performance. The stringent design criterion leads to the obvious increased level of performance. However, the optimum level is a matter of economics, which could be decided by considering minimum level of safety of people and conformance to the national regulations. [Ref. 13]

Since axial force is the only force for a truss element, the member has to be designed for either compression or tension. But reversal of loads may also induce alternate nature of forces; hence these members are to be designed for both compression and tension. The total force acting on any individual member under the normal condition and also under the broken wire condition is multiplied by the corresponding factor of safety and it is ensured that the values are within the permissible ultimate strength of the particular steel used.[Ref. 19]

IS 802: Part 2: Sec: 1:1995 has restricted the Slenderness Ratio as following:

Leg members, G.W. Peak, X arm lower member	$\leq$120
Bracings	$\leq$200
Redundant / Nominal stress carrying members	$\leq$250
Tension members	$\leq$400

5.0 NUMERICAL STUDY

5.0 NUMERICAL STUDY

5.1 EXERCISE 1:

This exercise consists of those solved parameters which are going to remain same for the complete transmission line that is for all towers.

This exercise is detailed in the following steps:

A. Transmission Line Components
B. Sag Tension for Conductor and Ground Wire
C. Configuration of Towers
D. Loading Calculations for the Transmission Line.

A. Transmission Line Components:

As per the guidelines of PGCIL, the following parameters for transmission line and its components are assumed from I.S. 802: Part 1: Sec: 1:1995, I.S. 5613: Part 2: Sec: 1: 1989 and CBIP Manual No. “268”:

1. Transmission Line Voltage: 220 KV (A. / C.)
2. Right of Way (Recommended): 35, 000 mm
3. Angle of Line Deviation: 0^0 to 2^0
4. Terrain Type considered: Plain
5. Terrain Category: 2
   (Normal cross country lines with very few obstacles)

6. Return Period: 50 yrs.
7. Wind Zone: 4
8. Basic Wind Speed: 47 m/s
9. Basic Wind Pressure: 71.45 kg/ sqm

10. Tower Type: Self Supporting Tower
    Suspension Type Tower
    Tower Type "A"

11. Tower Geometry: Square Base Tower
12. No. of Circuit: Single Circuit
13. Tower Configuration: Vertical Conductor Configuration
14. Tower Shape: Barrel Shaped

15. Bracing Pattern: Warren Type (Double Web System)
    Portal System (K Type)

16. Cross Arm: Pointed
17. Body Extension: Not Considered
18. Steel Used: Mild Steel (IS-2062)

19. Slope of Tower Leg: 4^0 to 9^0 (Permissible)

20. Conductor Material: ACSR
    (Aluminum Conductor Steel Reinforced)

21. Conductor Configuration: Zebra
22. Maximum Temperature: 75^0 C (ACSR)

23. Number of Ground Wire: Single
24. Peak Type: Triangular

25. G.W. Type: Earth wire – 7 / 3.66
26. Shielding Angle: 30^0
27. Maximum Temperature: 53^0 C (7 / 3.66)

28. Insulator Type: I String
29. Number of Insulator Disc: 14
30. Size of Insulator Disc: 255 * 145 mm (Skirt Diameter)
31. Length of Insulator String: 2,340 mm

32. Minimum Ground Clearance: 7,000 mm
33. Sag Error Considered: 160 mm
34. Creep Effect: Not Considered
35. Mid Span Clearance: 8,500 mm
36. Minimum Height above G.L.: 28,555 mm
37. Width at Hamper Level: 1,500 mm (Square Tower)
38. Width at Base: 4,500 mm (Square Tower)

39. Phase to Phase Clearance:
    - Vertical Spacing between Conductors (Minim): 5,200 mm
    - Horizontal Spacing between Conductors (Minim): 8,500 mm

40. Lightning Impulse Level (Air Clearance): 1700 mm
41. Minimum Phase to Earth (Air Clearance): 1970 mm
42. Phase to Ground Metal Clearance:

    -Swing Angle:

    - 0^0 - 2130 mm
    - 15^0 - 1980 mm
    - 30^0 - 1830 mm
    - 45^0 - 1675 mm

43. Tower Weight (Minim): 2,570 kg
44. Base Width (C.L.) / Height above G.L. = 1: 6.3

45. Minimum Thickness of Member:

- Leg Member, G.W. Peak & Lower Memb. of C.A.: 5 mm
- Others: 4 mm

46. Permissible Weight Span:

- Normal Condition:

  Maximum: 525 mm

  Minimum: 200 mm

- Broken Wire Condition:

  Maximum: 315 mm

  Minimum: 100 mm

47. Normal Span: 320 mm to 380 mm

48. -Design Span: 350 mm

49. -Wind Span = Normal Span: 350 mm

50. -Weight Span: 1.5 * 350 mm

51. Concrete Level to Ground Level: 225 mm

B. <u>Sag Tension for Conductor and Ground Wire:</u>

Sag tensions are calculated by using the parabolic equations as discussed in the I.S. 5613: Part 2: Sec: 1: 1989 by developing integrated program on Microsoft Excel for both the conductor and ground wire.

Parabolic Equation:

$$F_2^2.\ (F_2 - (K - \alpha.t.E)) = L^2.\partial^2.q_2^2.E / 24$$

$$\text{Take } K = \quad F1 - (L^2.\partial^2.q_o^2.E / 24.F_1^2)$$

Sag Tension for Conductor (ASCR)							
Temperature Variation (ºC):			0		32		75
Wind Variation(%)		0	0.36	0	0.75	1.0	0
Tension		**4060**	**4879**	**3322**	**5763**	**6804**	**2687**
(F*A)	(Kg)						
Sag		**6.114**	**5.088**	**7.471**	**4.307**	**3.648**	**9.239**
($w.L^2 / 8T$)	(m)						

We have considered the sag of ground wire as 90% the sag of conductor at 0^0 C and 0% wind condition.

Sag Tension for Ground Wire							
Temperature Variation (ºC):			0		32		53
Wind Variation(%)		0	0.36	0	0.75	1.0	0
Tension		**1520**	**2001**	**1327**	**2629**	**3127**	**1226**
(F*A)	(Kg)						
Sag	(m)	**5.874**	**4.462**	**6.725**	**3.395**	**2.855**	**7.284**

Discussion:

The Sag Tension calculation for the conductor and ground wire has been successfully calculated by using Parabolic Equation at different combinations of the temperature and the percentages of wind as per the Indian standards.

C. Configuration of Towers:

Configurations of all three towers are done by first fixing the outline of all the towers as per the Indian standard requirements. This is achieved using excel program with auto cad drawings.

For the configuration of towers, PGCIL guidelines have been considered as follows:

1. The base width of Triangular Tower is restricted as (4/3) * Base width of Square Tower and Guyed Mast as simply 1000 mm.

2. The width at the hamper level for both the Square Tower and the Triangular Tower is reduced to (1/3) of the base width but the width of the Guyed Mast is kept constant thought the height of the tower.

3. The members for all the towers are so chosen that the effective length is kept between 1200 mm to 1500 mm.

4. The bracing angle for all the towers is kept in between 40^0 to 50^0.

4. The minimum factor of safety is kept as 1.1 for the design of angle members.

Configuration of Towers			
	Square Tower	**Triangular Tower**	**Guyed Mast**
Base Width:	4500 mm	6000 mm	1000 mm
Hamper width (L.C.A)	1500 mm	2000 mm	1000 mm
Hamper width (U.C.A)	1500 mm	2000 mm	1000 mm
Height till L.C. A. level	18900 mm	18900 mm	18900 mm
Height till U.C. A. level	24100 mm	24100 mm	24100 mm

Total Tower Height:	(From G.L.)		
Minimum	28555 mm	28555 mm	28555 mm
Peak Clearance **(Fig.4)**	29100 mm	29600 mm	28700 mm
Mid Span Clear. **(Fig. 5)**	29900 mm	29900 mm	29900 mm
Horz. Gr. Metal Clear.	3600 mm	3600 mm	3600 mm
Horz. Spacing betw.	Cross Arm Tip		
Minimum	8500 mm	8500 mm	8500 mm
Actual **(Fig. 6)**	8700 mm	9200 mm	8200 mm

Discussion:

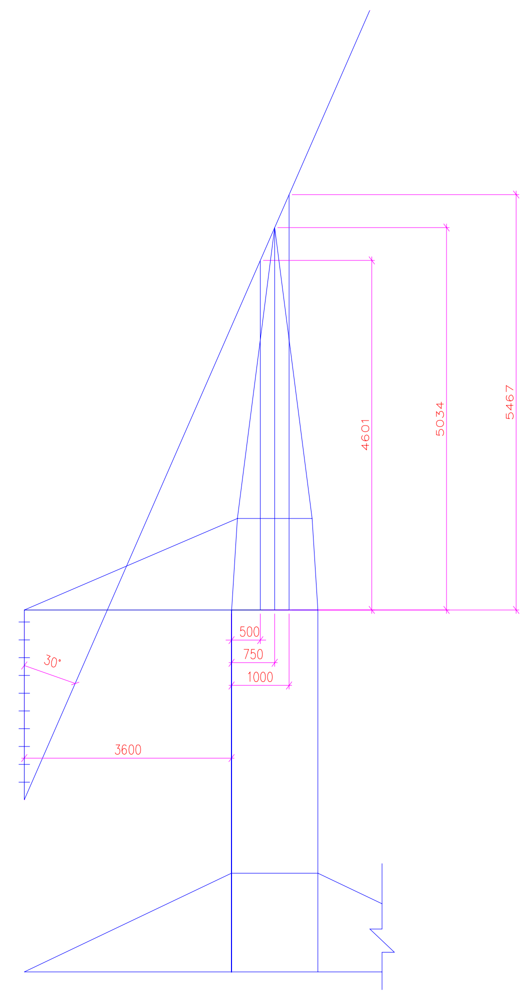
1. The Square and Triangular Towers are having there legs inclined till hamper level (for tower body) while Guyed Mast is having straight legs.

2. All the towers are having straight legs above the hamper level (cage).

3. Final height of each of the tower is taken as the maximum of both conditions that is 29900 mm. Thus, all the towers are having same height.

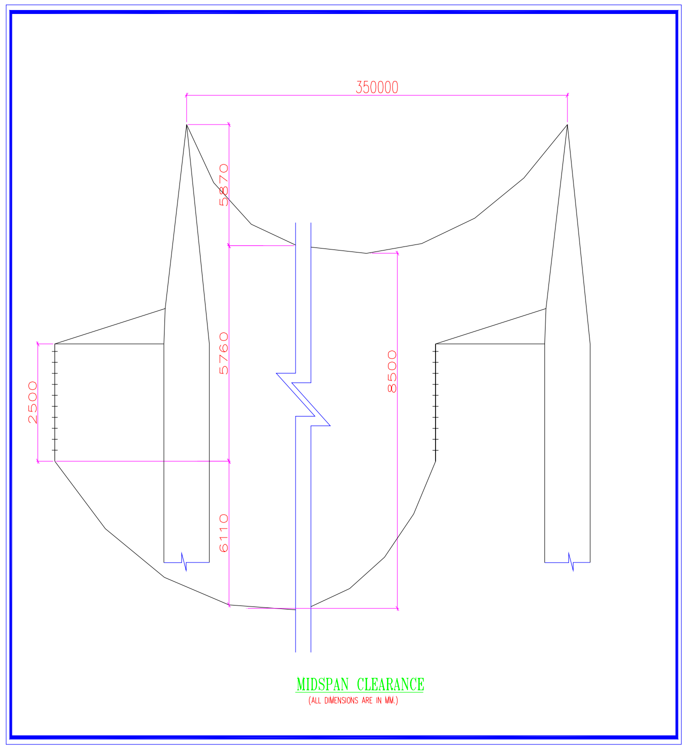
4. Horizontal grounded metal clearance for all the towers is coming same. (Except for the minor change in the slope of tower leg).

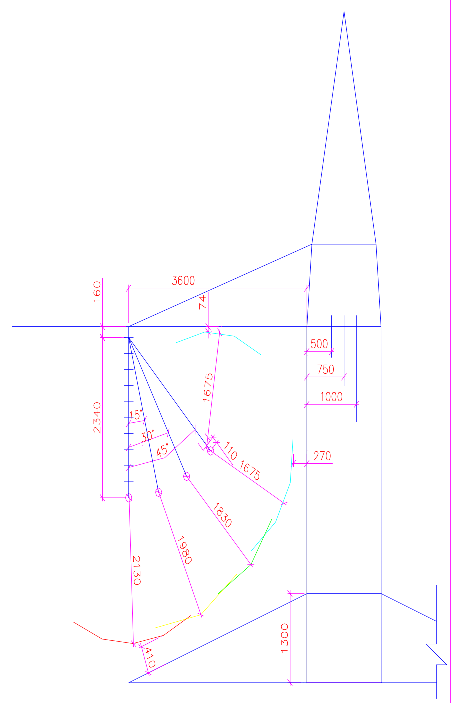
5. Horizontal clearance between the phases is maximum for the Triangular Tower and the least for Guyed Mast. This is because of there width at the hamper level.



PEAK CLEARANCE

(ALL DIMENSIONS ARE IN MM.)


350000
5870
5760
2500
8500
6110
MIDSPAN CLEARANCE
(ALL DIMENSIONS ARE IN MM.)



ELECTRICAL CLEARANCE

(ALL DIMENSIONS ARE IN MM.)
(SCALE 1:56.47)

D. Loading Calculations for Transmission Line:

Loading combinations on the ground wire, conductor and all the towers are found using Indian standards.

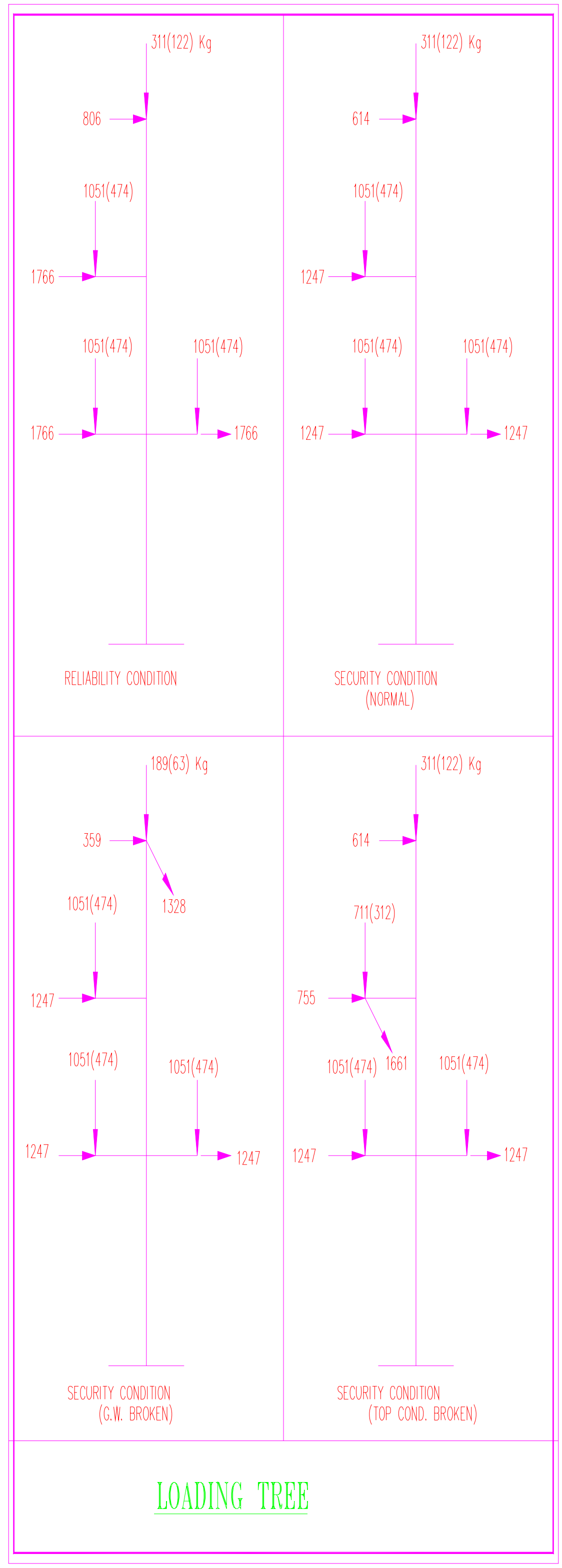
In present Indian Standards, the security conditions for suspension towers correspond to nil wind condition where as for tension towers this requirement is stipulated for 100% full wind condition. But, with the operational experience of towers designed on this basis the power utilities (PGCIL) have initiated amendment through BIS stipulating security conditions of suspension and tension tower corresponding to 75% of full wind load at every day temperature.

Tower being a space truss, loadings are synchronized as the point loadings at the tip of peak and at the three tips of the cross arms. These are shown in the form of Load Tree **(Fig. 7)** with the aid of AutoCAD. This Load tree consists of:

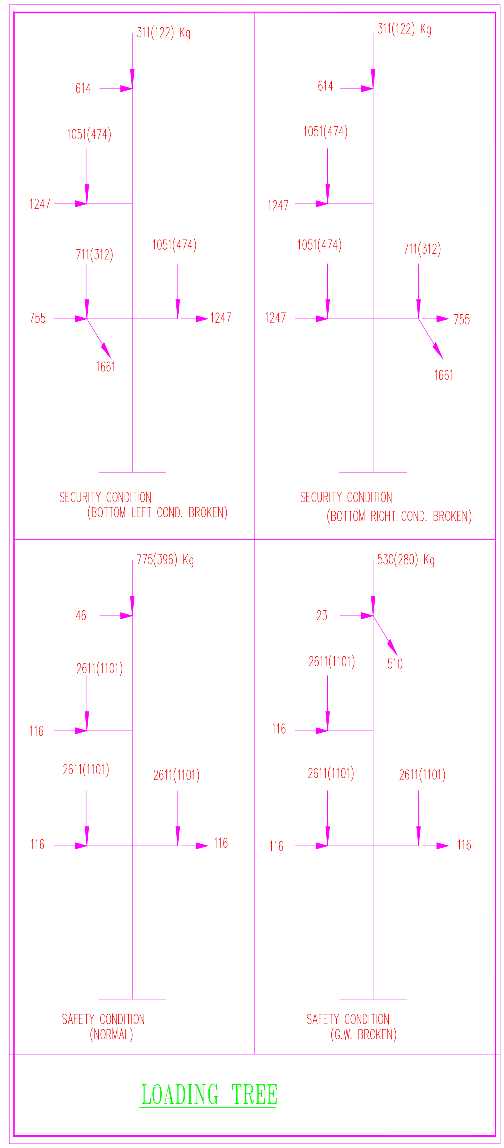
1. Reliability Condition – Normal Condition

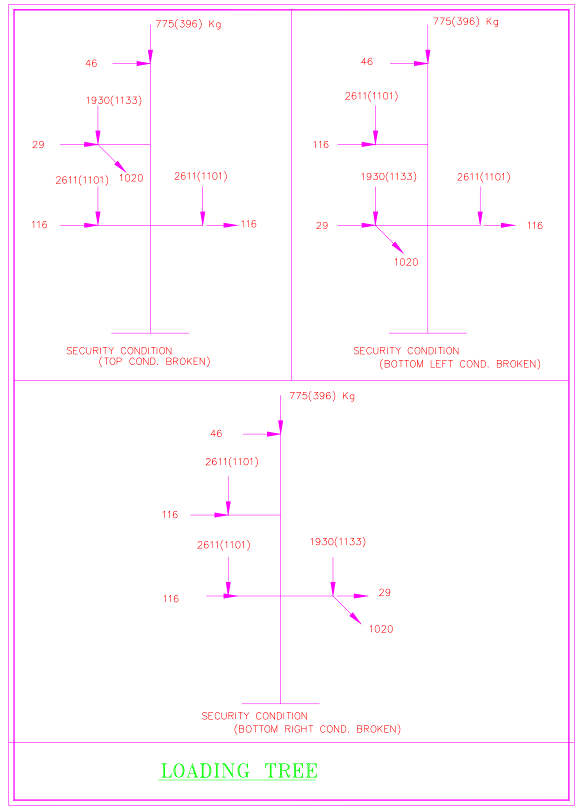
2. Security Condition – Normal Condition
   Ground Wire Broken Condition
   Top Conductor Broken Condition
   Bottom Left Conductor Broken Condition
   Bottom Right Conductor Broken Condition

3. Safety Condition - Normal Condition
   Ground Wire Broken Condition
   Top Conductor Broken Condition
   Bottom Left Conductor Broken Condition
   Bottom Right Conductor Broken Condition



311(122) Kg
806
1051(474)
1766
1051(474)
1051(474)
1766
1766
RELIABILITY CONDITION
311(122) Kg
614
1051(474)
1247
1051(474)
1051(474)
1247
1247
SECURITY CONDITION
(NORMAL)
189(63) Kg
359
1328
1051(474)
1247
1051(474)
1051(474)
1247
1247
SECURITY CONDITION
(G.W. BROKEN)
311(122) Kg
614
711(312)
755
1661
1051(474)
1051(474)
1247
1247
SECURITY CONDITION
(TOP COND. BROKEN)
LOADING TREE


311(122) Kg
614
1051(474)
1247
711(312)
1051(474)
755
1247
1661
SECURITY CONDITION
(BOTTOM LEFT COND. BROKEN)
311(122) Kg
614
1051(474)
1247
1051(474)
711(312)
1247
755
1661
SECURITY CONDITION
(BOTTOM RIGHT COND. BROKEN)
775(396) Kg
46
2611(1101)
116
2611(1101)
2611(1101)
116
116
SAFETY CONDITION
(NORMAL)
530(280) Kg
23
510
2611(1101)
116
2611(1101)
2611(1101)
116
116
SAFETY CONDITION
(G.W. BROKEN)
LOADING TREE


775(396) Kg
46
1930(1133)
29
1020
2611(1101)
2611(1101)
116
116
SECURITY CONDITION
(TOP COND. BROKEN)
775(396) Kg
46
2611(1101)
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1930(1133)
2611(1101)
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1020
SECURITY CONDITION
(BOTTOM LEFT COND. BROKEN)
775(396) Kg
46
2611(1101)
116
2611(1101)
1930(1133)
116
29
1020
SECURITY CONDITION
(BOTTOM RIGHT COND. BROKEN)
LOADING TREE

5.2 EXERCISE 2:

This exercise consists of the remaining parameters for the economical design of all the towers.

This exercise is detailed in the following steps:

A. Wind loading on Towers
B. Analysis of Towers
C. Design of Towers

A. Wind Loading on Towers:

Wind loading all the towers are calculated separately by developing excel programs by following Indian Standards.

For finding the drag coefficients for the members triangular towers, the solidity ratio is derived from table 30 –IS-875 (part 3)-1987 in the similar fashion as prescribed in the IS-826 (part-1/sec 1)-1995.

Wind Loading on Towers			
Height (m) / Wind (kg) (From G.L.)	**Square Tower**	**Triangular Tower**	**Guyed Mast**
0	292	306	129
8.91	-	-	279
10.5	475	-	-
12.14	-	461	-
18.9	243	210	195

20.2	118	111	101
24.1	127	119	108
25.4	107	101	89
29.1	122	118	103
Total	**5571**	**5353**	**3708**
No.of Exposed Memb.	**180**	**195**	**174**

Discussion:

1. The Square Tower is facing the maximum total wind load followed by the Triangular and then the Guyed Mast.

   This implies that the member sectional area exposed to wind is maximum in the Square Tower.

2. The maximum number of tower members exposed to the wind are in the Triangular Tower followed by Square Tower and then the Guyed Mast.

   This might be because of the fact that the loading is same (other than wind) thus Triangular Tower is handling same forces (almost) by three legs so the member sections have increased.

3. The lowest panel of Triangular Tower is having the highest wind load followed by the Square and then the Guyed mast.

   This might be because of the fact that the panel height of the Triangular Tower is comparatively higher as the number of panels are reduced in the trunk of the tower.

B. **Analysis of Towers**:

All the three towers are analyzed in STAAD Pro2004 and the following results are obtained:

Maximum Force in the Leg Member						
	Guyed	**Mast**	**Triangular Tower**		**Square**	**Tower**
	Compressive	Tensile	Compressive	Tensile	Compressive	Tensile
Panel	Load	Load	Load	Load	Load	Load
No.	(Kg)	(Kg)	(Kg)	(Kg)	(Kg)	(Kg)
0	3981	1160	-	-	-	-
1	2492	977	31175	28247	22945	20716
2	2661	1292	28469	25907	22033	20028
3	2839	1610	24726	22324	20560	18698
4	3013	1927	21430	19246	18306	16723
5	3188	2244	18355	16182	16536	15028
6	3362	2560	13826	11874	14242	12936
7	3535	2876	-	-	12892	11542
8	3708	3191	-	-	10604	9490
9	3884	3503	-	-	-	-
10	4608	3308	-	-	-	-
11	5335	3055	-	-	-	-
12	6063	2799	-	-	-	-
13	6792	2674	-	-	-	-
14	7522	3924	-	-	-	-
15	8255	4172	-	-	-	-
16	8990	4916	-	-	-	-
17	9736	5655	-	-	-	-
18	10463	6381	-	-	-	-
19	11302	7148	-	-	-	-
20	8498	12350	9999	8343	7950	5454
21	9013	1178	-	-	-	-
22	7853	8864	7455	6799	6755	6231
23	6556	7116	6206	4982	5509	4979
24	6638	5412	6935	4606	5090	3348
25	4008	3359	4660	2684	3322	2628
26	5256	4955	4641	3537	3553	3459

Maximum Force in the Cross Arm						
	Guyed	Mast	Triangular Tower		Square	Tower
	Compressive	Tensile	Compressive	Tensile	Compressive	Tensile
Panel	Load	Load	Load	Load	Load	Load
	(Kg)	(Kg)	(Kg)	(Kg)	(Kg)	(Kg)
	LOWER	**MEMBER**				
Lower	6268	4307	4969	3645	4651	2912
Upper	6767	4478	5463	2312	5111	2675
	UPPER	**MEMBER**				
Lower	1320	4801	1037	5418	669	4410
Upper	631	4064	825	5729	276	4150

Deflection of Towers			
Ht. (m)	**Square Tower**	**Triangular Tower**	**Guyed Mast**
	(mm)	(mm)	(mm)
0	0	0	0
18.9	85	71	8
20.2	98	90	14.5
24.1	142	129	60
25.4	157	142	76
29.9	216	192	144

Discussion:

1. Square Tower is found to have the maximum node deflection throughout the tower height, followed by Triangular Tower and then the Guyed Mast.
2. Guyed Mast is having the least deflection at the lower cross arm level as

those are the connection point of the guy ropes.

3. Triangular Tower is having the maximum forces in the legs members. The probable reason behind this can be the reduced numbers of legs.

4. Guyed Mast is having the least forces for the leg members. This is because of the guy ropes which themselves transfers the load to the ground.

5. Guyed Mast is having the maximum forces for the lower cross arm members.

C. Design of Towers:

The tower is designed using limit load concept by utilizing probabilistic method of approach and hence summed as:

Design of the Leg Member

	Guyed Mast			Triangular Tower			Square		Tower
Panel No.	Angle Section		F.O.S.		Effective Length (cm)	F.O.S.			F.O.S.
0	(MS └ 65*65*05)	87	3.4						
1	(MS └ 65*65*05)	99	5.1	(└100*100*08)	129	1.1	(└ 90*90*08)	110	1.3
2	(MS └ 65*65*05)	99	5.1	(└100*100*08)	127	1.2	(└ 90*90*08)	155	1.2
3	(MS └ 65*65*05)	99	4.5	(└ 90*90*08)	107	1.3	(└ 90*90*08)	140	1.4
4	(MS └ 65*65*05)	99	4.3	(└ 90*90*08)	130	1.4	(└ 90*90*06)	125	1.2
5	(MS └ 65*65*05)	99	4.1	(└ 90*90*06)	110	1.3	(└ 90*90*06)	135	1.3
6	(MS └ 65*65*05)	99	3.8	(└ 75*75*06)	105	1.3	(└75*75*06)	110	1.3
7	(MS └ 65*65*05)	99	3.6	-	-	-	(└75*75*06)	95	1.5
8	(MS └ 65*65*05)	99	3.5	-	-	-	(└75*75*06)	160	1.3
9	(MS └ 65*65*05)	99	3.3	-	-	-	-	-	-
10	(MS └ 65*65*05)	99	2.8	-	-	-	-	-	-

11	(MS └ 65*65*05)	99	2.4	-	-	-	-	-	-
12	(MS └ 65*65*05)	99	2.1	-	-	-	-	-	-
13	(MS └ 65*65*05)	99	1.9	-	-	-	-	-	-
14	(MS └ 65*65*05)	99	1.7	-	-	-	-	-	-
15	(MS └ 65*65*05)	99	1.6	-	-	-	-	-	-
16	(MS └ 65*65*05)	99	1.4	-	-	-	-	-	-
17	(MS └ 65*65*05)	99	1.3	-	-	-	-	-	-
18	(MS └ 65*65*05)	99	6.3	-	-	-	-	-	-
19	(MS └ 65*65*05)	99	1.1	-	-	-	-	-	-
20	(MS └ 65*65*05)	130	1.3	(└75*75*06)	130	1.7	(└ 65*65*05)	130	1.3
21	(MS └ 65*65*05)	97	1.4	-	-	-	-	-	-
22	(MS └ 65*65*05)	98	1.6	(└ 65*65*05)	130	1.4	(└ 65*65*05)	137	1.6
23	(MS └ 65*65*05)	98	2.0	(└ 65*65*05)	130	1.7	(└ 65*65*05)	127	2.0
24	(MS └ 65*65*05)	98	2.0	(└ 65*65*05)	130	1.5	(└ 65*65*05)	127	2.1
25	(MS └ 65*65*05)	131	2.6	(└ 65*65*05)	133	2.2	(└ 65*65*05)	132	3.2
26	(MS └ 65*65*05)	151	1.7	(└ 65*65*05)	153	1.9	(└ 65*65*05)	152	2.5

Design of Cross Arm

	Guyed	Mast		Triangular	Tower		Square		Tower
		Effective	F.O.S.			F.O.S.			F.O.S.
Panel	Angle Section	Length (cm)		Angle Sect.			Angle Sect.		
LOWER MEMBER									
Lower	(MS └75*75*06)	136	2.4	(└75*75*06)	164	2.6	(└75*75*06)	123	3.4
				(└65*65*05)	120	4.7			
Upper	(MS └75*75*06)	136	2.2	(└75*75*06)	164	2.4	(└75*75*06)	123	3.1
				(└65*65*05)	120	4.3			
	UPPER MEMBER								
Lower	(MS └50*50*04)	143	1.4	(└50*50*04)	143	1.2	(└50*50*04)	130	1.5
Upper	(MS └50*50*04)	154	1.4	(└50*50*04)	128	1.2	(└50*50*04)	146	1.6

Discussion:

1. Triangular Tower is having the heaviest member section for the legs.

As the forces (other than wind) are almost same, so the probable reason behind this can be the reduced numbers of legs. Also, the reduced number of panels can be one of the probable reasons, because of which the base panel height has increased. Thus increasing the forces in the leg sections and thus, making the member sections comparatively heavy.

2. Guyed Mast is having the least member sections with the maximum factor of safety.

This might be because of the guy ropes which themselves transfers the load to the ground.

3. The lower cross arm members for Triangular Tower is having different lengths.

This could be because of the unsymmetrical geometry of the tower.

4. Square Tower is having the maximum factor of safety for the upper cross arm member.

This behavior might be because of the minimum length of the members.

5. Upper cross arm member sections are found to be same for all the towers.

This may be because these members are designed as the tension members and steel already have good margin of safety in tension.

5.3 **DISCUSSION OF RESULTS**:

As already we have seen that all the towers are designed with the enough factor of safety.

The self weight of different towers obtained is as follows:

Tower Type	Square Tower	Triangular Tower	Guyed Mast
Weight (Kg)	2775	2519	1666

Triangular Tower is compared with the Square Tower in the following aspects:

1. The self weight for the Triangular Tower is found to be 9.23% less than the Square Tower.
   Hence, Triangular Tower is more economical than the Square Tower (self supporting tower).

2. Triangular Tower is found to have the lesser amount of node deflection throughout the height of the tower as compared with the Square Tower.
   This implies that the Triangular Tower is behaving more rigidly than the Square Tower.

3. The Square Tower is facing the maximum total wind load followed by the Triangular and then the Guyed Mast.
   This implies that the member sectional area exposed to wind is maximum in the Square Tower.

4. The lowest panel of Triangular Tower is having the highest wind load followed by the Square and then the Guyed mast.

This might be because of the fact that the panel height of the Triangular Tower is comparatively higher as the number of panels are reduced in the trunk of the tower.

5. Triangular Tower is found to have little higher amount of axial forces in the leg member in comparison with Square Tower.
   This might because the forces are being transferred by three legs instead of the Four.

Guyed Mast is coming all the way economical than the Triangular Tower and the Square Tower. Even the self weight of tower, wind loading on tower, axial forces in the members (except the lower cross arm members) and the node deflection, all are coming comparatively lesser. The above noted weight of Guyed Mast is excluding the self weight of guy ropes.

The different structural behavior of Guyed Mast and its right of way requirement needs to be checked before its use. The value of land is one of the major factors to be taken into considerations in case of Guyed Mast. The saving in the cost of transmission line by using Guyed Mast can be nullified by the premium value of land.

6.0 CONCLUSION

6.0 CONCLUSION

Least weight of the tower implies greatest economy in the transmission line costs.Our research work has guided us to the following conclusions:

1. Configuration of towers has reveled that all the three towers are having the same height but different base width.

2. Loading including reliability, security and safety conditions have been kept same for all the three towers.

3. Wind loading is calculated for each tower and has lead to following results:

Tower Type	Total Wind Load (Kg)
Square Tower	5571
Triangular Tower	5353
Guyed Mast	3708

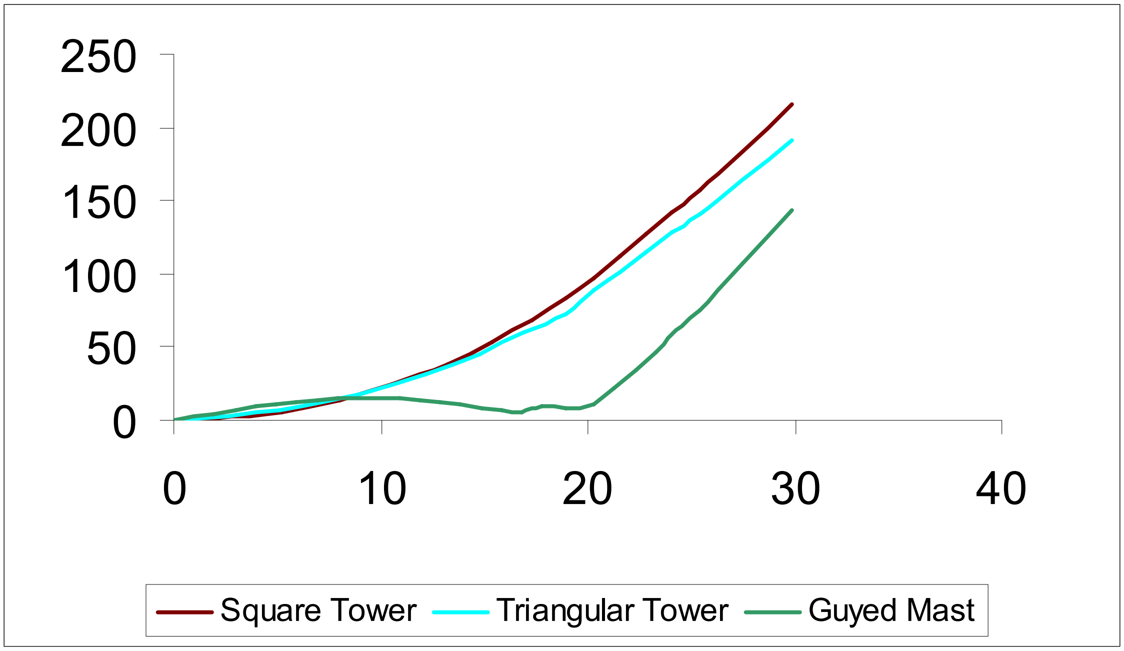
(Note: Above developed programs are in Microsoft Excel using AutoCaD2002)

4. Analysis of Towers as a 3-D space structure with STAADPRO 2004 is showing :

   - Maximum Axial Compressive Force In Leg Member of the Lowest Panel (Panel one) :

Tower Type	Maximum Force (Kg)
Square Tower	22945
Triangular Tower	31175
Guyed Mast	11302

- Deflection of Tower :



Note: * Height – “m” (X Axis) and Deflection – “mm” (Y Axis).

* Deflection is at the Reliability Condition (Minimum Weight Span).

5. Design has been done with super most thought of conserving every Kg of steel possible within the limitations of the specifications by developing excel programs.

After performing three iterations, the economic design of towers has lead to the following conclusion:

Tower Type	Tower Self Weight (Kg)
Square Tower	2775
Triangular Tower	2519
Guyed Mast	1666

Thus, using Triangular Base Self Supporting Tower will bring a saving of **9.23%** in the weight of structural steel and using Square Base Guyed Mast will lead to saving of **39.96%** in the structural steel (excluding guy ropes), which is directly the cost saving in each tower or the structural optimization of transmission line.

7.0 SCOPE OF FUTURE STUDY

7.0 SCOPE OF FUTURE STUDY

The need for electric power is increasing every second and simultaneously the available right of way is becoming more critical. As much of the transmission line structural optimization is already worked out that is by reconsidering the behavior of tower and geometry of tower. Still, the following are the ways of improvement:

1. Effective static loading on transmission line structure, conductor and ground wire can be replaced with the actual dynamic loading and the results can be compared for all the three towers.
2. Instead of considering wind as the prominent force seismic force can be considered and the snow load can be checked with different combinations.
3. The towers leg members can be changed from angle section to pipe / rod section and there detailed behavior can be analyzed.
4. Also, an effort of trying different structural material like aluminum should go on till some wonderful results would be achieved.
5. Different shapes like cat head tower can be further developed with keeping in mind the harmony of the surrounding scenery.
6. Attempt in changing the shape of cross arm can lead to wonderful results.
7. Use of insulated cross arms should be studied in detail, as it reduce electrical clearances, thus, allowing the tower to somewhat more slender and hence bringing cost saving of the line as a whole.
8. Developing pole type structures in an elaborative way can bring a tremendous change in the market. Even the general advantage of lightweight, erection ease, pre assembly, and simple foundation design of guyed mast can be extended to pole type structures.
9. Looking into India’s theft condition efforts can be make to develop components like guy ropes to be of no scrap value.

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APPENDIX A

Sag Tension Calculation Using Parabolic Equation			Units
DATA:			
Basic Span (L):		350	(m)
Basic Pressure Wind :		71.45	(kg / sqm)
Wind Pressure (P):		146.81	(kg / sqm)
CONDUCTOR DETAILS:			
Type:		**ACSR ZEBRA**	
Overall Diameter (D)		0.02862	(m)
Cross Sectional Area (A):		4.845	(sqcm)
Unit weight of Conductor (w):		1.621	(kg / m)
Ultimate Tensile Strength (UTS)		13289	(kg)
Coeff. of Linear Expansion (α) :		1.93E-05	(/ deg C)
Modulus of Elasticity (E):		7.04E+05	(kg/sqcm)
Gust Factor :		2.0547	
Drag Factor :		1	
Creep :		0	(%)
BASIC CONDITIONS:			
Temperature:		32.00	deg C
Wind Factor:		0.0	
Ice Thickness:		0.0	
Initial Sag-Tension Calculations:			
Initial Tension: T_1	25% OF UTS	3322.25	kg
Initial Stress: F_1	T_1 / A	685.71	kg/sqcm
Initial Sag: S_1	$w.L^2 / 8.T_1$	7.47	m
Parameters:			
∂	Weight of Conductor in kg / m / sqcm		
∂	W / A	0.335	kg/m/sqcm
p	Wind Load on Conductor in kg /m length of conductor		
p	P*D	4.202	kg / m

q	Loading Factors
$q_{0.0}$	$(\sqrt{((p*0.0)^2 + w^2)}) / w$ 1
$q_{0.36}$	$(\sqrt{((p*0.36)^2 + w^2)}) / w$ 1.368
$q_{0.75}$	(√ ((p*0.75)2 + w2)) / w 2.186
$q_{1.00}$	$(\sqrt{((p*1.0)^2 + w^2)}) / w$ 2.778
F	Working Tensile Strength of Conductor in kg / sqcm
K	Constant (computed from initial temperature & wind pressure conditions)
t	Change in temperature

Parabolic Formula:

$$F_2^2.(F_2 – (K – \alpha.t.E)) = L^2.\partial^2.q_2^2.E / 24$$

As K= $F_1 – (L^2.\partial^2.qo^2.E / 24.F_1^2)$

keep $l^2.\partial^2.q_2^2.E / 24$ = Z

Temperature Variation(ºC):		0	32			75
α.t.E		-434.54	0			583.92
Wind Variation:	**0**	**0.36**	**0**	**0.75**	**1.0**	**0**
Z	4.02E+08	7.52E+08	4.02E+08	1.92E+09	3.10E+09	4.02E+08
K	-1.69E+02	-1.69E+02	-1.69E+02	-1.69E+02	-1.69E+02	-1.69E+02
(K-α.t.E)	2.65E+02	265.3	-1.69E+02	-1.69E+02	-169.27	-7.53E+02
F	837.89	1006.95	685.705	1189.4	1404.3	554.49
T Tension (F*A) (Kg)	**4060**	**4879**	**3322**	**5763**	**6804**	**2687**
S Sag ($w.L^2/8T$) (m)	**6.114**	**5.088**	**7.471**	**4.307**	**3.648**	**9.239**

Maximum Allowed Tension is 70% of UTS 9302.3 Kg

Sag Tension Calculation Using Parabolic Equation				Units
DATA:				
Basic Span (L)			350	(m)
Basic Wind Pressure (P):			71.45	(kg / sqm)
Wind Pressure (P):			181.34	(kg / sqm)
CONDUCTOR DETAILS:				
Type:			**E - Wire**	
Overall Diameter (D) :			0.01098	(m)
Cross Sectional Area (A):			0.7365	(sqcm)
Unit weight (w):			0.583	(kg / m)
Ultimate Tensile Strength (UTS) :			6972.0	(kg)
Coeff. of Linear Expansion (α) :			1.15E-05	(/ deg C)
Modulus of Elasticity (E):			1.94E+06	(kg/sqcm)
Gust Factor :			2.115	
Drag Factor :			1.2	
Creep :			0	(%)
BASIC CONDITIONS:				
Temperature:			32.00	deg C
Wind Factor:			0.0	
Ice Thickness:			0.0	
Initial Sag-Tension Calculations:				
Initial Tension:	T_1	$(w.L^2 / 8S)$	0.19 (% OF UTS) 1327.62	kg
Initial Stress:	F_1	T_1 / A	1802.61	kg/sqcm
Initial Sag:	S_1	0.9 * 7.47=	6.72	m
Parameters:				
	∂	Weight of Conductor in kg / m / sqcm		
	∂	W / A	0.7916	kg/m/sqcm
	p	Wind Load on Conductor in kg /m length of conductor		

p	P*D	1.9911	kg / m
q	Loading Factors		
$q_{0.0}$	$(\sqrt{((p*0.0)^2 + w^2)}) / w$	1	
$q_{0.36}$	$(\sqrt{((p*0.36)^2 + w^2)}) / w$	1.585	
$q_{0.75}$	(√ ((p*0.75)2 + w2)) / W	2.750	
$q_{1.00}$	$(\sqrt{((p*1.0)^2 + w^2)}) / w$	3.559	
F	Working Tensile Strength of Conductor in kg / sqcm		
K	Constant (computed from initial temperature & wind pressure conditions)		
t	Change in temperature		

Parabolic Formula:

$$F_2^2.(F_2 – (K – \alpha.t.E)) = L^2.\partial^2.q_2^2.E / 24$$

As $K = F_1 – (L^2.\partial^2.qo^2.E / 24.F_1^2)$

keep $l^2.\partial^2.q_2^2.E / 24 = Z$

Temperature Variation(ºC):		0		32		53
α.t.E		-712.48		0		467.57
Wind Variation:	0	0.36	0	0.75	1.0	0
Z	6.19E+09	1.56E+10	6.19E+09	4.68E+10	7.84E+10	6.19E+09
K	-1.03E+02	-1.03E+02	-1.03E+02	-103.02	-1.03E+02	-1.03E+02
(K-α.t.E)	6.09E+02	609.5	-1.03E+02	-103.02	-103.01873	-5.71E+02
F	2063.38	2716.8	1802.4	3569.8	4246	1664.15
T (F*A) Tension (Kg)	**1520**	**2001**	**1327**	**2629**	**3127**	**1226**
S ($w.L^2/8T$) Sag (m)	**5.874**	**4.462**	**6.725**	**3.395**	**2.855**	**7.284**

Maximum Allowed Tension is 70% of UTS = 4880.4 Kg

CONFIGURING TOWER: TTA - 220 KV

A. Height Till Waist Level (From G.L.)**:**

Minimum Ground Clearance	7000	mm
Sag Error Considered:	160	mm
Max. Sag of Conductor	9240	mm
Length of Insulator:	2340	mm
Length of hanger:	160	mm
Height Till Lower Cross Arm:	**18900**	**mm**

B. Vertical Spacing Between Cross Arms.

Minim. Vertical Spacing Between Conductor:	5200	mm
Provided Vertical Spacing Between Cross Arm:	**5200**	**mm**

C. Height Till Upper Cross Arm:

24100 mm

D. Vertical Clearance Between Ground Wire And Top Conductor:

1- **MIDSPAN CLEARANCE CHECK :**

SAG OF GROUND WIRE (0^0 +0.0) =	5874	mm
SAG OF CONDUCTOR (0^0 +0.0) =	6114	mm
LENTGH OF INSULATOR =	2340	mm
LENTGH OF HANGER =	160	mm
SAG DIFFERENCE:	240	mm
MINIMUM MIDSPAN CLEARENCE ALLOWED:	8500	mm

HEIGHT BETWEEN TOWER TOP AND U.C.A (BOTTOM) :	5760	
(THIS HT. INCLUDES THE 150 mm FOR G.W. CLAMP)	**5800**	mm
TOTAL TOWER HEIGHT : 24100 + 5800 =	**29900**	mm

2- **PEAK CLEARANCE CHECK :**

TOWER TYPE	SQUARE BASE	TRIANGULAR BASE	GUYED MAST	
HEIGHT FROM G.L.				
LOWER CROSS ARM (BOTTOM)	18900	18900	18900	mm
UPPER CROSS ARM (BOTTOM)	5200	5200	5200	mm
AS PER SHIELDING ANGLE REQUIREMENT:	5000	5500	4600	mm
TOWER TOTAL HEIGHT :	**29100**	**29600**	**28700**	**mm**

MINIMUM SPECIFIED HEIGHT OF TOWER: 28555 mm

E. Total Tower Height: **29900 mm**

(This includes 150 mm for G.W..Clamp)

F. Horizontal Spacing Beween Cross Arm Tip :

Minim. Horizontal Spacing Between Conductor: 8500 mm

ELECTRICAL CLEARANCE CHECK :

TOWER TYPE	SQUARE BASE	TRIANGULAR BASE	GUYED MAST	
Width At Waist Level:	1500	2000	1000	mm
Electrical Clearance :	3600	3600	3600	mm
	8700	9200	8200	mm
Total Horz. Spacing:	**8700**	**9200**	**8500**	**mm**

Loading Calculations:

Design Data:

P_d	(kg/m)	71.45	Design Wind pressure				
l	(m)	350	Normal Span				
Diameter :							
d	(m)	G.W. --	0.01098	Conductor	0.02862	Insulator -	0.255
Gust Response Factor:							
G_C / Gi		G.W. --	2.115	Conductor	2.055	Insulator -	2.25
Drag Coefficient:							
C_{dC} / C_di		G.W. --	1.2	Conductor	1.0	Insulator -	1.2
Tension:							
T	(kg)	G.W. --	3127	Conductor	6804		
T1(0.0)	(kg)	G.W. --	1328	Conductor	3322		
T(0.75)	(kg)	G.W. --	2629	Conductor	5762		
w	(kg/m)	G.W. --	0.583	Conductor	1.621		
n		1	For No. of Sub-Conductors/ Phase				
m		1	For Suspension towers -1 & Tension Towers - 2				
Length of Insulator-		2.34	(m)				
Units: Kg & m							

			Normal Condition (N.C.)	Factor	Broken Wire Condition (B.W.C.)	
Deviation Angle:(ºC)		Φ_1	0		2	Φ_2
Wind Span: (m)	L		350	0.6	210	
Weight Span (Max.)	L_1		525	1.0	315	
Weight Span (Min.)	L_2		200	1.0	100	

Reliability Condition:-

Normal Condition

I. Ground Wire:

A. Transverse Load:

1 Wind on Wire:

$F_{WC} = P_d . L . d . G_C . C_{dC}$ 696.89

2 Due to Deviation:

	$F_{Wd} = 2 \cdot T \cdot \sin(\Phi_2 / 2)$		109.16096		
		Total:	806.051		
			806	kg	
B.	Vertical Load:				
1	Weight of Wire:				
	$VR = w \cdot (L_1 \text{ or } L_2)$		306.075	116.6	
2	Weight of G.W. Clamp: VR = 50 N = 5 Kg		5	5	
		Total:	311.08	121.6	
			311	**122**	kg
C.	Longitudinal Load:				
	$LR = 0 * T \cdot \cos(\Phi_1/2)$		**0**	kg	
			Normal Condition		
II.	**Conductor:**				
A.	Transverse Load:				
1	Wind on Wire:				
	$F_{WC} = n \cdot P_d \cdot L \cdot d \cdot G_C \cdot C_{dC}$		1470.7936		
2	Wind on Insulator:				
	$F_{Wi} = n \cdot m \cdot P_d \cdot Ai \cdot Gi \cdot C_d i$		57.556		
3	Due to Deviation:				
	$F_{Wd} = 2 \cdot n \cdot T \cdot \sin(\Phi_2 / 2)$		237.490		
		Total:	1,765.840		
			1,766	kg	
B.	Vertical Load:				
1	Weight of Wire:				
	$VR = w \cdot n \cdot (L_1 \text{ or } L_2)$		851.025	324.2	
2	Weight of Insulator: VR = n *m *indiviual wt.		200	150	
		Total:	1,051.025	474.2	
			1,051	**474**	kg
C.	Longitudinal Load:				

$LR = 0 * n * T \cdot \cos(\Phi_1/2)$ **0** kg

Security Condition:

I.	**Ground Wire:**		**Normal Condition**			**Broken Wire Condition**
A.	Transverse Load:					
1	Wind on Wire:					
	$F_{WC} = P_{d(0.75)} \cdot L \cdot d \cdot G_C \cdot C_{dC}$		523		0.6	314
2	Due to Deviation:					
	$F_{Wd} = 2 \cdot T(0.75) \cdot \sin(\Phi_2 / 2)$		91.782			
	$F_{Wd} = T(0.75) \cdot \sin(\Phi_2 / 2)$				1.0	45.89
		Total:	614.449			359.49
			614 kg			**359** kg

B.	Vertical Load:					
1	Weight of Wire:					
	$VR = w \cdot (L_1 \text{ or } L_2)$		306.075	116.6	183.645	58.3
2	Weight of G.W. Clamp: VR = 50 N = 5 Kg		5	5	5	5
		Total:	311.08	121.6	188.645	63.3
			311	**122** kg	**189**	**63** kg

C.	Longitudinal Load:		
	$LS = 0 * T1 \cdot \cos(\Phi_1/2)$	0	
	$LS = T1 \cdot \cos(\Phi_1/2)$		1327.66
		0 kg	**1328** kg

II.	**Conductor:**	**Normal Condition**		**Broken Wire Condition**
A.	Transverse Load:			
1	Wind on Wire:			
	$F_{WC} = n \cdot P_{d(0.75)} \cdot L \cdot d \cdot G_C \cdot C_{dC}$	1103.095	0.6	662

2	Wind on Insulator:					
	$F_{Wi} = n \,.\, m \,.\, P_{d(0.75)} \,.\, Ai \,.\, Gi \,.\, C_d i$	43.167		1.0	43.17	
3	Due to Deviation:					
	$F_{Wd} = n \,.\, T(0.75) \,.\, \sin(\Phi_2 / 2)$	100.561				
	$F_{Wd} = 0.5 * n \,.\, T(0.75) \,.\, \sin(\Phi_2 / 2)$				50.281	
	Total:	1,246.824			755.30	
		1,247 kg			**755** kg	
B.	Vertical Load:					
1	Weight of Wire:					
	$VR = w \,.\, n \,.\, (L_1 \text{ or } L_2)$	851.025	324.2		510.615	162.1
2	Weight of Insulator:					
	VR = n *m *indiviual wt.	200	150		200	150
	Total:	1,051.025	474.2		710.62	312.10
		1,051	**474** kg		**711**	**312** kg
C.	Longitudinal Load:					
	$LR = 0 * n * T1 \,.\, \cos(\Phi_1/2)$	0				
	$LR = 0.5 * n * T1 \,.\, \cos(\Phi_1/2)$				1661.125	
		0 kg			**1661** kg	

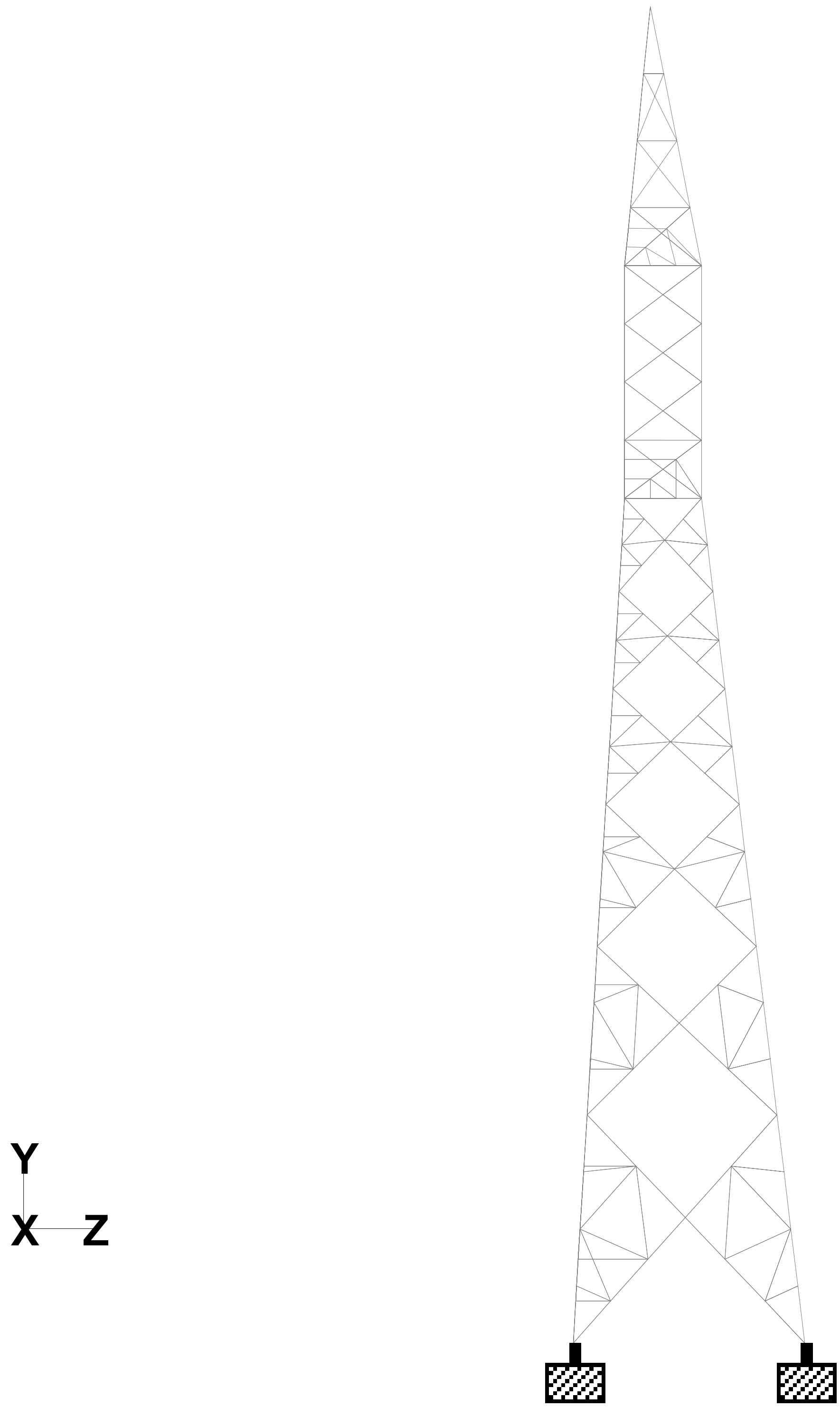
Safety Condition:

		Normal Condition			Broken Wire Condition	
I.	**Ground Wire:**					
A.	Transverse Load:					
	Due to Deviation:					
	$TM = 2 \,.\, T_1 \,.\, \sin(\Phi_2 / 2)$	46.342				
	$TM = T_1 \,.\, \sin(\Phi_2 / 2)$				23.171	
		46 kg			**23** kg	
B.	Vertical Load:					
1	Weight of Wire:					
	$VM = 2 \,.\, w \,.\, (L_1 \text{ or } L_2)$ (2- over load factor)	612.15	233.2		367.29	116.6
2	Weight of G.W. Clamp:					
	VM = 2* 50 N = 2* 5 Kg (2- over load factor)	10	10		10	10

3	Weight of Man with Tool: VM = 1500 N= 153 kg		153	153		153	153
		Total:	775.15	396.2		530.29	279.6
			775	**396**	kg	**530**	**280**
C.	Longitudinal Load:						kg
	$LM = 0 * 0.5 * T_1$		0			509.684	
			0	kg		**510**	kg

II.	**Conductor:**						
A.	Transverse Load:						
	Due to Deviation:						
	$TM = 2 . N . T_1 . \sin(\Phi_2 / 2)$		115.963			28.991	
	$TM = 1 . N . (0.5*T_{1)} . \sin(\Phi_2 / 2)$						
			116	kg		**29**	kg
B.	Vertical Load:						
1	Weight of Wire: $VM = 2. n. w . (L_1 \text{ or } L_2)$ (2- over load factor)		1702.05	648.4		1021.23	324.2
2	Weight of Insulator: VR = 2 * n *m *indiviual wt.		400	300		400	300
3	Weight of Man with Tool: VM = 1500 N= 153 kg		153	153		153	153
4	Weight at Arm Tip		356.7788	356.7788		356.7788	356.7788
		Total:	2,611.83	1,458.2		1,931.009	1,133.98
			2,612	**1,458**	kg	**1,931**	**1,134**
							kg
c.	Longitudinal Load:						
			Normal				
	$LM = 0 *n * 0.5 * T_1$		0			1019.368	
			0	kg		**1019**	kg

TRIANGULAR BASE TOWER



WIND FACE

WIND AREA CALCULATION

Panel N0.	Member No.	Member	No.	Length (m)	Breadth (m)	Area (m*m)
1	Panel Bound	By ABCD				
		Main Legs :				
	1	(MS └ 100*100*08)	8	1.29	0.1	1.0320
		Lattices :				
	2	(MS └ 45*45*04)	4	1.68	0.045	0.3024
	3	(MS └ 45*45*04)	6	1.37	0.045	0.3699
		Redundants :				
	4	(MS └ 45*30*04)	2	1.37	0.045	0.1233
	5	(MS └ 45*30*04)	2	0.93	0.045	0.0837
	6	(MS └ 45*45*04)	2	1.78	0.045	0.1602
	7	(MS └ 45*45*04)	2	2.06	0.045	0.1854
	8	(MS └ 45*45*04)	2	2.10	0.045	0.1890
	9	(MS └ 45*45*04)	2	1.86	0.045	0.1674
					TOTAL	**2.6133**
2	Panel Bound	By CDEF				
		Main Legs :				
	10	(MS └ 100*100*08)	6	1.27	0.1	0.762
		Lattices :				
	11	(MS └ 50*50*04)	4	1.34	0.05	0.2680
	12	(MS └ 50*50*04)	4	1.6	0.05	0.3200
		Redundants :				
	13	(MS └ 45*30*04)	2	1.23	0.045	0.1107
	14	(MS └ 45*45*04)	2	1.90	0.045	0.1710
	15	(MS └ 45*30*04)	2	1.12	0.045	0.1008
	16	(MS └ 45*45*04)	2	1.78	0.045	0.1602
					TOTAL	**1.8927**
3	Panel Bound	By EFGH				
		Main Legs :				
	17	(MS └ 90*90*08)	6	1.07	0.09	0.5778
		Lattices :				
	18	(MS └ 45*45*04)	4	1.13	0.045	0.2034
	19	(MS └ 45*45*04)	4	1.35	0.045	0.2430

		<u>Redundants :</u>				
	20	(MS └ 45*30*04)	2	0.94	0.045	0.0846
	21	(MS └ 45*30*04)	2	1.03	0.045	0.0927
	22	(MS └ 45*30*04)	2	1.49	0.045	0.1341
	23	(MS └ 45*45*04)	2	1.88	0.045	0.1692
						1.5048
4	Panel Bound	By GHIJ				
		<u>Main Legs :</u>				
	24	(MS └ 90*90*08)	4	1.3	0.09	0.468
		<u>Lattices :</u>				
	25	(MS └ 45*45*04)	4	0.94	0.045	0.1692
	26	(MS └ 45*45*04)	4	1.11	0.045	0.1998
		<u>Redundants :</u>				
	27	(MS └ 45*30*04)	2	1.11	0.045	0.0999
	28	(MS └ 45*30*04)	2	0.94	0.045	0.0846
	29	(MS └ 45*45*04)	2	1.59	0.045	0.1431
					TOTAL	**1.1646**
5	Panel Bound	By IJKL				
		<u>Main Legs :</u>				
	30	(MS └ 90*90*06)	4	1.1	0.09	0.396
		<u>Lattices :</u>				
	31	(MS └ 45*45*04)	4	0.79	0.045	0.1422
	32	(MS └ 45*45*04)	4	0.94	0.045	0.1692
		<u>Redundants :</u>				
	33	(MS └ 45*30*04)	2	1.34	0.045	0.1206
	34	(MS └ 45*30*04)	2	0.94	0.045	0.0846
	35	(MS └ 45*30*04)	2	0.79	0.045	0.0711
					TOTAL	**0.9837**
6	Panel Bound	By KLMN				
		<u>Main Legs :</u>				
	36	(MS └ 75*75*06)	4	1.05	0.075	0.315
		<u>Lattices :</u>				
	37	(MS └ 50*50*04)	4	0.69	0.05	0.138

	38	(MS └ 50*50*04)	4	0.84	0.05	0.168
		Redundants :				
	39	(MS └ 45*30*04)	2	1.11	0.045	0.0999
	40	(MS └ 45*30*04)	2	0.84	0.045	0.0756
	41	(MS └ 45*30*04)	2	0.69	0.045	0.0621
		Horizontals :				
	42	(MS └ 45*45*04)	2	1	0.045	0.0900
					TOTAL	**0.9486**
7	Panel Bound	By MNOP				
		Main Legs :				
	43	(MS └ 75*75*06)	2	1.3	0.075	0.1950
		Lattices :				
	44	(MS └ 45*45*04)	2	1.19	0.045	0.1071
	45	(MS └ 45*45*04)	2	1.19	0.045	0.1071
		Horizontals :				
	46	(MS └ 45*30*04)	2	1	0.045	0.0900
					TOTAL	**0.4992**
8	Panel Bound	By OPQR				
		Main Legs :				
	47	(MS └ 65*65*05)	2	1.3	0.065	0.1690
		Lattices :				
	48	(MS └ 45*45*04)	2	1.19	0.045	0.1071
	49	(MS └ 45*45*04)	2	1.19	0.045	0.1071
					TOTAL	**0.3832**
9	Panel Bound	By QRST				
		Main Legs :				
	50	(MS └ 65*65*05)	2	1.3	0.065	0.1690
		Lattices :				
	51	(MS └ 45*45*04)	2	1.19	0.045	0.1071
	52	(MS └ 45*45*04)	2	1.19	0.045	0.1071

					TOTAL	**0.3832**
10	Panel Bound	By STUV				
		Main Legs :				
	53	(MS └ 65*65*05)	2	1.3	0.065	0.1690
		Lattices :				
	54	(MS └ 45*45*04)	2	1.19	0.045	0.1071
	55	(MS └ 45*45*04)	2	1.19	0.045	0.1071
		Horizontals :				
	56	(MS └ 45*45*04)	2	1	0.045	0.0900
					TOTAL	**0.4732**
11	Panel Bound	By UVWX				
		Main Legs :				
	57	(MS └ 65*65*05)	2	1.33	0.065	0.1729
		Lattices :				
	58	(MS └ 45*45*04)	2	0.96	0.045	0.0864
	59	(MS └ 45*45*04)	2	1.24	0.045	0.1116
		Horizontals :				
	60	(MS └ 45*45*04)	1	1.55	0.045	0.0698
					TOTAL	**0.4407**
12	Panel Bound	By WXY				
		Main Legs :				
	61	(MS └ 65*65*05)	2	1.53	0.065	0.1989
	62	(MS └ 65*65*05)	2	1.53	0.065	0.1989
	63	(MS └ 65*65*05)	2	1.53	0.065	0.1989
		Redundants:				
	64	(MS └ 45*45*04)	2	1.98	0.045	0.1782
	65	(MS └ 45*45*04)	2	1.7	0.045	0.153
	66	(MS └ 45*30*04)	1	1.03	0.045	0.04635
	67	(MS └ 45*30*04)	1	0.52	0.045	0.0234
					TOTAL	**0.9977**
13	Panel Bound	By MZN				
		Horizontals :				

	68	(MS └ 75*75*06)	1	2	0.075	0.1500	
					TOTAL	**0.1500**	
14	Panel Bound	By MZNOP					
		Main Legs :					
	69	(MS └ 50*50*04)	1	2.385	0.05	0.1193	
	70	(MS └ 50*50*04)	1	1.30	0.05	0.0650	
							0.87
		Redundants :					0.44
	71	(MS └ 45*45*04)	1	1.10	0.045	0.0494	0.67
	72	(MS └ 45*30*04)	1	0.87	0.045	0.0392	
	73	(MS └ 45*45*04)	1	0.80	0.045	0.0360	
	74	(MS └ 45*30*04)	1	0.44	0.045	0.0199	
	75	(MS └ 45*30*04)	1	0.67	0.045	0.0300	
	76	(MS └ 45*30*04)	1	1.33	0.045	0.0600	
					TOTAL	**0.4187**	
15	Panel Bound	By UaV					
		Horizontals :					
	77	(MS └ 75*75*06)	1	2	0.075	0.1500	
					TOTAL	**0.1500**	
16	Panel Bound	By UaVWX					
		Main Legs :					0.23
	78	(MS └ 50*50*04)	1	2.055	0.05	0.1027	1.35
	79	(MS └ 50*50*04)	1	1.33	0.05	0.0665	
		Redundants :					
	80	(MS └ 50*50*04)	1	1.11	0.05	0.0556	
	81	(MS └ 45*30*04)	1	0.89	0.045	0.0401	
	82	(MS └ 45*45*04)	1	0.81	0.05	0.0403	
	83	(MS └ 45*30*04)	1	0.45	0.045	0.0203	
	84	(MS └ 45*30*04)	1	0.67	0.045	0.0300	
	85	(MS └ 45*30*04)	1	1.33	0.045	0.0600	
					TOTAL	**0.4156**	

TOTAL NO. OF LEG MEMBER:	50
TOTAL NO. OF LATTICE MEMBER:	74
TOTAL NO. OF HORIZONTAL MEMBER:	7
TOTAL NO. OF REDUNDANT :	64
TOTAL NO. OF MEMBER IN WIND FACE :	195

WIND LOAD CALCULATION

Panel No.	Bottom Width "b" (m)	Top Width "a" (m)	Height of Panel "h" (m)	Area of Panel **"Ap"** (m*m) A=b*h // A= 0.5*b*h A=0.5*h*(a +b)	C.G. of Panel From Its Base "c.g." (m) h / 3 // h / 2 ((2a+b)/(a+b))*(h/3)	C.G. BY HEIGHT	C.G. from Tower Base **"C.G."** (m) (+10 m)	check for Gt : C.G.	Gust Response Factor **Gt** α (Height & Terrain 2)	check for Gt
1	6	4.92	5.1	**27.85**	2.47	0.48	**12.47**	GO	**1.99**	OK
2	4.92	4.12	3.77	**17.04**	1.83	0.49	**16.93**	GO	**2.11**	OK
3	4.12	3.45	3.18	**12.04**	1.54	0.49	**20.41**	GO	**2.20**	OK
4	3.45	2.9	2.58	**8.19**	1.25	0.49	**23.30**	GO	**2.23**	OK
5	2.9	2.44	2.18	**5.82**	1.06	0.49	**25.69**	GO	**2.26**	OK
6	2.44	2	2.08	**4.62**	1.01	0.48	**27.82**	GO	**2.28**	OK
7	2	2	1.3	**2.6**	0.65	0.50	**29.54**	GO	**2.30**	OK
8	2	2	1.3	**2.6**	0.65	0.50	**30.84**	GO	**2.31**	OK
9	2	2	1.3	**2.6**	0.65	0.5	**32.14**	GO	**2.32**	OK
10	2	2	1.3	**2.6**	0.65	0.5	**33.44**	GO	**2.33**	OK
11	2	1.55	1.3	**2.31**	0.62	0.48	**34.71**	GO	**2.35**	OK
12	1.55	-	4.5	**3.49**	1.50	0.33	**36.89**	GO	**2.37**	OK
13	2	-	0.075	**0.15**	-	-	**28.89**	GO	**2.29**	OK
14	2	2	1.3	**2.6**	0.65	0.5	**29.54**	GO	**2.30**	OK
15	2	-	0.075	**0.15**	-	-	**34.09**	GO	**2.34**	OK
16	2	1.55	1.3	**2.31**	0.62	0.48	**34.71**	GO	**2.35**	OK
		Total Panel Height:			18.9		5.2	5.8	m	
		Total Height of Tower:			29.9	m				

WIND LOADING

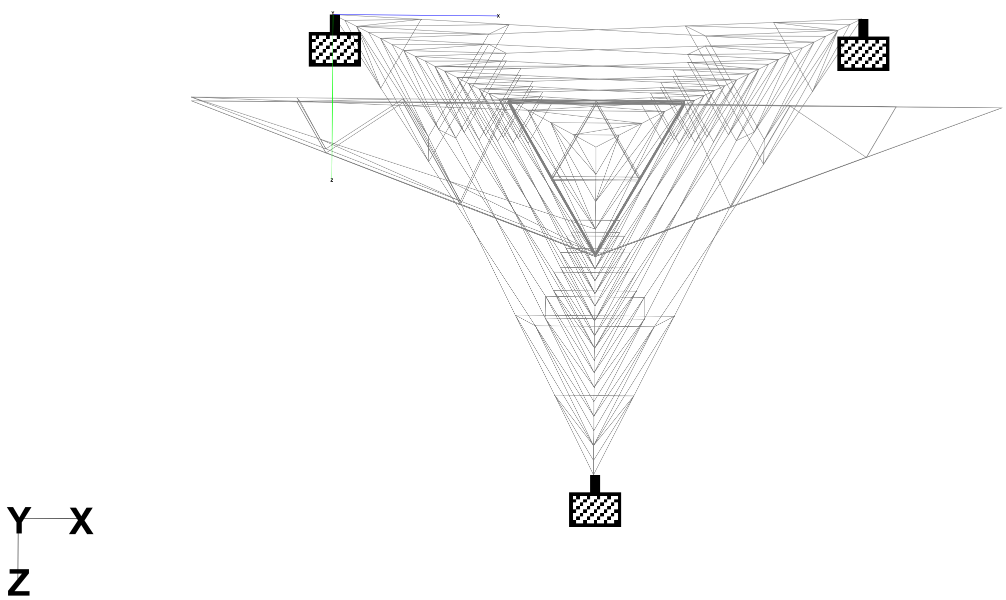
Panel No.	Area of Members	Area of Panel	Solidity Ratio	Check for Cd : Φ	Drag Coefficient	Check for Cd	Gust Response Factor	Wind Load	on Tower
- -	Ae	Ap	Φ		Cd		Gt	Wt=Pd*Gt*Cd*Ae	- -
	(m*m)	(m*m) Trap. & Rec. or Triang.	(Ae/Ap)		α (Φ)		α (Height & Terrain 2)	(kg)	(kg)
Design Wind Pressure:								Factor: 0.75	**Factor: 1.00**
Pd - Kg / (m*m)	71.45	α (R.Level 1	& Terrain 2	& W-Zone 4)					
1	2.61	27.85	0.09	GO	2.79	OK	1.99	777	**1037**
2	1.89	17.04	0.11	GO	2.73	OK	2.11	584	**779**
3	1.50	12.04	0.13	GO	2.67	OK	2.20	475	**633**
4	1.16	8.19	0.14	GO	2.60	OK	2.23	363	**483**
5	0.98	5.82	0.17	GO	2.49	OK	2.26	297	**396**
6	0.95	4.62	0.21	GO	2.35	OK	2.28	272	**363**
7	0.50	2.60	0.19	GO	2.40	OK	2.30	147	**197**
8	0.38	2.60	0.15	GO	2.58	OK	2.31	122	**163**
9	0.38	2.60	0.15	GO	2.58	OK	2.32	123	**164**
10	0.47	2.60	0.18	GO	2.44	OK	2.33	145	**193**
11	0.44	2.31	0.19	GO	2.41	OK	2.35	133	**178**
12	1.00	3.49	0.29	GO	2.09	OK	2.37	265	**354**
13	0.15	0.15	1.00	GO	1.42	OK	2.29	26	**35**
14	0.42	2.60	0.16	GO	2.53	OK	2.30	130	**173**
15	0.15	0.15	1.00	GO	1.42	OK	2.34	27	**36**
16	0.42	2.31	0.18	GO	2.45	OK	2.35	128	**171**
							check:	4015	5353

APPLICATION

Panel No.	Wind Load Factor: 0.75	Wind on Tower Factor: 1.00	Panel Distr.	Load Distr. Factor	Distributed Load Factor: 0.75	Distributed Load Factor: 1.00	-	-	Final Applied Load Factor: 0.75	Final Applied Load Factor: 1.00	-	-
12	265	354	Top	0.33	88	118	88	118	**88**	**118**	88	118
			Bottom	0.67	177	236	177	236	**-**	**-**	-	-
11	133	178	Top	0.48	64	85	125	167	**302**	**403**	76	101
			Bottom	0.52	69	93	163	217	**358**	**477**	89	119
15	27	36	Top	0.0	0	0	-	-	**-**	**-**	-	-
			Bottom	1.0	27	36	-	-	**-**	**-**	-	-
16	128	171	Top	0.48	61	82	-	-	**-**	**-**	-	-
			Bottom	0.52	67	89	-	-	**-**	**-**	-	-
10	145	193	Top	0.50	72	96	195	260	**-**	**-**	-	-
			Bottom	0.50	72	96	-	-	**-**	**-**	-	-
9	123	164	Top	0.50	62	82	-	-	**-**	**-**	-	-
			Bottom	0.50	62	82	-	-	**-**	**-**	-	-
8	122	163	Top	0.50	61	82	-	-	**-**	**-**	-	-
			Bottom	0.50	61	82	195	260	**-**	**-**	-	-
7	147	197	Top	0.50	74	98	139	185	**334**	**445**	83	111
			Bottom	0.50	74	98	165	220	**631**	**841**	158	210
13	26	35	Top	0	0	0	-	-	**-**	**-**	-	-
			Bottom	1.0	26	35	-	-	**-**	**-**	-	-
14	130	173	Top	0.50	65	87	-	-	**-**	**-**	-	-
			Bottom	0.50	65	87	-	-	**-**	**-**	-	-
6	272	363	Top	0.48	132	176	466	621	**-**	**-**	-	-
			Bottom	0.52	141	188	-	-	**-**	**-**	-	-
5	297	396	Top	0.49	144	192	-	-	**-**	**-**	-	-
			Bottom	0.51	153	203	-	-	**-**	**-**	-	-
4	363	483	Top	0.49	176	235	-	-	**-**	**-**	-	-
			Bottom	0.51	186	249	466	621	**-**	**-**	-	-
3	475	633	Top	0.49	230	307	918	1224	**1384**	**1845**	346	461
			Bottom	0.51	244	326	-	-	**-**	**-**	-	-
2	584	779	Top	0.49	284	378	-	-	**-**	**-**	-	-
			Bottom	0.51	301	401	-	-	**-**	**-**	-	-
1	777	1037	Top	0.48	376	501	-	-	**-**	**-**	-	-
			Bottom	0.52	402	535	918	1224	**918**	**1224**	230	306
Check:	4015	5353			4015	5353	4015	5353			4015	5353
								Check:	4015	5353		

(

APPENDIX B



TOP VIEW

TOWER-TYPE-"A"-TRIANGULAR BASE-220KV

```
**************************************************
*                                                *
*           STAAD.Pro                            *
*           Version  2004    Bld 1001.INDIA      *
*           Proprietary Program of               *
*           Research Engineers,  Intl.           *
*           Date=    JUL  5, 2005                *
*           Time=    15:50:11                    *
*                                                *
*     USER ID: AMAN (D.C.E.)                     *
**************************************************
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INPUT FILE: Structure2-Suspension.STD

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1. STAAD SPACE TOWER-TYPE-"A"-TRIANGULAR BASE-220KV
2. START JOB INFORMATION
3. ENGINEER DATE 18-MAY-05
4. END JOB INFORMATION
5. INPUT WIDTH 79
6. UNIT METER KG

7. JOINT COORDINATES
8. 1 0 0 0; 2 6 0 0; 4 3 0 5.196; 19 3 18.9 2.882; 20 2.00053 18.9 1.15497
9. 21 3.99947 18.9 1.15497; 22 3 24.1 2.882; 23 2.00053 24.1 1.15497
10. 24 3.99947 24.1 1.15497; 31 -1.59947 24.1 1.15497; 32 7.59947 18.9 1.15497
11. 33 -1.59947 18.9 1.15497; 34 3 20.2 2.882; 35 2.00053 20.2 1.15497
12. 36 3.99947 20.2 1.15497; 61 3 22.8 2.882; 62 3 21.5 2.882
13. 63 2.00053 22.8 1.15497; 64 2.00053 21.5 1.15497; 65 3.99947 22.8 1.15497
14. 66 3.99947 21.5 1.15497; 80 3 18.9 1.15497; 81 3.49973 18.9 2.01849
15. 82 2.50027 18.9 2.01849; 83 4.22011 16.8155 1.02759
16. 84 4.45126 14.6318 0.89414; 85 4.72443 12.051 0.736429
17. 86 5.06064 8.8746 0.542323; 87 5.45989 5.10267 0.311822
18. 88 1.77989 16.8155 1.02759; 89 1.54874 14.6318 0.89414
19. 90 1.27557 12.051 0.736429; 91 0.93936 8.8746 0.542323
20. 92 0.540108 5.10267 0.311822; 93 3 16.8156 3.13721; 94 3 14.6319 3.40456
21. 95 3 12.0511 3.72053; 96 3 8.87486 4.10942; 97 3 5.10302 4.57122
22. 107 1.46684 24.1 2.30632; 108 -0.0663135 24.1 1.73065
23. 109 0.80053 24.1 1.15497; 110 -0.39947 24.1 1.15497; 113 4.53316 18.9
2.30632
24. 114 6.06631 18.9 1.73065; 115 5.19947 18.9 1.15497; 116 6.39947 18.9 1.15497
25. 117 4.53316 19.7667 2.30632; 118 6.06631 19.3333 1.73065
26. 119 5.19947 19.7667 1.15497; 120 6.39947 19.3333 1.15497
27. 121 1.46684 18.9 2.30632; 122 -0.0663135 18.9 1.73065
28. 123 0.80053 18.9 1.15497; 124 -0.39947 18.9 1.15497
29. 125 1.46684 19.7667 2.30632; 126 -0.0663135 19.3333 1.73065
30. 127 0.80053 19.7667 1.15497; 128 -0.39947 19.3333 1.15497
31. 142 4.10979 17.8577 1.09128; 143 1.89021 17.8577 1.09128; 144 3 17.8578
3.0096
32. 145 3 2.80372 0.171334; 146 4.35179 2.80408 2.51199
33. 147 1.64847 2.80406 2.51184; 148 3 7.1552 0.437251
34. 149 4.12119 7.15554 2.37852; 150 1.87858 7.15555 2.37865
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35. 151 2.0611 10.6042 2.27294; 152 3.93866 10.6041 2.2728; 153 3 10.6039 0.647997
36. 154 3.78793 13.4526 2.18543; 155 3 13.4524 0.822068
37. 156 2.21184 13.4526 2.18556; 157 2.33705 15.8184 2.11302
38. 158 3 15.8181 0.966639; 159 3.66273 15.8184 2.1129
39. 160 2.45048 17.9616 2.04735; 161 3 17.9614 1.09761
40. 162 3.54926 17.9616 2.04719; 163 3 20.85 1.15497; 164 2.50027 20.85 2.01849
41. 165 3.49974 20.85 2.01849; 166 2.50027 22.15 2.01849
42. 167 3.49974 22.15 2.01849; 168 3 22.15 1.15497; 169 3.49973 23.45 2.01849
43. 170 3 23.45 1.15497; 171 2.50026 23.45 2.01848; 175 1.66431 15.7236 0.960865
44. 176 3 15.7237 3.27088; 177 4.33568 15.7236 0.960865; 178 3 13.3415 3.56255
45. 179 4.58784 13.3414 0.815284; 180 1.41216 13.3414 0.815284
46. 190 3 19.55 1.15497; 191 2.50026 19.55 2.01848; 192 3.49974 19.55 2.01848
47. 193 1.09429 3.95337 1.41183; 194 2.32423 3.95354 3.54153
48. 195 3.67589 3.95355 3.5416; 196 4.90584 3.95338 1.41191
49. 197 4.22995 3.9532 0.241578; 198 1.77005 3.9532 0.241578
50. 199 4 1.86915 0.114223; 200 5 0.934573 0.0571113; 201 2 1.86915 0.114223
51. 202 1 0.934573 0.0571113; 203 1.09898 1.86937 1.67456
52. 204 0.54949 0.934687 0.83728; 205 2.09898 1.86937 3.40656
53. 206 2.54949 0.934687 4.30128; 207 3.90119 1.86939 3.40666
54. 208 3.4506 0.934693 4.30133; 209 4.90119 1.86939 1.67466
55. 210 5.4506 0.934693 0.83733; 211 5.59492 3.827 0.233866
56. 212 5.72995 2.55134 0.155911; 213 5.86497 1.27567 0.0779555
57. 214 0.405081 3.827 0.233866; 215 0.270054 2.55134 0.155911
58. 216 0.135027 1.27567 0.0779555; 217 3 3.82727 4.72742; 218 3 2.55151 4.88361
59. 219 3 1.27576 5.0398; 220 0.806276 7.61729 0.465489
60. 221 0.673192 6.35998 0.388656; 222 3 7.61758 4.26335; 223 3 6.3603 4.41729
61. 224 5.19372 7.61729 0.465489; 225 5.32681 6.35998 0.388656
62. 226 1.96968 8.0149 0.489787; 227 1.20934 6.12911 1.34524
63. 228 1.40897 8.01508 1.46049; 229 1.77005 6.12893 0.374537
64. 230 2.43929 8.01521 3.24403; 231 2.43929 6.12928 3.47494
65. 232 4.03032 8.0149 0.489787; 233 4.22995 6.12893 0.374537
66. 234 4.79054 6.12911 1.34517; 235 4.59091 8.01507 1.46042
67. 236 3.5606 6.12928 3.47487; 237 3.5606 8.0152 3.24397
68. 238 4.8365 10.9922 0.671727; 239 4.94857 9.9334 0.607025
69. 240 1.1635 10.9922 0.671727; 241 1.05143 9.9334 0.607025
70. 242 3 10.9924 3.85016; 243 3 9.93361 3.97979; 244 3.86222 11.3274 0.692213
71. 245 4.03032 9.73925 0.59516; 246 4.49965 9.73935 1.40756
72. 247 1.96968 9.73925 0.59516; 248 2.13778 11.3274 0.692213
73. 249 4.33154 11.3275 1.50461; 250 3.46933 11.3276 2.99667
74. 251 3.46933 9.73948 3.19111; 252 2.53055 11.3277 2.99674
75. 253 2.53055 9.73953 3.19118; 254 1.50023 9.7394 1.40763
76. 255 1.66833 11.3276 1.50468; 256 3.39397 14.0422 2.795
77. 257 3.39397 12.7519 2.95298; 258 2.60592 12.7519 2.95304
78. 259 2.60592 14.0422 2.79506; 260 2.13778 12.7517 0.779248
79. 261 2.27437 14.0421 0.858104; 262 3.86222 12.7517 0.779248
80. 263 3.72563 14.0421 0.858104; 264 1.88029 14.0422 1.53985
81. 265 1.74371 12.7518 1.46099; 266 4.25618 12.7518 1.46093
82. 267 4.1196 14.0422 1.53979; 268 3.33137 16.317 2.62505
83. 269 3.61005 16.3168 0.997115; 270 3.94142 16.3169 1.57025
84. 271 3.72563 15.2249 0.93039; 272 4.05699 15.2251 1.50352
85. 273 3.33137 15.2252 2.75873; 274 2.27437 15.2249 0.93039
86. 275 2.38995 16.3168 0.997115; 276 1.94289 15.2251 1.50358
87. 277 2.05847 16.3169 1.5703; 278 2.66852 16.317 2.62511
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89. 281 2.2255 18.4308 1.60116; 282 2.11519 17.3885 1.53747
90. 283 2.72524 18.4308 2.46467; 284 2.38995 17.3885 1.0626
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92. 287 2.50027 18.4307 1.12629; 288 3.88469 17.3885 1.53739
93. 289 3.27463 18.4308 2.46459; 290 3.27463 17.3886 2.5922
94. 291 3.77436 18.4308 1.60108; 292 3 20.2 1.15497; 293 3.49973 20.2 2.01849
95. 294 2.50027 20.2 2.01849; 299 3 29.9 1.73175; 304 2.22455 25.4 1.28428
96. 305 3 25.4 2.62421; 306 3.77545 25.4 1.28425; 307 3 24.832 1.22777
97. 308 3.43666 24.832 1.9823; 309 2.56334 24.832 1.98231
98. 310 2.48303 26.9 1.43344; 311 2.74152 28.4 1.58259; 312 3 26.9 2.32672
99. 313 3 28.4 2.02924; 314 3.51697 26.9 1.43342; 315 3.25848 28.4 1.58258
100. 316 0.871868 24.9401 1.23853; 317 1.3413 24.9312 2.09435
101. 318 -0.363801 24.5201 1.19675; 319 -0.129078 24.5156 1.62467
102. 320 3.49973 24.1 2.01849; 321 3 24.1 1.15497; 322 2.50027 24.1 2.01849

103. MEMBER INCIDENCES
104. 1000 87 211; 1001 92 214; 1002 97 217; 1003 211 212; 1004 212 213; 1005 213
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105. 1006 214 215; 1007 215 216; 1008 216 1; 1009 217 218; 1010 218 219; 1011
219 4
106. 1020 87 196; 1021 97 195; 1022 92 198; 1023 87 197; 1024 97 194; 1025 92
193
107. 1026 145 199; 1027 145 201; 1028 146 207; 1029 146 209; 1030 147 203
108. 1031 147 205; 1032 193 147; 1033 194 147; 1034 195 146; 1035 196 146
109. 1036 197 145; 1037 198 145; 1038 199 200; 1039 200 2; 1040 201 202; 1041
202 1
110. 1042 203 204; 1043 204 1; 1044 205 206; 1045 206 4; 1047 208 4; 1048 209
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114. 1074 198 193; 1075 215 202; 1076 197 199; 1077 199 212; 1078 197 212
115. 1079 197 211; 1080 212 200; 1081 200 213; 1082 194 205; 1083 205 218
116. 1084 194 218; 1085 217 194; 1086 218 206; 1087 206 219; 1088 195 207
117. 1089 218 208; 1090 208 219; 1091 207 218; 1092 195 218; 1093 195 217
118. 1094 196 209; 1095 212 210; 1096 210 213; 1097 209 212; 1098 196 212
119. 1099 196 211; 1100 210 200; 1101 209 199; 1102 196 197; 1103 207 205
120. 1104 208 206; 1105 194 195; 2000 86 224; 2001 91 220; 2002 96 222
121. 2003 220 221; 2004 221 92; 2005 222 223; 2006 223 97; 2007 224 225
122. 2008 225 87; 2020 86 232; 2021 91 226; 2022 91 228; 2023 96 230; 2024 96
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123. 2025 86 235; 2026 148 229; 2027 148 233; 2028 149 234; 2029 149 236
124. 2030 150 231; 2031 150 227; 2032 226 148; 2033 227 92; 2034 228 150
125. 2035 229 92; 2036 230 150; 2037 231 97; 2038 232 148; 2039 233 87; 2040 234
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126. 2041 235 149; 2042 236 97; 2043 237 149; 2060 228 227; 2061 227 221
127. 2062 228 220; 2063 230 231; 2064 231 223; 2065 230 222; 2066 237 222
128. 2067 236 223; 2068 237 236; 2069 235 234; 2070 235 224; 2071 234 225
129. 2072 237 230; 2073 236 231; 2074 226 229; 2075 229 221; 2076 226 220
130. 2077 232 224; 2078 233 225; 2079 233 234; 2080 232 235; 2081 226 228
131. 2082 229 227; 2083 232 233; 2084 222 236; 2085 231 222; 2086 224 233
132. 2087 224 234; 2088 220 229; 2089 220 227; 3000 85 238; 3001 90 240
133. 3002 95 242; 3003 238 239; 3004 239 86; 3005 240 241; 3006 241 91
134. 3007 242 243; 3008 243 96; 3020 95 250; 3021 85 249; 3022 90 255; 3023 95
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135. 3024 85 244; 3025 90 248; 3026 151 253; 3027 151 254; 3028 152 246
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138. 3039 251 96; 3040 252 151; 3041 253 96; 3042 254 91; 3043 255 151
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146. 4020 84 263; 4021 89 261; 4022 89 264; 4023 94 259; 4024 94 256; 4025 84 267
147. 4026 154 266; 4027 154 257; 4028 155 260; 4029 155 262; 4030 156 258
148. 4031 156 265; 4032 256 154; 4033 257 95; 4034 258 95; 4035 259 156
149. 4036 260 90; 4037 261 155; 4038 262 85; 4039 263 155; 4040 264 156
150. 4041 265 90; 4042 266 85; 4043 267 154; 4060 154 178; 4061 156 178
151. 4062 154 179; 4063 155 179; 4064 155 180; 4065 156 180; 4066 180 261
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160. 5040 276 89; 5041 277 157; 5042 278 157; 5043 279 94; 5060 159 176
161. 5061 157 176; 5062 158 175; 5063 158 177; 5064 157 175; 5065 159 177
162. 5066 175 277; 5067 175 275; 5068 175 276; 5069 175 274; 5070 176 279
163. 5071 176 273; 5072 176 278; 5073 176 268; 5074 177 269; 5075 177 270
164. 5076 177 271; 5077 177 272; 5078 272 271; 5079 276 274; 5080 273 279
165. 5081 268 278; 5082 270 269; 5083 277 275; 6000 20 143; 6001 19 144
166. 6002 21 142; 6003 142 83; 6004 143 88; 6005 144 93; 6020 21 286; 6021 20 287
167. 6022 20 281; 6023 19 283; 6024 19 289; 6025 21 291; 6026 160 280; 6027 160 282
168. 6028 161 284; 6029 161 285; 6030 162 288; 6031 162 290; 6032 280 93
169. 6033 281 160; 6034 282 88; 6035 283 160; 6036 284 88; 6037 285 83
170. 6038 286 161; 6039 287 161; 6040 288 83; 6041 289 162; 6042 290 93
171. 6043 291 162; 6050 20 80; 6051 21 81; 6052 20 82; 6053 80 21; 6054 81 19
172. 6055 82 19; 6060 162 144; 6061 162 142; 6062 161 142; 6063 161 143
173. 6064 160 143; 6065 160 144; 6066 283 144; 6067 290 144; 6068 143 282
174. 6069 143 281; 6070 143 287; 6071 143 284; 6072 142 286; 6073 142 285
175. 6074 142 288; 6075 142 291; 6076 291 286; 6077 288 285; 6078 282 284
176. 6079 144 280; 6080 289 144; 6081 283 289; 6082 280 290; 6083 281 287
177. 6085 82 81; 6086 81 80; 6087 80 82; 7000 34 19; 7001 35 20; 7002 36 21
178. 7020 34 192; 7021 36 192; 7022 19 191; 7023 34 191; 7024 36 190; 7025 35 190
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181. 7060 292 293; 7061 294 293; 7062 292 294; 8000 62 34; 8001 64 35; 8002 66
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182. 8020 36 163; 8021 66 163; 8022 34 164; 8023 62 164; 8024 36 165; 8025 66
165
183. 8026 163 64; 8027 163 35; 8028 164 64; 8029 164 35; 8030 165 62; 8031 165
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184. 9000 61 62; 9001 63 64; 9002 65 66; 9020 65 167; 9021 61 167; 9022 66 168
185. 9023 65 168; 9024 62 166; 9025 61 166; 9026 166 63; 9027 166 64; 9028 167
62
186. 9029 167 66; 9030 168 63; 9031 168 64; 10000 24 65; 10001 23 63; 10002 22
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187. 10020 24 169; 10021 22 169; 10022 65 170; 10023 24 170; 10024 22 171
188. 10025 23 171; 10026 169 61; 10027 169 65; 10028 170 23; 10029 170 63
189. 10030 171 63; 10031 171 61; 10050 24 321; 10051 22 322; 10052 24 320
190. 10053 322 23; 10054 320 22; 10055 321 23; 10060 321 320; 10061 321 322
191. 10062 322 320; 11000 24 306; 11001 305 22; 11002 304 23; 11020 22 309
192. 11021 305 309; 11022 24 308; 11023 306 308; 11024 23 307; 11025 304 307
193. 11026 307 306; 11027 307 24; 11028 308 305; 11029 308 22; 11030 309 304
194. 11031 309 23; 11050 306 304; 11051 304 305; 11052 305 306; 12000 304 310
195. 12001 305 312; 12002 306 314; 12003 310 311; 12004 311 299; 12005 312 313
196. 12006 313 299; 12007 314 315; 12008 315 299; 12060 312 314; 12061 312 310
197. 12062 314 310; 12063 313 315; 12064 313 311; 12065 315 311; 12066 304 314
198. 12067 314 311; 12068 305 310; 12069 310 313; 12070 306 312; 12071 312 315
199. 13000 21 115; 13001 19 113; 13002 20 123; 13003 19 121; 13004 113 114
200. 13005 114 32; 13006 115 116; 13007 116 32; 13008 121 122; 13009 122 33
201. 13010 123 124; 13011 124 33; 13020 36 119; 13021 35 127; 13022 34 125
202. 13023 34 117; 13024 117 118; 13025 118 32; 13026 119 120; 13027 120 32
203. 13028 125 126; 13029 126 33; 13030 127 128; 13031 128 33; 13060 117 113
204. 13061 119 117; 13062 113 115; 13063 119 115; 13064 120 118; 13065 118 114
205. 13066 120 116; 13067 116 114; 13068 113 118; 13069 115 120; 13070 19 117
206. 13071 21 119; 13072 127 125; 13073 125 121; 13074 121 123; 13075 123 127
207. 13076 122 124; 13077 124 128; 13078 128 126; 13079 126 122; 13080 126 121
208. 13081 128 123; 13082 125 19; 13083 127 20; 13084 20 121; 13085 123 122
209. 13086 21 113; 13087 115 114; 14000 109 23; 14001 107 22; 14002 107 108
210. 14003 108 31; 14004 109 110; 14005 110 31; 14020 31 319; 14021 31 318
211. 14022 316 304; 14023 318 316; 14024 319 317; 14025 317 305; 14060 107 317
212. 14061 109 316; 14062 109 107; 14063 110 108; 14064 108 319; 14065 109 108
213. 14066 317 316; 14067 318 110; 14068 318 319; 14069 23 107; 14070 319 107
214. 14071 318 109; 14072 317 22; 14073 316 23

215. *00-19: LEG           ....    00-19:LOWER MEMBER-C.A.
216. *20-39; 59: BRACING   ....     20-39:UPPER MEMBER-C.A.
217. *50-59: HORIZONTAL   ....
218. *60-99: REDUNDANT    ....    60-99:REDUNDANT-C.A.

219. DEFINE MATERIAL START
220. ISOTROPIC STEEL
221. E 2.05E+010
222. POISSON 0.3
223. DENSITY 7850
224. ALPHA 1.2E-005
225. DAMP 0.03
226. END DEFINE MATERIAL
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227. MEMBER PROPERTY INDIAN
228. *LEG:
229. 1000 TO 1011 2000 TO 2008 TABLE ST ISA100X100X8
230. 3000 TO 3008 4000 TO 4005 TABLE ST ISA90X90X8
231. 5000 TO 5005 TABLE ST ISA90X90X6
232. 6000 TO 6005 7000 TO 7002 TABLE ST ISA75X75X6
233. 8000 TO 8002 9000 TO 9002 10000 TO 10002 11000 TO 11002 12000 TO 12007 -
234. 12008 TABLE ST ISA65X65X5
235. *BRACING:
236. 1020 TO 1045 1047 TO 1050 4020 TO 4043 5020 TO 5043 7020 TO 7031 8020 TO
8031-
237. 9020 TO 9031 10020 TO 10031 11020 TO 11031 3020 TO 3043 TABLE ST ISA45X45X4
238. 2020 TO 2043  6020 TO 6043 TABLE ST ISA50X50X4
239. *HORIZONTAL
240. 7050 TO 7055 10050 TO 10055 TABLE ST ISA45X45X4
241. 6050 TO 6055 11050 TO 11052 TABLE ST ISA50X50X4
242. *REDUNDANT
243. 1064 1071 1072 1074  1081  1087 1090 1096 1100 1102 1104 1105 2062 2065
2066 -
244. 2070 2072 2073 2076 2077 2079 TO 2082 3060 3062 3064 TO 3067 3074 TO 3076 -
245. 3079 TO 3087 4066 TO 4083 5066 TO 5083 6066 TO 6083 6085 TO 6087 -
246. 7060 TO 7062 10060 TO 10062 12063 TO 12065 TABLE ST ISA45X30X4
247. 1061 TO 1063 1066 TO 1068 1070 1073 1075 TO 1078 1080 1082 TO 1084 1086
1088 -
248. 1089 1091 1092 1094 1095 1097 1098 1101 1103 2060 2063 2068 2069 2074 2083
-
249. 2084 TO 2089 5060 TO 5065 6060 TO 6065 12060 TO 12062 12066 TO 12071 -
250. 1065 1069 1079 1085 1093 1099 2061 2064 2067 2071 2075 2078 -
251. 3063 3069 3077 3078 3088 3089 TABLE ST ISA45X45X4
252. 3061 3068 3070 TO 3073 4060 TO 4065 TABLE ST ISA55X55X5
253. *CROSSARM:
254. *LOWER MEMBER
255. 13001 13003 TO 13005 13008 13009 14001 TO 14003 TABLE ST ISA75X75X6
256. 13000 13002 13006 13007 13010 13011 14000 14004 14005 TABLE ST ISA65X65X5
257. *UPPER MEMBER
258. 13020 TO 13031 14020 TO 14025 TABLE ST ISA50X50X4
259. *REDUNDANT
260. 13060 TO 13067 13069 13071 TO 13079 13081 13083 TO 13087 14060 TO 14069
14071-
261. 14073 TABLE ST ISA45X30X4
262. 13068 13070 13080 13082 14070 14072 TABLE ST ISA45X45X4

263. CONSTANTS
264. MATERIAL STEEL MEMB 1000 TO 1011 1020 TO 1045 1047 TO 1050 1061 TO 1105
2000 -
265. 2001 TO 2008 2020 TO 2043 2060 TO 2089 3000 TO 3008 3020 TO 3043 3060 TO
3089-
266. 4000 TO 4005 4020 TO 4043 4060 TO 4083 5000 TO 5005 5020 TO 5043 -
267. 5060 TO 5083 6000 TO 6005 6020 TO 6043 6050 TO 6055 6060 TO 6083 -
268. 6085 TO 6087 7000 TO 7002 7020 TO 7031 7050 TO 7055 7060 TO 7062 -
269. 8000 TO 8002 8020 TO 8031 9000 TO 9002 9020 TO 9031 10000 TO 10002 10020 -
270. 10021 TO 10031 10050 TO 10055 11000 TO 11002 11020 TO 11031 11050 TO 11052
-
271. 12000 TO 12008 12060 TO 12071 13000 TO 13011 13020 TO 13031 13060 TO 13087
-
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272. 14000 TO 14005 14020 TO 14025 14060 TO 14073 10060 TO 10062

273. SUPPORTS
274. 1 2 4 FIXED

275. LOAD 1 RELIABILITY CONDITION
276. SELFWEIGHT Y -1
277. JOINT LOAD
278. 299 FX 806 FY -311
279. 31 FX 1766 FY -1051
280. 32 FX 1766 FY -1051
281. 33 FX 1766 FY -1051
282. 299 FX 118
283. 304 TO 306 FX 101
284. 22 TO 24 FX 119
285. 34 TO 36 FX 111
286. 19 TO 21 FX 210
287. 85 90 95 FX 461
288. 1 2 4 FX 306
289. LOAD 2 SECURITY- NORMAL CONDITION
290. SELFWEIGHT Y -1
291. JOINT LOAD
292. 299 FX 614 FY -311
293. 32 FX 1247 FY -1051
294. 31 FX 1247 FY -1051
295. 33 FX 1247 FY -1051
296. 299 FX 88
297. 304 TO 306 FX 76
298. 22 TO 24 FX 89
299. 34 TO 36 FX 83
300. 19 TO 21 FX 158
301. 85 90 95 FX 346
302. 1 2 4 FX 230
303. LOAD 3 SECURITY- GROUND WIRE BROKEN CONDITION
304. SELFWEIGHT Y -1
305. JOINT LOAD
306. 299 FX 359 FY -189 FZ 1328
307. 31 FX 1247 FY -1051
308. 32 FX 1247 FY -1051
309. 33 FX 1247 FY -1051
310. 299 FX 88
311. 304 TO 306 FX 76
312. 22 TO 24 FX 89
313. 34 TO 36 FX 83
314. 19 TO 21 FX 158
315. 85 90 95 FX 346
316. 1 2 4 FX 230
317. LOAD 4 SECURITY- TOP CONDUCTOR BROKEN CONDITION
318. SELFWEIGHT Y -1
319. JOINT LOAD
320. 299 FX 614 FY -311
321. 32 FX 1247 FY -1051
322. 31 FX 755 FY -711 FZ 1661
323. 33 FX 1247 FY -1051
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324. 299 FX 88
325. 304 TO 306 FX 76
326. 22 TO 24 FX 89
327. 34 TO 36 FX 83
328. 19 TO 21 FX 158
329. 85 90 95 FX 346
330. 1 2 4 FX 230
331. LOAD 5 SECURITY- BOTTOM LEFT CONDUCTOR BROKEN CONDITION
332. SELFWEIGHT Y -1
333. JOINT LOAD
334. 299 FX 614 FY -311
335. 31 FX 1247 FY -1051
336. 32 FX 755 FY -711 FZ 1661
337. 33 FX 1247 FY -1051
338. 299 FX 88
339. 304 TO 306 FX 76
340. 22 TO 24 FX 89
341. 34 TO 36 FX 83
342. 19 TO 21 FX 158
343. 85 90 95 FX 346
344. 1 2 4 FX 230
345. LOAD 6 SECURITY- BOTTOM RIGHT CONDUCTOR BROKEN CONDITION
346. SELFWEIGHT Y -1
347. JOINT LOAD
348. 299 FX 614 FY -311
349. 31 FX 1247 FY -1051
350. 33 FX 755 FY -711 FZ 1661
351. 32 FX 1247 FY -1051
352. 299 FX 88
353. 304 TO 306 FX 76
354. 22 TO 24 FX 89
355. 34 TO 36 FX 83
356. 19 TO 21 FX 158
357. 85 90 95 FX 346
358. 1 2 4 FX 230
359. LOAD 7 SAFETY- NORMAL CONDITION
360. SELFWEIGHT Y -1
361. JOINT LOAD
362. 299 FX 46 FY -775
363. 31 FX 116 FY -2611
364. 32 FX 116 FY -2611
365. 33 FX 116 FY -2611
366. 299 FX 118
367. 304 TO 306 FX 101
368. 22 TO 24 FX 119
369. 34 TO 36 FX 111
370. 19 TO 21 FX 210
371. 85 90 95 FX 461
372. 1 2 4 FX 306
373. LOAD 8 SAFETY- GROUND WIRE BROKEN CONDITION
374. SELFWEIGHT Y -1
375. JOINT LOAD
376. 299 FX 23 FY -530 FZ 510
377. 31 FX 116 FY -2611
378. 32 FX 116 FY -2611
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379. 33 FX 116 FY -2611
380. 299 FX 118
381. 304 TO 306 FX 101
382. 22 TO 24 FX 119
383. 34 TO 36 FX 111
384. 19 TO 21 FX 210
385. 85 90 95 FX 461
386. 1 2 4 FX 306
387. LOAD 9 SAFETY- TOP CONDUCTOR BROKEN
388. SELFWEIGHT Y -1
389. JOINT LOAD
390. 299 FX 46 FY -775
391. 31 FX 29 FY -1930 FZ 1020
392. 32 FX 116 FY -2611
393. 33 FX 116 FY -2611
394. 299 FX 118
395. 304 TO 306 FX 101
396. 22 TO 24 FX 119
397. 34 TO 36 FX 111
398. 19 TO 21 FX 210
399. 85 90 95 FX 461
400. 1 2 4 FX 306
401. LOAD 10 SAFETY- BOTTOM LEFT CONDUCTOR BROKEN CONDITION
402. SELFWEIGHT Y -1
403. JOINT LOAD
404. 299 FX 46 FY -775
405. 32 FX 29 FY -1930 FZ 1020
406. 31 FX 116 FY -2611
407. 33 FX 116 FY -2611
408. 299 FX 118
409. 304 TO 306 FX 101
410. 22 TO 24 FX 119
411. 34 TO 36 FX 111
412. 19 TO 21 FX 210
413. 85 90 95 FX 461
414. 1 2 4 FX 306
415. LOAD 11 SAFETY- BOTTOM RIGHT CONDUCTOR BROKEN CONDITION
416. SELFWEIGHT Y -1
417. JOINT LOAD
418. 299 FX 46 FY -775
419. 33 FX 29 FY -1930 FZ 1020
420. 32 FX 116 FY -2611
421. 31 FX 116 FY -2611
422. 299 FX 118
423. 304 TO 306 FX 101
424. 22 TO 24 FX 119
425. 34 TO 36 FX 111
426. 19 TO 21 FX 210
427. 85 90 95 FX 461
428. 1 2 4 FX 306
429. LOAD 12 RELIABILITY CONDITION
430. SELFWEIGHT Y -1
431. JOINT LOAD
432. 299 FX 806 FY -122
433. 31 FX 1766 FY -474
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434. 32 FX 1766 FY -474
435. 33 FX 1766 FY -474
436. 299 FX 118
437. 304 TO 306 FX 101
438. 22 TO 24 FX 119
439. 34 TO 36 FX 111
440. 19 TO 21 FX 210
441. 85 90 95 FX 461
442. 1 2 4 FX 306
443. LOAD 13 SECURITY- NORMAL CONDITION
444. SELFWEIGHT Y -1
445. JOINT LOAD
446. 299 FX 614 FY -122
447. 33 FX 1247 FY -474
448. 31 FX 1247 FY -474
449. 32 FX 1247 FY -474
450. 299 FX 88
451. 304 TO 306 FX 76
452. 22 TO 24 FX 89
453. 34 TO 36 FX 83
454. 19 TO 21 FX 158
455. 85 90 95 FX 346
456. 1 2 4 FX 230
457. LOAD 14 SECURITY- GROUND WIRE BROKEN CONDITION
458. SELFWEIGHT Y -1
459. JOINT LOAD
460. 299 FX 359 FY -63 FZ 1328
461. 31 FX 1247 FY -474
462. 32 FX 1247 FY -474
463. 33 FX 1247 FY -474
464. 299 FX 88
465. 304 TO 306 FX 76
466. 22 TO 24 FX 89
467. 34 TO 36 FX 83
468. 19 TO 21 FX 158
469. 85 90 95 FX 346
470. 1 2 4 FX 230
471. LOAD 15 SECURITY- TOP CONDUCTOR BROKEN CONDITION
472. SELFWEIGHT Y -1
473. JOINT LOAD
474. 299 FX 614 FY -122
475. 33 FX 1247 FY -474
476. 31 FX 755 FY -312 FZ 1661
477. 32 FX 1247 FY -474
478. 299 FX 88
479. 304 TO 306 FX 76
480. 22 TO 24 FX 89
481. 34 TO 36 FX 83
482. 19 TO 21 FX 158
483. 85 90 95 FX 346
484. 1 2 4 FX 230
485. LOAD 16 SECURITY- BOTTOM LEFT CONDUCTOR BROKEN CONDITION
486. SELFWEIGHT Y -1
487. JOINT LOAD
488. 299 FX 614 FY -122
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489. 31 FX 1247 FY -474
490. 32 FX 755 FY -312 FZ 1661
491. 33 FX 1247 FY -474
492. 299 FX 88
493. 304 TO 306 FX 76
494. 22 TO 24 FX 89
495. 34 TO 36 FX 83
496. 19 TO 21 FX 158
497. 85 90 95 FX 346
498. 1 2 4 FX 230
499. LOAD 17 SECURITY- BOTTOM RIGHT CONDUCTOR BROKEN CONDITION
500. SELFWEIGHT Y -1
501. JOINT LOAD
502. 299 FX 614 FY -122
503. 31 FX 1247 FY -474
504. 33 FX 755 FY -312 FZ 1661
505. 32 FX 1247 FY -474
506. 299 FX 88
507. 304 TO 306 FX 76
508. 22 TO 24 FX 89
509. 34 TO 36 FX 83
510. 19 TO 21 FX 158
511. 85 90 95 FX 346
512. 1 2 4 FX 230
513. LOAD 18 SAFETY- NORMAL CONDITION
514. SELFWEIGHT Y -1
515. JOINT LOAD
516. 299 FX 46 FY -396
517. 31 FX 116 FY -1101
518. 32 FX 116 FY -1101
519. 33 FX 116 FY -1101
520. 299 FX 118
521. 304 TO 306 FX 101
522. 22 TO 24 FX 119
523. 34 TO 36 FX 111
524. 19 TO 21 FX 210
525. 85 90 95 FX 461
526. 1 2 4 FX 306
527. LOAD 19 SAFETY- GROUND WIRE BROKEN CONDITION
528. SELFWEIGHT Y -1
529. JOINT LOAD
530. 299 FX 23 FY -280 FZ 510
531. 31 FX 116 FY -1101
532. 32 FX 116 FY -1101
533. 33 FX 116 FY -1101
534. 299 FX 118
535. 304 TO 306 FX 101
536. 22 TO 24 FX 119
537. 34 TO 36 FX 111
538. 19 TO 21 FX 210
539. 85 90 95 FX 461
540. 1 2 4 FX 306
541. LOAD 20 SAFETY- TOP CONDUCTOR BROKEN
542. SELFWEIGHT Y -1
543. JOINT LOAD
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544. 299 FX 46 FY -396
545. 31 FX 29 FY -1133 FZ 1020
546. 32 FX 116 FY -1101
547. 33 FX 116 FY -1101
548. 299 FX 118
549. 304 TO 306 FX 101
550. 22 TO 24 FX 119
551. 34 TO 36 FX 111
552. 19 TO 21 FX 210
553. 85 90 95 FX 461
554. 1 2 4 FX 306
555. LOAD 21 SAFETY- BOTTOM LEFT CONDUCTOR BROKEN CONDITION
556. SELFWEIGHT Y -1
557. JOINT LOAD
558. 299 FX 46 FY -396
559. 32 FX 29 FY -1133 FZ 1020
560. 33 FX 116 FY -1101
561. 31 FX 116 FY -1101
562. 299 FX 118
563. 304 TO 306 FX 101
564. 22 TO 24 FX 119
565. 34 TO 36 FX 111
566. 19 TO 21 FX 210
567. 85 90 95 FX 461
568. 1 2 4 FX 306
569. LOAD 22 SAFETY- BOTTOM RIGHT CONDUCTOR BROKEN CONDITION
570. SELFWEIGHT Y -1
571. JOINT LOAD
572. 299 FX 46 FY -396
573. 33 FX 29 FY -1133 FZ 1020
574. 32 FX 116 FY -1101
575. 31 FX 116 FY -1101
576. 299 FX 118
577. 304 TO 306 FX 101
578. 22 TO 24 FX 119
579. 34 TO 36 FX 111
580. 19 TO 21 FX 210
581. 85 90 95 FX 461
582. 1 2 4 FX 306

583. PERFORM ANALYSIS PRINT STATICS CHECK
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P R O B L E M   S T A T I S T I C S

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NUMBER OF JOINTS/MEMBER+ELEMENTS/SUPPORTS =   220/   579/     3

ORIGINAL/FINAL BAND-WIDTH=   213/    20/    126 DOF

TOTAL PRIMARY LOAD CASES =   22, TOTAL DEGREES OF FREEDOM =   1302
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TOWER-TYPE-"A"-TRIANGULAR BASE-220KV

SIZE OF STIFFNESS MATRIX = 165 DOUBLE KILO-WORDS

REQRD/AVAIL. DISK SPACE = 15.5/ 17768.8 MB, EXMEM = 690.7 MB

584. PRINT SUPPORT REACTION LIST 1 2 4

SUPPORT REACTIONS -UNIT KG METE STRUCTURE TYPE = SPACE

JOINT	***LOAD***	***FORCE-X***	***FORCE-Y***	***FORCE-Z***	***MOM-X***	***MOM-Y***	***MOM Z***
1	1	-4720.20	-28408.13	-2063.10	92.97	-9.67	-17.86
	2	-3366.32	-19799.48	-1460.65	65.33	-6.95	-10.34
	3	-3660.64	-22392.94	-1581.15	71.59	-7.46	-16.28
	4	-3225.36	-22070.00	-2271.89	-28.97	8.34	-72.85
	5	-3906.75	-21141.52	-1028.23	141.96	-18.85	31.13
	6	-3163.49	-21664.13	-2307.44	-36.63	9.50	-75.12
	7	-1587.22	-4416.00	-607.87	15.16	-2.73	13.03
	8	-1745.94	-5851.81	-681.97	18.21	-2.91	9.50
	9	-1638.98	-7221.60	-1177.96	-39.23	6.50	-28.88
	10	-2034.02	-5738.51	-382.29	65.53	-10.55	40.03
	11	-1594.78	-6785.40	-1194.91	-44.01	7.15	-29.27
	12	-4791.72	**-29588.03**	-2113.88	94.90	-9.59	-22.22
	13	-3437.84	-20979.38	-1511.42	67.27	-6.87	-14.71
	14	-3729.94	-23551.84	-1630.64	73.50	-7.38	-20.59
	15	-3287.42	-23043.84	-2314.81	-27.25	8.37	-76.28
	16	-3975.93	-22389.01	-1080.77	143.74	-18.70	26.17
	17	-3226.81	-22637.96	**-2349.82**	-34.89	9.54	-78.55
	18	-1770.32	-7465.25	-738.39	20.17	-2.52	1.70
	19	-1924.49	-8858.06	-809.87	23.14	-2.70	-1.71
	20	-1784.16	-9445.42	-1277.01	-35.09	6.54	-36.48
	21	-2207.72	-9058.48	-519.87	69.92	-10.08	26.36
	22	-1745.03	-9009.22	-1291.84	-39.80	7.18	-36.80
2	1	**-5167.17**	**32749.19**	2320.69	-103.11	-10.04	-30.64
	2	-3813.32	24140.54	1718.22	-75.47	-7.31	-23.13
	3	-3255.48	19002.99	1435.77	-65.57	-6.90	-9.92
	4	-2699.54	18437.87	1957.72	22.33	6.99	-61.99
	5	-3511.53	19176.25	666.51	-164.12	-22.19	41.67
	6	-2775.50	19698.87	1946.58	14.43	6.15	-64.50
	7	-2371.46	12707.50	1058.04	-35.22	-3.60	-9.86
	8	-2188.97	11042.22	969.33	-31.84	-3.43	-5.68
	9	-1789.59	10249.48	1259.57	22.31	5.09	-36.38
	10	-2274.74	9789.99	434.74	-92.04	-13.20	32.44
	11	-1836.65	10836.89	1247.59	17.50	4.49	-36.84
	12	-5112.74	32456.34	2299.52	-101.36	-9.77	-31.24
	13	-3758.89	23847.69	1697.05	-73.72	-7.04	-23.72
	14	-3203.27	18731.15	1415.88	-63.85	-6.63	-10.58
	15	-2649.30	18077.44	1935.28	23.92	7.19	-61.99

	16	-3465.31	19089.48	653.72	-162.57	-21.87	40.13
	17	-2723.41	19338.44	1923.64	16.02	6.36	-64.52
	18	-2233.10	11979.68	1004.98	-30.70	-2.89	-11.53
	19	-2055.15	10357.40	918.90	-27.39	-2.72	-7.46
	20	-1668.01	9250.95	1201.41	26.20	5.53	-35.64
	21	-2169.24	9887.60	415.27	-88.31	-12.31	26.98
	22	-1707.67	9838.35	1187.47	21.40	4.95	-36.17
4	1	-258.63	1640.31	-257.60	5.33	2.72	21.34
	2	-209.36	1640.31	-257.58	5.33	2.26	17.49
	3	-217.87	9249.32	-1182.63	29.62	2.37	17.97
	4	-972.10	9273.50	-1346.84	26.48	16.67	121.92

JOINT	***LOAD***	***FORCE-X***	***FORCE-Y***	***FORCE-Z***	***MOM-X***	***MOM-Y***	***MOM Z***
	5	521.28	7606.64	-1299.28	18.17	-11.79	-84.68
	6	-958.01	7606.63	-1300.15	18.16	16.34	119.73
	7	-477.32	2833.87	-450.17	8.15	5.20	36.93
	8	-478.08	5689.96	-797.37	17.27	5.21	36.97
	9	-920.43	7416.50	-1101.61	20.91	13.61	98.16
	10	-40.24	6392.89	-1072.45	15.80	-3.14	-23.89
	11	-917.57	6392.88	-1072.69	15.80	13.55	97.77
	12	-241.54	1193.06	-185.65	4.27	2.37	19.01
	13	-192.27	1193.06	-185.64	4.27	1.91	15.16
	14	-200.78	8823.06	-1113.25	28.63	2.02	15.65
	15	-960.28	8865.76	-1281.48	25.51	16.42	120.31
	16	544.23	7198.90	-1233.96	17.19	-12.25	-87.73
	17	-946.78	7198.89	-1234.83	17.18	16.10	118.13
	18	-432.59	1701.94	-266.60	5.50	4.28	30.84
	19	-433.35	4601.03	-619.04	14.75	4.29	30.89
	20	-896.82	6442.84	-944.40	18.60	13.12	94.95
	21	27.96	5419.24	-915.40	13.50	-4.50	-32.89
	22	-896.31	5419.24	-915.64	13.49	13.07	94.60

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585. *PRINT MEMBER FORCES LIST ALL

586. PRINT MAXFORCE ENVELOPE NSECTION 12 LIST 1000 TO 1011 2000 TO 2008 -
587. 3000 TO 3008 4000 TO 4005 5000 TO 5005 6000 TO 6005 7000 TO 7002 8000 TO
8002-
588. 9000 TO 9002 10000 TO 10002 11000 TO 11002 12000 TO 12007 12008 1020 TO
1045 -
589. 1047 TO 1050 2020 TO 2043 3020 TO 3043 4020 TO 4043 5020 TO 5043 6020 TO
6043-
590. 7020 TO 7031 8020 TO 8031 9020 TO 9031 10020 TO 10031 11020 TO 11031  -
591. 6050 TO 6055 7050 TO 7055 10050 TO 10055 11050 TO 11052 1061 TO 1105 -
592. 2060 TO 2089 3060 TO 3089 4060 TO 4083 5060 TO 5083 6060 TO 6083 -
593. 6085 6086 TO 6087 7060 TO 7062 10060 TO 10062 12060 TO 12071 -
594. 13000 TO 13011 14000 TO 14005 13020 TO 13031 14020 TO 14025 -
595. 13060 TO 13087 14060 TO 14073
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TOWER-TYPE-"A"-TRIANGULAR BASE-220KV

MAX AND MIN FORCE VALUES AMONGST ALL SECTION LOCATIONS

MEMB		***FY/ FZ***	***DIST DIST***	***LD LD***	***MZ/ MY***	***DIST DIST***	***LD LD***	***FX***	***DIST***	***LD***
1000	MAX	101.04	0.00	1	69.41	0.00	1			
		2.79	0.00	10	87.79	0.00	14	31134.54 C	1.29	1
	MIN	29.00	1.29	20	-59.24	1.29	1			
		-83.74	1.29	15	-23.00	1.29	15	8385.03 C	0.00	20
1001	MAX	-0.74	0.00	7	52.18	1.29	12			
		9.08	0.00	10	83.89	0.00	1	3500.48 T	1.29	7
	MIN	-84.39	1.29	12	-55.07	0.00	12			
		-58.51	1.29	1	-21.52	1.29	6	**28246.75 T**	0.00	**12**
1002	MAX	33.36	0.00	3	24.53	0.00	3			
		135.63	0.00	12	33.24	1.29	16	9116.46 C	1.29	3
	MIN	5.24	1.29	13	-17.21	1.29	4			
		10.75	1.29	9	-161.45	0.00	12	1025.38 C	0.00	12
1003	MAX	-19.47	0.00	20	38.66	1.29	1			
		23.32	0.00	15	34.17	0.00	5	31113.31 C	1.29	1
	MIN	-76.44	1.29	1	-58.38	0.00	1			
		-40.06	1.29	5	-22.76	0.00	15	8393.51 C	0.00	20
1004	MAX	84.63	0.00	1	40.81	0.00	1			
		10.78	0.00	15	21.11	1.29	15	31094.63 C	1.29	1
	MIN	21.82	1.29	20	-66.74	1.29	1			
		-29.53	1.29	5	-54.04	1.29	5	8443.59 C	0.00	20
1005	MAX	-23.32	0.00	20	68.51	1.29	1			
		167.60	0.00	5	160.93	1.29	5	**31174.30 C**	1.29	**1**
	MIN	-105.36	1.29	1	-65.68	0.00	1			
		-56.17	1.29	15	-54.47	0.00	5	8476.60 C	0.00	20
1006	MAX	71.41	0.00	12	53.38	0.00	12			
		23.13	0.00	6	32.44	0.00	5	3477.24 T	1.29	7
	MIN	8.95	1.29	7	-37.19	1.29	12			
		-37.09	1.29	5	-21.34	0.00	6	28189.93 T	0.00	12
1007	MAX	-2.92	0.00	7	58.77	1.29	12			
		13.57	0.00	17	25.61	1.29	17	3415.92 T	1.29	7
	MIN	-72.77	1.29	12	-33.55	0.00	12			
		-25.60	1.29	5	-47.29	1.29	5	28049.82 T	0.00	12
1008	MAX	92.66	0.00	12	58.37	0.00	12			
		143.52	0.00	5	136.78	1.29	5	3400.93 T	1.29	7
	MIN	-1.48	1.29	7	-59.50	1.29	12			
		-73.42	1.29	17	-68.55	1.29	17	28087.50 T	0.00	12
1009	MAX	-0.39	0.00	13	10.25	1.29	3			
		25.74	0.00	9	32.92	0.00	16	9124.21 C	1.29	3
	MIN	-21.52	1.29	3	-16.25	0.00	4			
		-34.74	1.29	16	-22.68	0.00	9	1043.92 C	0.00	12

1010	MAX	28.40	0.00	3	13.09	0.00	3				
		21.59	0.00	4	38.78	1.29	4	9156.39	C	1.29	3
	MIN	3.72	1.29	12	-22.20	1.29	3				
		-18.38	1.29	16	-35.34	1.29	16	1105.80	C	0.00	12
1011	MAX	-3.57	0.00	12	25.77	1.29	3				
		94.92	0.00	16	86.39	1.29	16	9194.40	C	1.29	3
	MIN	-37.99	1.29	3	-21.84	0.00	3				
		-124.06	1.29	4	-120.36	1.29	4	1125.82	C	0.00	12
2000	MAX	23.67	0.00	12	20.58	0.00	12				
		4.73	0.00	16	35.53	1.27	16	**28468.19**	**C**	1.27	**1**
	MIN	2.89	1.27	9	-8.22	1.27	12				
		-17.19	1.27	9	-12.74	1.27	4	6974.01	C	0.00	20
2001	MAX	-2.74	0.00	10	7.82	1.27	1				
		4.47	0.00	5	30.77	1.27	5	1978.50	T	1.27	7
	MIN	-21.44	1.27	12	-18.31	0.00	12				
		-7.33	1.27	17	-16.55	1.27	17	**25906.20**	**T**	0.00	**12**
2002	MAX	8.78	0.00	14	8.26	0.00	14				
		18.63	0.00	21	23.09	1.27	16	9081.16	C	1.27	3
	MIN	-0.18	1.27	7	-2.06	1.27	17				
		-3.94	1.27	17	-26.67	1.27	4	880.04	C	0.00	13
2003	MAX	5.47	0.00	7	37.88	1.27	12				
		25.35	0.00	17	29.89	0.00	5	1937.86	T	1.27	7
	MIN	-26.50	1.27	12	-1.54	1.27	7				
		-63.82	1.27	5	-50.96	1.27	5	25793.72	T	0.00	12
2004	MAX	75.55	0.00	12	39.12	0.00	12				
		98.15	0.00	1	84.89	1.27	1	1919.14	T	1.27	7
	MIN	-3.44	1.27	7	-55.40	1.27	12				
		-10.24	1.27	20	-51.35	0.00	5	25786.64	T	0.00	12
2005	MAX	14.00	0.00	3	1.15	0.00	7				
		68.07	0.00	4	60.02	1.27	4	9098.88	C	1.27	3
	MIN	1.38	1.27	13	-15.97	1.27	3				
		-22.89	1.27	16	-26.20	0.00	4	922.41	C	0.00	13
2006	MAX	-3.10	0.00	13	22.27	1.27	3				
		-19.11	0.00	10	60.59	0.00	4	9121.80	C	1.27	3
	MIN	-30.97	1.27	3	-15.79	0.00	3				
		-157.08	1.27	12	-160.60	1.27	12	941.36	C	0.00	13
2007	MAX	32.83	0.00	1	-0.26	0.00	9				
		12.97	0.00	9	34.70	0.00	5	28436.15	C	1.27	1
	MIN	6.76	1.27	20	-43.78	1.27	1				
		-80.63	1.27	5	-67.43	1.27	5	7000.39	C	0.00	20
2008	MAX	-21.86	0.00	20	65.94	1.27	1				
		117.09	0.00	16	88.55	1.27	14	28467.59	C	1.27	1
	MIN	-87.76	1.27	1	-44.04	0.00	1				
		14.56	1.27	11	-68.00	0.00	5	7022.05	C	0.00	20

1020	MAX	0.89	0.00	20	2.85	1.68	1				
		-1.71	0.00	20	4.14	0.00	1	1509.51	C	1.68	16
	MIN	-4.83	1.68	1	-2.46	0.00	1				
		-5.28	1.68	1	-4.75	1.68	1	854.99	T	0.00	4
1021	MAX	1.40	0.00	18	1.22	1.68	3				
		1.87	0.00	3	2.20	1.68	4	1503.65	C	1.68	4
	MIN	-3.00	1.68	4	-1.10	0.14	4				
		0.54	1.68	13	-2.14	0.00	5	800.82	T	0.00	16
1022	MAX	3.91	0.00	12	2.13	0.00	15				
		4.20	0.00	12	3.25	1.68	15	2270.35	C	1.68	5
	MIN	-1.62	1.68	7	-1.76	1.68	12				
		0.14	1.68	7	-4.10	0.00	12	0.80	C	0.00	20
1023	MAX	1.17	0.00	21	2.63	1.68	1				
		4.98	0.00	1	3.47	1.68	1	134.13	T	1.68	22
	MIN	-4.04	1.68	1	-1.36	0.00	1				
		1.43	1.68	20	-4.91	0.00	1	**2430.07**	**T**	0.00	**5**
1024	MAX	2.42	0.00	12	1.33	0.00	12				
		0.00	0.00	12	2.18	0.00	4	375.99	C	1.68	16
	MIN	-2.11	1.68	10	-0.36	0.56	10				
		-1.43	1.68	4	-1.48	1.68	5	1798.44	T	0.00	6
1025	MAX	4.75	0.00	12	3.17	0.00	12				
		-0.29	0.00	7	3.50	0.00	15	1325.01	C	1.68	6
	MIN	-1.37	1.68	7	-2.02	1.68	12				
		-4.45	1.68	12	-4.20	1.68	12	913.53	T	0.00	16
1026	MAX	1.18	0.00	11	1.07	1.37	5				
		1.16	0.00	5	0.86	1.37	1	**2314.49**	**C**	1.37	**5**
	MIN	-2.06	1.37	16	-0.08	0.57	15				
		-0.33	1.37	17	-0.73	0.00	5	38.92	C	0.00	20
1027	MAX	1.41	0.00	10	0.67	1.37	15				
		1.13	0.00	5	1.03	1.37	12	99.61	T	1.37	17
	MIN	-1.90	1.37	15	-0.32	0.68	16				
		-0.32	1.37	17	-0.54	0.00	5	2393.12	T	0.00	5
1028	MAX	1.80	0.00	4	0.73	0.00	4				
		0.99	0.00	5	0.21	0.00	20	1424.08	C	1.37	16
	MIN	-1.51	1.37	21	-0.09	0.91	15				
		-0.44	1.37	15	-1.31	0.00	16	944.36	T	0.00	4
1029	MAX	1.84	0.00	5	0.90	0.00	1				
		0.48	0.00	16	0.81	0.00	4	1414.19	C	1.37	4
	MIN	-1.55	1.37	20	-0.08	0.91	16				
		-0.74	1.37	4	-0.43	0.00	16	881.46	T	0.00	16
1030	MAX	1.27	0.00	11	0.90	1.37	16				
		0.44	0.00	16	0.30	0.00	11	467.41	C	1.37	16
	MIN	-2.30	1.37	12	-0.50	0.23	12				
		-0.68	1.37	6	-0.87	0.00	16	1703.31	T	0.00	6

1031	MAX	1.14	0.00	10	1.02	1.37	17				
		0.70	0.00	16	0.61	0.00	11	1422.47	C	1.37	6
	MIN	-2.20	1.37	17	-0.34	0.23	12				
		-0.71	1.37	11	-1.01	0.00	16	816.60	T	0.00	16
1032	MAX	1.75	0.00	7	0.57	0.00	10				
		0.63	0.00	6	0.62	1.68	11	1417.59	C	1.68	6
	MIN	-1.80	1.68	15	-0.50	0.84	17				
		0.24	1.68	16	-1.37	0.00	16	821.80	T	0.00	16
1033	MAX	2.12	0.00	15	1.02	0.00	4				
		0.08	0.00	11	0.28	1.68	11	462.07	C	1.68	16
	MIN	-1.50	1.68	7	-0.29	0.98	12				
		-0.27	1.68	16	-0.90	1.68	16	1709.02	T	0.00	6
1034	MAX	1.90	0.00	10	0.90	0.00	5				
		0.23	0.00	20	0.79	1.68	15	1408.34	C	1.68	4
	MIN	-1.69	1.68	1	-0.17	0.98	22				
		-0.08	1.68	5	-0.44	1.68	16	887.57	T	0.00	16
1035	MAX	2.17	0.00	12	1.29	0.00	1				
		0.24	0.00	4	0.21	1.68	20	1418.06	C	1.68	16
	MIN	-1.43	1.68	10	-0.13	0.98	21				
		-0.21	1.68	16	-1.29	1.68	16	950.72	T	0.00	4
1036	MAX	2.38	0.00	12	1.48	0.00	12				
		0.06	0.00	17	0.86	1.68	17	105.22	T	1.68	17
	MIN	-1.42	1.68	9	-0.14	1.12	15				
		-0.28	1.68	1	-0.51	1.68	5	2399.10	T	0.00	5
1037	MAX	1.71	0.00	22	0.53	0.00	11				
		-0.32	0.00	11	1.25	0.00	15	2309.40	C	1.68	5
	MIN	-2.02	1.68	1	-0.52	0.70	12				
		-0.65	1.68	5	-0.74	1.68	5	33.22	C	0.00	20
1038	MAX	3.01	0.00	1	0.99	0.00	1				
		-0.87	0.00	10	1.80	0.00	4	2244.58	C	1.37	5
	MIN	-1.25	1.37	20	-1.26	1.37	1				
		-3.23	1.37	1	-2.82	1.37	1	50.37	C	0.00	20
1039	MAX	0.64	0.00	10	3.45	1.37	1				
		7.39	0.00	1	5.21	1.37	1	2147.19	C	1.37	5
	MIN	-6.04	1.37	1	-2.96	0.00	1				
		0.75	1.37	20	-4.92	0.00	1	117.03	C	0.00	20
1040	MAX	0.72	0.00	7	2.21	1.37	12				
		0.48	0.00	10	1.08	0.00	17	119.70	T	1.37	17
	MIN	-3.69	1.37	12	-0.98	0.00	12				
		-2.02	1.37	17	-2.15	1.37	12	2335.27	T	0.00	5
1041	MAX	5.24	0.00	12	2.99	0.00	12				
		6.51	0.00	12	4.57	1.37	12	191.26	T	1.37	22
	MIN	-1.75	1.37	10	-2.41	1.37	15				
		-0.35	1.37	11	-4.35	0.00	12	2255.54	T	0.00	5

1042	MAX	0.78	0.00	7	2.21	1.37	12				
		2.55	0.00	12	2.32	1.37	12	405.04	C	1.37	16
	MIN	-3.54	1.37	12	-0.77	0.00	12				
		-0.28	1.37	11	-1.48	0.00	16	1689.49	T	0.00	6
1043	MAX	6.17	0.00	12	3.46	0.00	12				
		1.13	0.00	10	3.67	0.00	17	216.34	C	1.37	16
	MIN	-1.31	1.37	11	-3.12	1.37	12				
		-5.43	1.37	17	-3.77	1.37	17	1676.71	T	0.00	6
1044	MAX	1.64	0.00	3	0.46	1.37	18				
		1.84	0.00	5	0.99	1.37	3	1353.79	C	1.37	6
	MIN	-1.65	1.37	18	-0.36	0.80	3				
		0.49	1.37	22	-1.70	0.00	16	807.37	T	0.00	16
1045	MAX	1.15	0.00	18	1.62	1.37	5				
		0.38	0.00	16	2.36	0.00	4	1266.06	C	1.37	6
	MIN	-3.22	1.37	5	-0.92	0.00	5				
		-3.87	1.37	4	-2.94	1.37	4	695.68	T	0.00	16
1047	MAX	0.96	0.00	13	2.17	1.37	4				
		3.14	0.00	5	2.19	1.37	16	1361.83	C	1.37	16
	MIN	-3.87	1.37	4	-1.27	0.00	4				
		-0.43	1.37	22	-2.13	0.00	5	715.01	T	0.00	4
1048	MAX	2.86	0.00	1	0.78	0.00	1				
		3.83	0.00	1	3.03	1.37	1	1429.64	C	1.37	4
	MIN	-1.32	1.37	20	-1.27	1.37	1				
		0.99	1.37	20	-2.28	0.00	5	789.06	T	0.00	16
1049	MAX	0.32	0.00	20	4.28	1.37	1				
		-0.03	0.00	10	3.82	0.00	1	1431.65	C	1.37	4
	MIN	-7.00	1.37	1	-3.44	0.00	1				
		-5.35	1.37	1	-3.52	1.37	12	580.08	T	0.00	16
1050	MAX	1.44	0.00	3	0.56	1.37	12				
		-0.44	0.00	12	1.43	0.00	4	1428.04	C	1.37	16
	MIN	-1.87	1.37	12	-0.44	0.69	4				
		-1.92	1.37	4	-1.20	1.37	4	860.48	T	0.00	5

596. **PRINT CG**

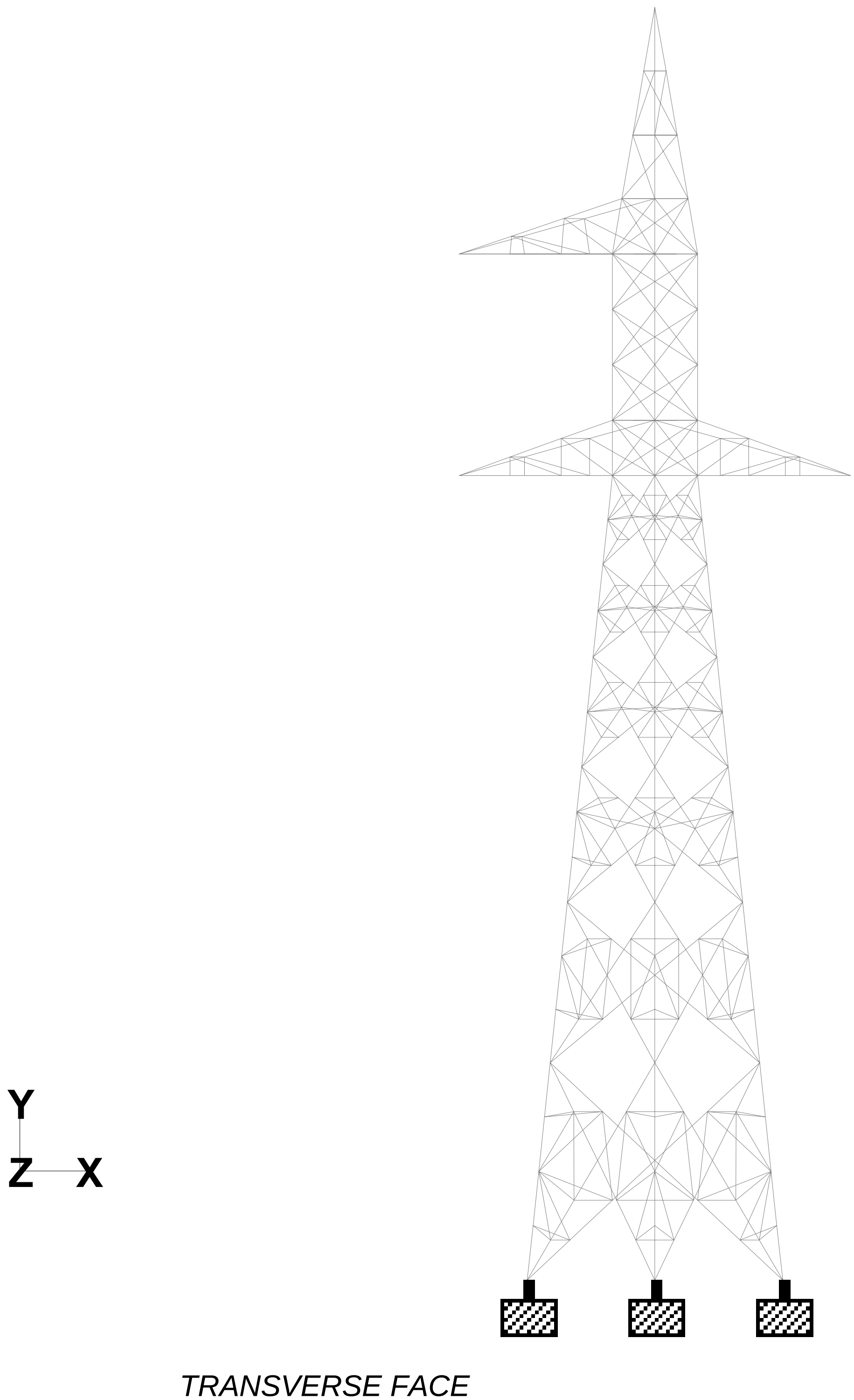
CENTER OF GRAVITY OF THE STRUCTURE IS LOCATED AT: (METE UNIT)

X = 2.90 Y = 13.33 Z = 1.73

TOTAL SELF WEIGHT = 2519.293 (KG UNIT)

597. **FINISH**

APPENDIX C



TRANSVERSE FACE

DESIGN OF LEG MEMBER

Panel No.	**1**						
Effective Length:	$L_{eff.}$	1.29	m	or	128.5	cm	
Load in Compression:	P_C	31175	kg				
Load in Tension:	P_T	28247	kg				
Steel used:		M.S.	Angle Section :	L	**100*100*8**		
Angle :		Single	Rv.v.:		1.95	cm	
			Area:		15.39	cm^2	
Curve Used:		1					
Design for Compression:							
Slenderness Ratio:							
$\lambda =$		65.90	66	**<**	120		OK
Compressive Stress:							OK
$\sigma_{cbc} =$		2198					
Gross Area :		14.18	cm^2				
Ultimate Compressive Strength:		33827	**>**		31175	kg	OK
Factor of Safety:		**1.1**					
Check for Tension:							
Net Area:		13.29	cm^2				
Tensile Stress:							
$\sigma_{at} =$		2600	Kg/cm^2				2548
Tensile Load:		34554	**>**		28247	kg	OK
Factor of Safety:		1.2					

Panel No.	**2**						
Effective Length:	$L_{eff.}$	1.27	m	or	127	cm	
Load in Compression:	P_C	28469	kg				
Load in Tension:	P_T	25907	kg				
Steel used:		M.S.	Angle Section :	L	**100*100*8**		
Angle :		Single	Rv.v.:		1.95	cm	
			Area:		15.39	cm^2	
Curve Used:		1					
Design for Compression:							
Slenderness Ratio:							
$\lambda =$		65.13	65	**<**	120		OK
Compressive Stress:							STOP
$\sigma_{cbc} =$		2208					
Gross Area:		12.89	cm^2				
Ultimate Compressive Strength:		33981	**>**		28469	kg	OK
Factor of Safety:		**1.2**					
Check for Tension:							
Net Area:		13.29	cm^2				
Tensile Stress:							
$\sigma_{at} =$		2600	Kg/cm^2				2548
Tensile Load:		34554	**>**		25907	kg	OK
Factor of Safety:		1.3					

DESIGN BRACING

Panel	**1**							
Effective Length:	$L_{eff.}$	1.37	m or	137	cm			
Load in Comp.:	P_C	2315	kg					
Load in Tension:	P_T	2431	kg					
Steel used:		M.S.	Angle Section :	L	**45*45*4**			
Angle :		Single	Rv.v.:	0.87	Rx.x.:		1.37 cm	
			Area:		3.47	cm^2		
Curve Used:		3 & 6						
Design for Compression:								
Slenderness Ratio:								
λ_1 :		157.47	157	**<**	200			OK
λ_2 :		167.24	167					
Compressive Stress:								OK
σ_{cbc} =		908						
Gross Area :		2.55	cm^2					
Ultimate Compressive Strength:		3151	**>**	2315	kg			OK
Factor of Safety:		**1.4**						
Check for Tension:								
Net Area:		2.42	cm^2					
Tensile Stress:								
σ_{at} =		2600	Kg/cm^2					2548
Tensile Load:		6292	**>**	2431	kg			OK
Factor of Safety:		2.6						

Panel	**1**							
Effective Length:	$L_{eff.}$	1.69	m or	168.5	cm			
Load in Compression:	P_C	2315	kg					
Load in Tension:	P_T	2431	Angle Section :	L	**45*45*4**			
Angle :		Single	Rv.v.:	0.87	Rx.x.:		1.37 cm	
			Area:		3.47	cm^2		
Curve Used:		3 & 6						
Design for Compression:								
Slenderness Ratio:								
λ_1 :		193.68	194	**<**	200			OK
λ_2 :		167.24	167					
Compressive Stress:								OK
σ_{cbc} =		735						
Gross Area :		3.15	cm^2					
Ultimate Compressive Strength:		2550	**>**	2315	kg			OK
Factor of Safety:		**1.1**						
Check for Tension:								
Net Area:		2.42	cm^2					
σ_{at} =		2600	Kg/cm^2					2548
Tensile Load:		6292	**>**	2431	kg			OK
Factor of Safety:		2.6						

		DESIGN	**LOWER CROSS ARM**				
Panel No. **13**							
Effective Length:	$L_{eff.}$	1.64	m	or	164	cm	
Load in Compression:	P_C	4969	kg				
Load in Tension:	P_T	3645	kg				
Steel used:		M.S.	Angle Section :	L	**75*75*6**		
Angle :		Single	Rv.v.:		1.46	cm	
			Area:		8.66	cm^2	
Curve Used:		2					
Design for Compression:							
Slenderness Ratio:							
$\lambda =$		112.33	112	<	120		OK
Compressive Stress:							OK
$\sigma_{cbc} =$		1500					
Gross Area :		3.31	cm^2				
Ultimate Compressive Strength:		12990	>		4969	kg	OK
Factor of Safety:		**2.6**					
Check for Tension:							
Net Area:		6.56	cm^2				
Tensile Stress:							
$\sigma_{at} =$		2600	Kg/cm^2				2548
Tensile Load:		17056	>		3645	kg	OK
Factor of Safety:		4.7					

Panel No. **13**							
Effective Length:	$L_{eff.}$	1.20	m	or	120	cm	
Load in Compression:	P_C	4969	kg				
Load in Tension:	P_T	3645	kg				
Steel used:		M.S.	Angle Section :	L	**65*65*5**		
Angle :		Single	Rv.v.:		2.77	cm	
			Area:		10.47	cm^2	
Curve Used:		2					
Design for Compression:							
Slenderness Ratio:							
$\lambda =$		43.32	43	<	120		OK
Compressive Stress:							OK
$\sigma_{cbc} =$		2237					
Gross Area:		2.22	cm^2				
Ultimate Compressive Strength:		23421	>		4969	kg	OK
Factor of Safety:		**4.7**					
Check for Tension:							
Net Area:		8.37	cm^2				
$\sigma_{at} =$		2600	Kg/cm^2				2548
Tensile Load:		21762	>		3645	kg	OK
Factor of Safety:		6.0					

		DESIGN	**HORIZONTAL**					
Panel	**6**							
Effective Length:	$L_{eff.}$	1.00	m	or	100	cm		
Load in Compression:	P_C	4206	kg					
Load in Tension:	P_T	1559	kg					
Steel used:		M.S.	Angle Section :	L	**50*50*4**			
Angle :		Single	Rv.v.:	0.97	Rx.x.:	1.53	cm	
			Area:		3.88	cm^2		
Curve Used:		3 & 6						
Design for Compression:								
Slenderness Ratio:								
λ_{1} :		103.09	103	<	120			OK
λ_{2} :		130.72	131					
Compressive Stress:								FALSE
σ_{cbc} =		1253						
Gross Area :		3.36	cm^2					
Ultimate Compressive Strength:		4862	>	4206	kg			OK
Factor of Safety:		**1.2**						
Check for Tension:								
Net Area:		2.83	cm^2					
Tensile Stress:								
σ_{at} =		2600	Kg/cm^2					2548
Tensile Load:		7358	>	1559	kg			OK
Factor of Safety:		4.7						

		DESIGN	**UPPER CROSS ARM**					
Panel	**13**							
Effective Length:	$L_{eff.}$	1.43	m	or	143	cm		
Load in Compression:	P_C	1037	kg					
Load in Tension:	P_T	5418	Angle Section :	L	**50*50*4**			
Angle :		Single	Rv.v.:	0.97	Rx.x.:	1.53	cm	
			Area:		3.88	cm^2		
Design for Tension:								
Net Area:		2.83	cm^2					
Area of Angle Section:								
Area of Connected Leg		1.84						
Area of another Leg		1.3						
k=		0.669						
Area:		2.53						
Tensile Stress:								
σ_{at} =		2600	Kg/cm^2					2548
Tensile Load:		6579	>	5418	kg			OK
Factor of Safety:		**1.2**						
Check for Compression:								
λ :		147		<	400			OK

DESIGN SUMMARY - TRIANGULAR TOWER

C.G. Is Located At:

X= 2.9 Y= 13.21 Z= 1.73

TOTAL SELF WEIGHT: **2519** Kg

A. LEG MEMBER

(Rvv) curve1 < 120

Panel No.	Angle Section	Effective Length (cm)	Compressive Load (Kg)	Tensile Load (Kg)	F.O.S.
1	(MS └ 100*100*08)	129	31175	28247	**1.1**
2	(MS └ 100*100*08)	127	28469	25907	**1.2**
3	(MS └ 90*90*08)	107	24726	22324	**1.3**
4	(MS └ 90*90*08)	130	21430	19246	**1.4**
5	(MS └ 90*90*06)	110	18355	16182	**1.3**
6	(MS └ 75*75*06)	105	13826	11874	**1.3**
7	(MS └ 75*75*06)	130	9999	8343	**1.7**
8	(MS └ 65*65*05)	130	7455	6799	**1.4**
9	(MS └ 65*65*05)	130	6206	4982	**1.7**
10	(MS └ 65*65*05)	130	6935	4606	**1.5**
11	(MS └ 65*65*05)	133	4660	2684	**2.2**
12	(MS └ 65*65*05)	153	4641	3537	**1.9**

DESIGN SUMMARY - TRIANGULAR TOWER

Panel No.	Angle Section	Effective Length (cm)	Compressive Load (Kg)	Tensile Load (Kg)	F.O.S.
B.	**LATTICE**	(Rxx & Rvv)	Curve 3 & 6	< 120 < 200	
1	(MS └ 45*45*04)	137	2315	2431	**1.4**
	(MS └ 45*45*04)	169	2315	2431	**1.1**
2	(MS └ 50*50*04)	161	2773	2674	**1.3**
	(MS └ 50*50*04)	135	2773	2674	**1.5**
3	(MS └ 45*45*04)	135	3243	3323	**1.1**
	(MS └ 45*45*04)	113	3243	3323	**1.3**
4	(MS └ 45*45*04)	111	3448	3351	**1.3**
	(MS └ 45*45*04)	94	3448	3351	**1.5**
5	(MS └ 45*45*04)	94	3963	4136	**1.3**
	(MS └ 45*45*04)	79	3963	4136	**1.7**
6	(MS └ 50*50*04)	84	5216	4981	**1.1**
	(MS └ 50*50*04)	69	5216	4981	**1.2**
7	(MS └ 45*45*04)	119	2135	2307	**1.9**
8	(MS └ 45*45*04)	119	3386	3521	**1.2**
9	(MS └ 45*45*04)	119	3553	3316	**1.2**
10	(MS └ 45*45*04)	119	3276	3604	**1.3**
11	(MS └ 45*45*04)	124	2923	2559	**1.3**
	(MS └ 45*45*04)	96	2923	2559	**1.6**
12	-	-	-	-	

DESIGN SUMMARY - TRIANGULAR TOWER

Panel No.	Angle Section	Effective Length (cm)	Compressive Load (Kg)	Tensile Load (Kg)	F.O.S.
C.	**HORIZONTAL**	(Rxx & Rvv)	Curve 3 & 6	< 120 < 200	
6	(MS └ 50*50*04)	100	4206	1559	**1.2**
7	(MS └ 45*45*04)	100	1179	4579	**-4.2**
10	(MS └ 45*45*04)	100	2589	2682	**1.9**
11	(MS └ 50*50*04)	155	1482	2725	**2.1**

CROSS ARM

		Curve 2	(Rvv)	< 120	
D.	**LOWER MEMBER**				
Panel No.	Angle Section	Effective Length (cm)	Compressive Load (Kg)	Tensile Load (Kg)	F.O.S.
13	(MS └ 75*75*06)	164	4969	3645	**2.6**
	(MS └ 65*65*05)	120	4969	3645	**4.7**
14	(MS └ 75*75*06)	164	5463	2312	**2.4**
	(MS └ 65*65*05)	120	5463	2312	**4.3**
E.	**UPPER MEMBER**				
Panel No.	Angle Section	Effective Length (cm)	Compressive Load (Kg)	Tensile Load (Kg)	F.O.S.
13	(MS └ 50*50*04)	143	1037	5418	**1.2**
14	(MS └ 50*50*04)	128	825	5729	**1.2**