Parametric Study on Structural Efficiency and Economy of Transmission T

SEMINAR ONE PRESENTATION.

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Indian Institute of Technology Tirupati.

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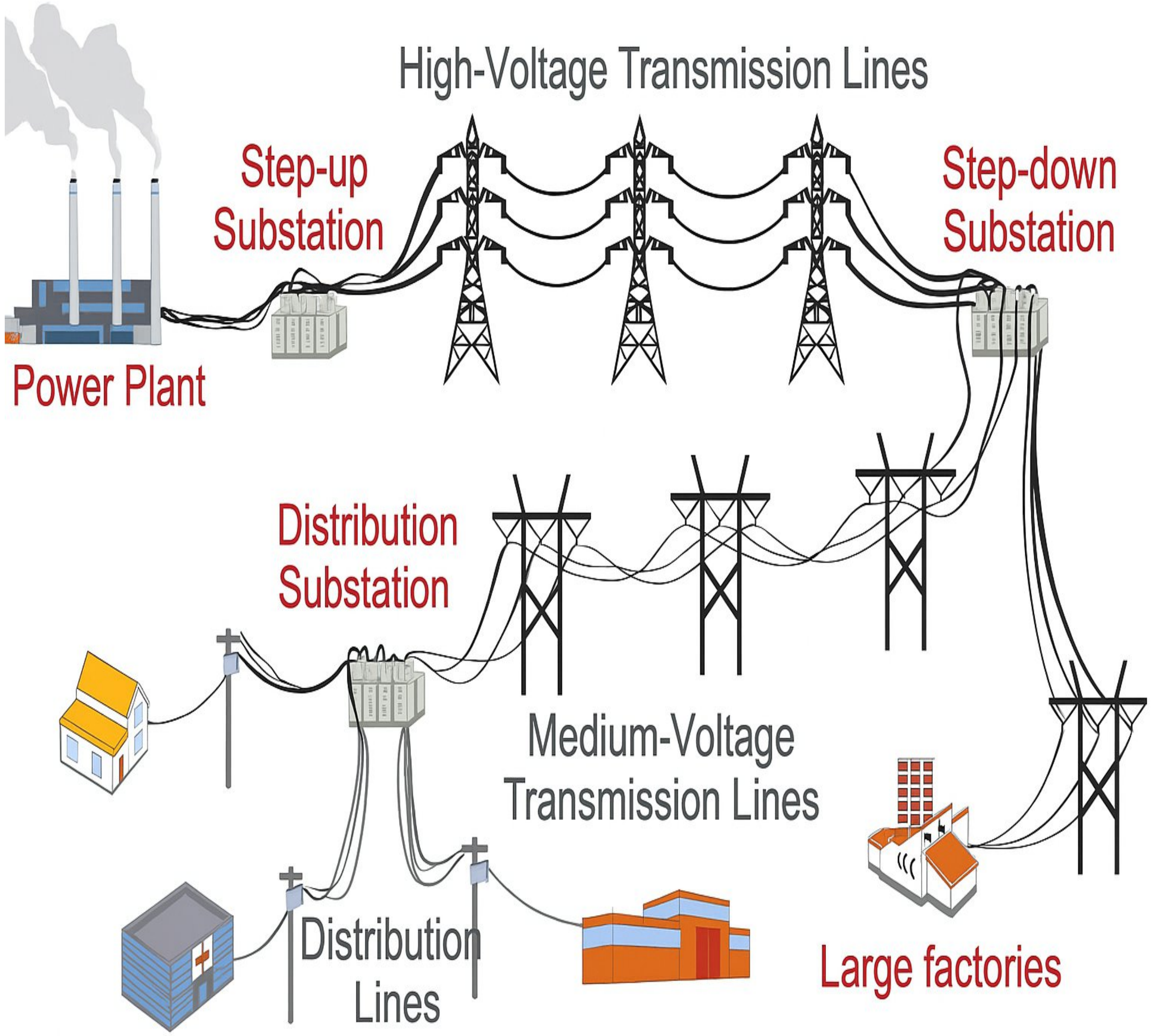
Electric Power Transmission and Distribution Layout.



https://www.eia.gov/energyexplained/electricity/delivery-to-consumers.php

1.1 - ABOUT THE TRANSMISSION TOWER.

- Transmission towers (electrical pylons) carry high-voltage electricity over long distances.
- Typical heights range from 50-150 ft (16-45 m) and tallest reach 1,247 ft (380 m).
- They connect power plants to substations, linking different grid regions.
- Transmission line towers form a major component of the power transmission network, contributing nearly 30 to 40% of the overall project cost.
- Inefficient design may lead to excessive deflection, higher steel consumption or increased cost.
- Most towers are made of steel, while some use concrete, wood or ductile iron.

Types of transmission towers

Based on circuit
a) Single circuit tower
b) Double circuit tower
c) Multi circuit tower.

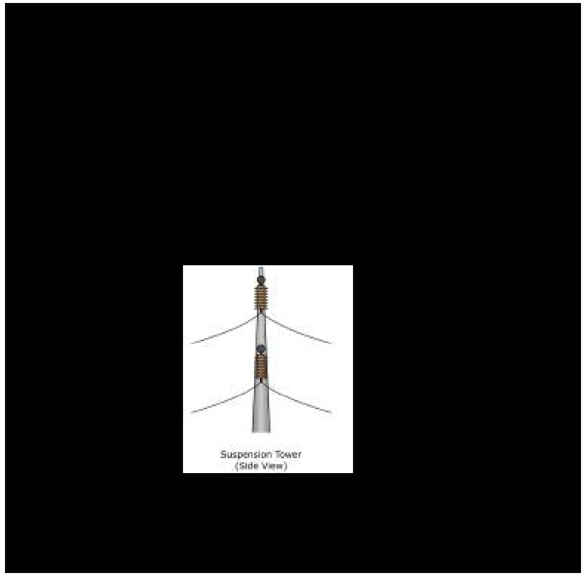
Based on angle
a) A – type tower – angle of deviation 0^{o} to 2^{o}.
b) B – type tower – angle of deviation 2^{o} to 15^{o}.
c) C – type tower – angle of deviation 15^{o} to 30^{o}.
d) D – type tower – angle of deviation 30^{o} to 60^{o}.
e) E – type tower – angle of deviation 60^{o} to 90^{o}.

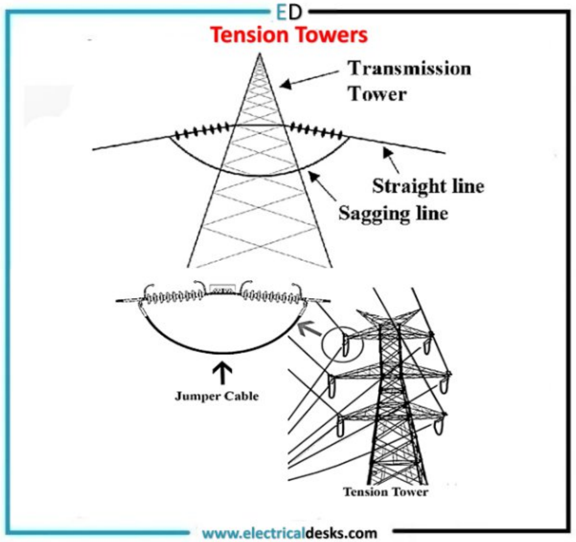
Structure type
a) Lattice Structure
b) Hybrid Structure
c) Tubular Pole Structure.

Current capacity
a) 11 kV,
b) 33 kV
c) 66 kV
d) 110 kV
e) 132 kV
f) 220 kV
g) 400 kV
h) 500 kV

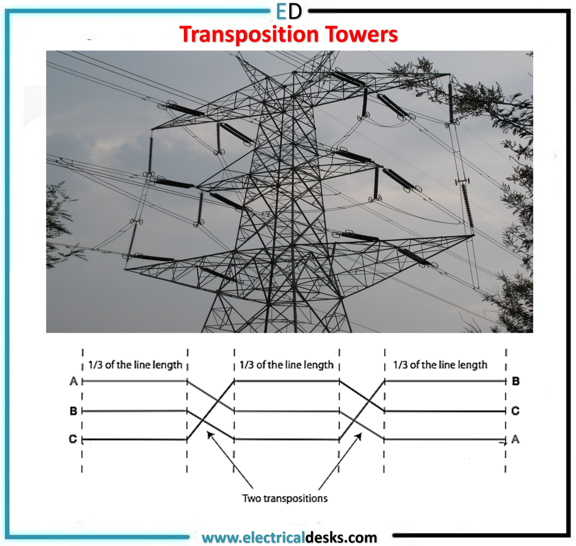
Material used
a) Steel Structure
b) Wooden Material
c) RCC Pole

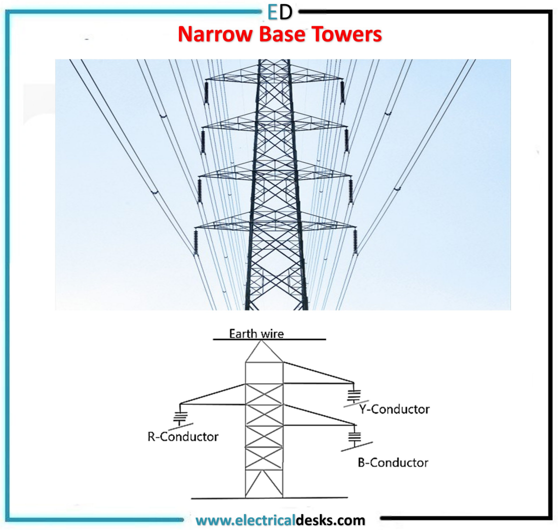
Force applied by the conductor on the cross arms
a) Tangent suspension tower
b) Angle tower or tension tower

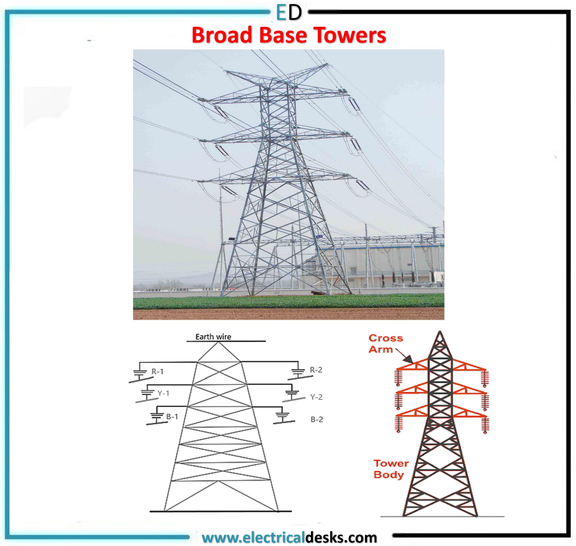

Suspension Tower
(Side View)

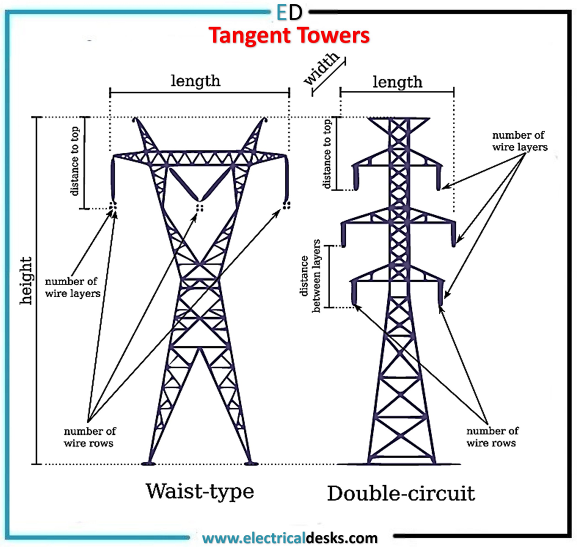

ED
Tension Towers
Transmission
Tower
Straight line
Sagging line
Jumper Cable
Tension Tower
www.electricaldesks.com

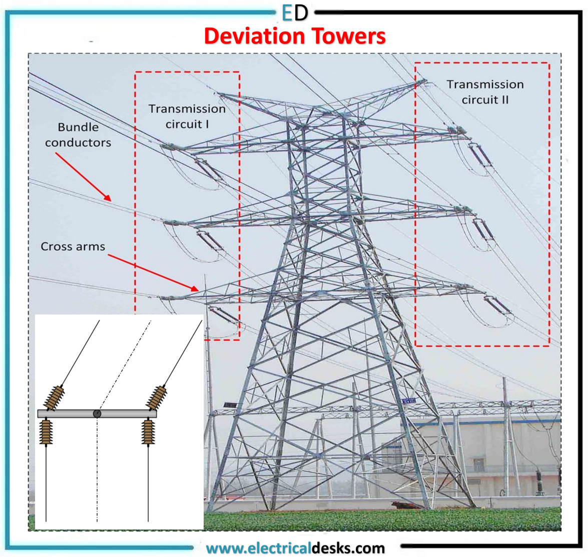

ED
Terminal Towers
www.electricaldesks.com

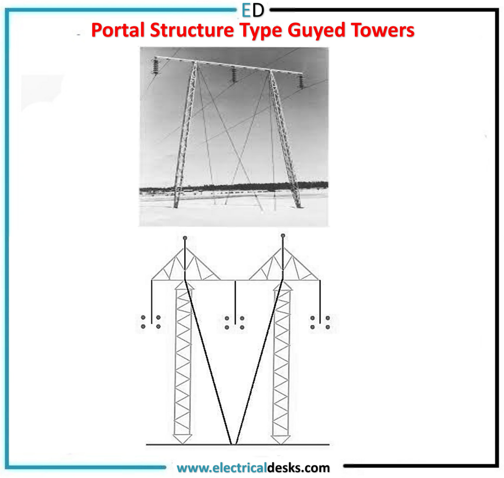

ED
Transposition Towers
1/3 of the line length
1/3 of the line length
1/3 of the line length
A
B
C
B
C
A
Two transpositions
www.electricaldesks.com

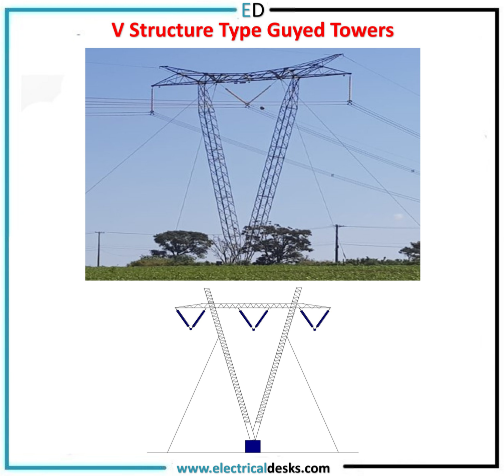

ED
Narrow Base Towers
Earth wire
Y-Conductor
R-Conductor
B-Conductor
www.electricaldesks.com

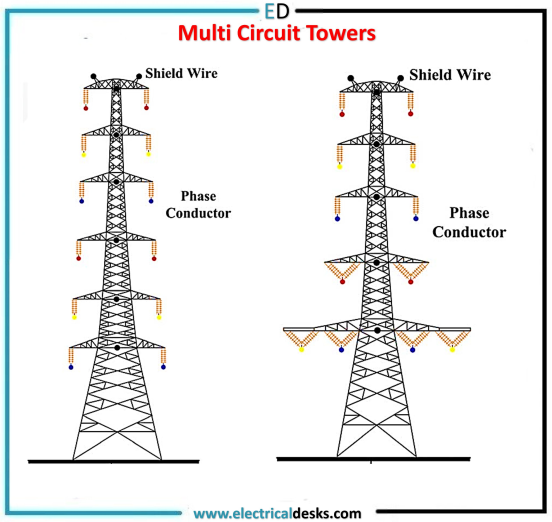

ED
Broad Base Towers
Earth wire
R-1
Y-1
B-1
R-2
Y-2
B-2
Cross
Arm
Tower
Body
www.electricaldesks.com

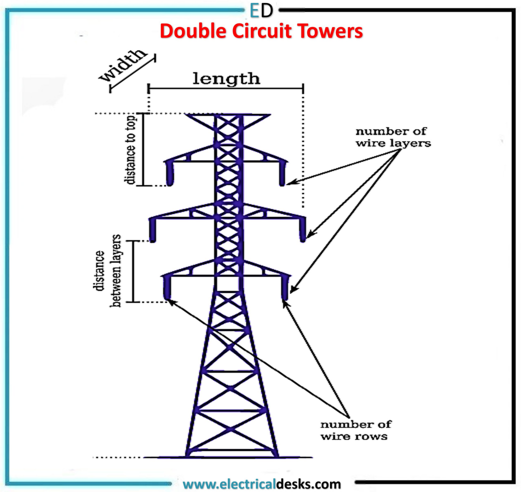

ED
Tangent Towers
length
width
length
distance to top
distance to top
height
number of
wire layers
number of
wire layers
distance
between layers
number of
wire rows
number of
wire rows
Waist-type
Double-circuit
www.electricaldesks.com

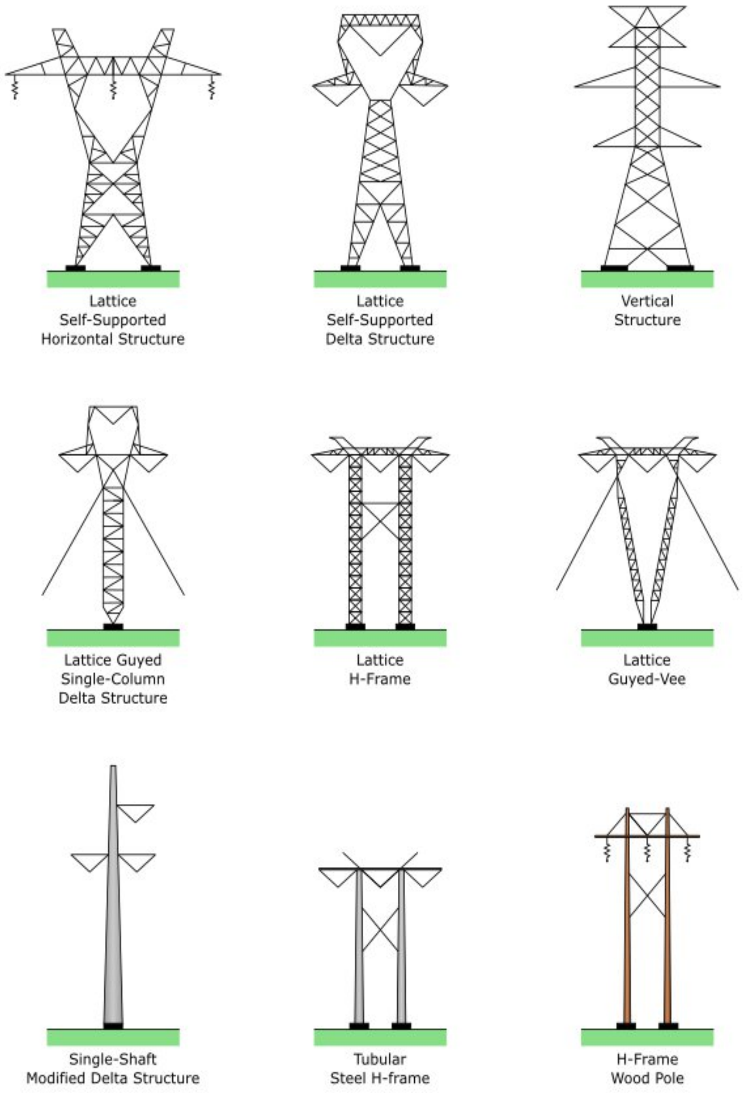

ED
Deviation Towers
Transmission
circuit I
Transmission
circuit II
Bundle
conductors
Cross arms
www.electricaldesks.com





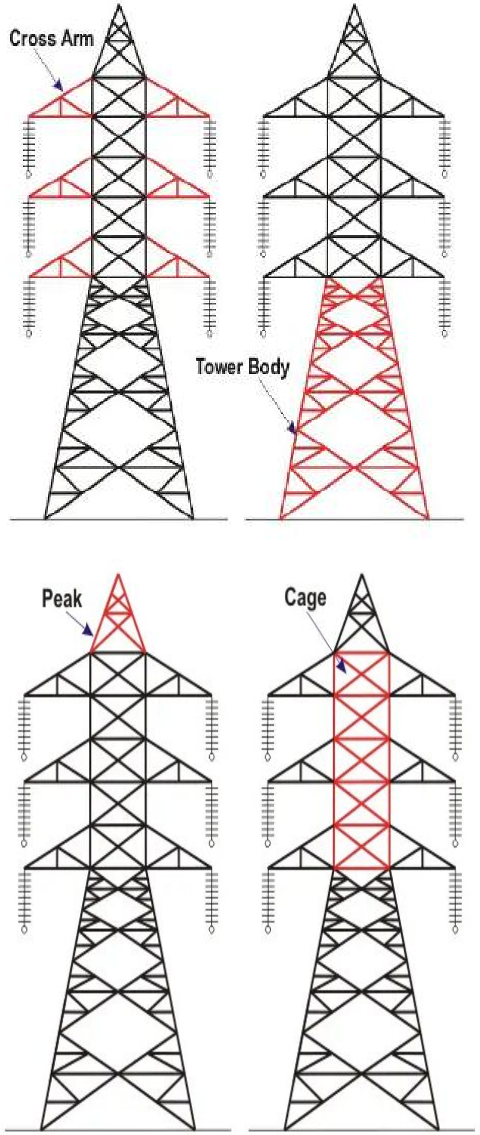


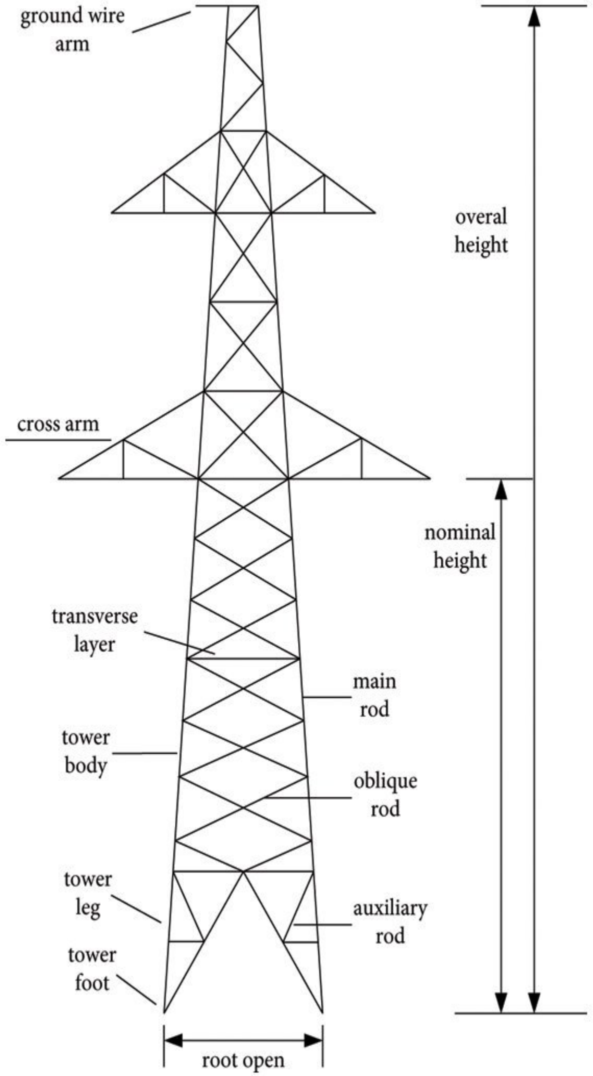




www.savree.com/en/encyclopedia/electrical-transmission-towers

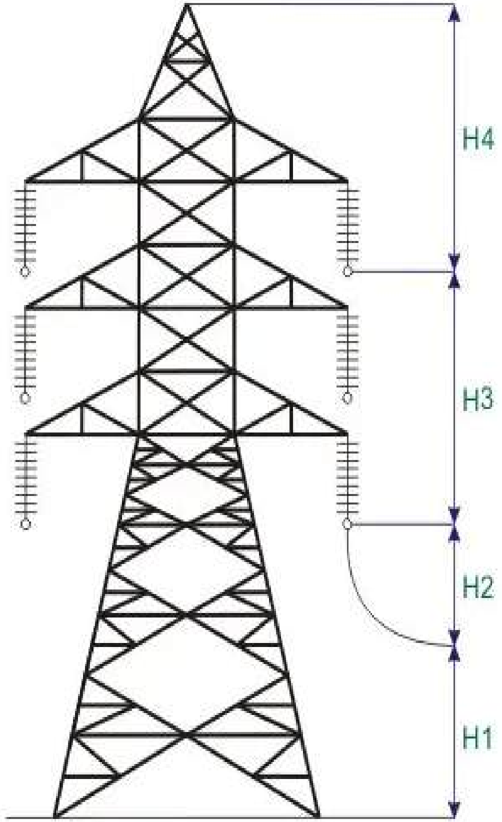
Guyed mast tower at north of IIT Tirupati.





https://www.electrical4u.com/electrical-transmission

Fig. - Nesting platform for bird nesting.



1. Minimum permissible ground clearance (H1).
2. Maximum sag of overhead conductor (H2).
3. Vertical spacing between the top and bottom conductors (H3).
4. Vertical clearance between the ground wire and top conductor (H4).

- To select the efficient configuration (VCT and HCT) of towers.
- To select the efficient bracing configuration.
- To decide the efficient code for tower design.
- To select the effective base width for the different wind zones.
- To select the best sections out of angle and hollow tube sections.

Parameters.

Bracing
- K type
- X type
- Diagonal
- XD
- Combined

Base width

In different wind zones :-
- Z-1
- Z-2
- Z-3
- Z-4
- Z-5
- Z-6

Configuration
- Vertical
- Horizontal

Sections
- Angular
- Tubular

Codes
- Is 802
- Is 800
- AISC
- EN

5.1 - SECTIONS COMPARASION[1].

Fig - Four legged suspended tower.

(IJAERD), vol. 4, 2017.

1. Tower Specifications.

Type	-	Four legged suspended tower of 400 KV double circuit.
Height	-	40 m.
Sections	-	Angle and closed hollow section.
Configuration	-	X-Bracing and K-Bracing Patterns.

2. Tower Analyses.

- Linear Static Analysis.
- Dynamic analysis.

3. Loads Considered.

- Self-weight (Dead load)
- Conductors & Hardware load
- Wind load on tower and conductors
- Ice/Snow load (if applicable)
- Earthquake/Dynamic load
- Load combinations for extreme conditions

4. Soft ware Used

- STAAD Pro for 3D modeling and analysis.
- One broken wire and anti-cascading condition.
- Indian code is 802 part1.

Cont.

5 - Parameters used to decide which section is better.

- Structural Deflection.
- Economy (Weight and Cost).
- Permissible Limits Check.

6 - RESULTS.

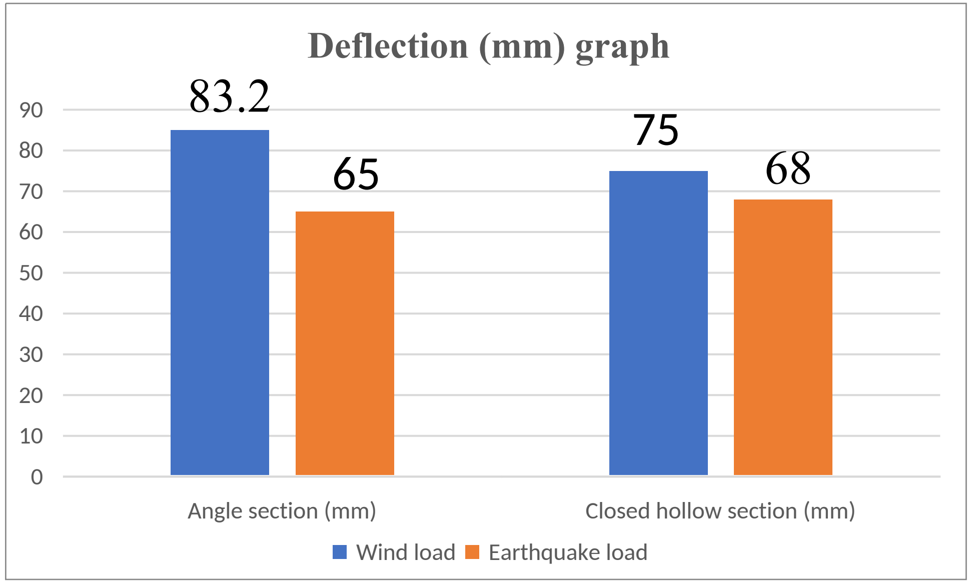


Fig. - Deflections for various sections.

Fig - Costs for various sections.

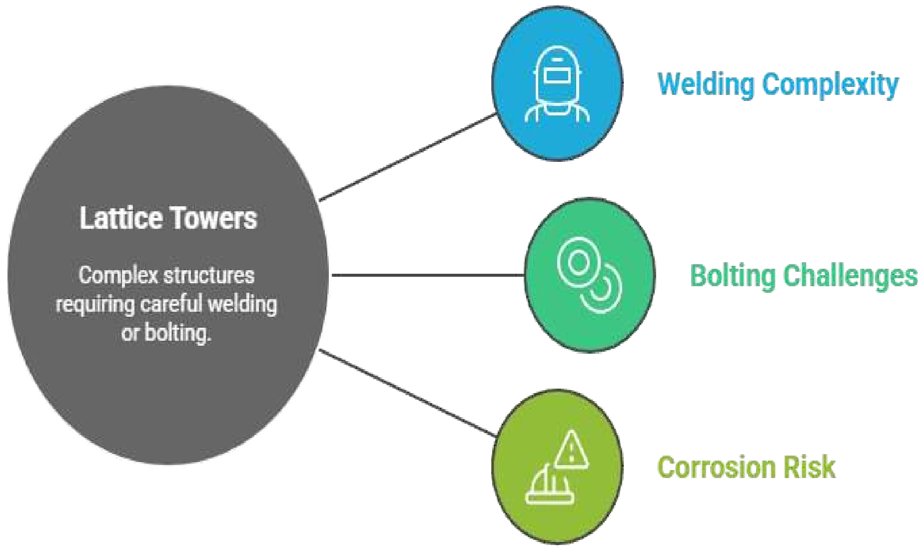
Cont.

7 - Observations.

Best section was concluded as the four-legged transmission tower with "*Closed Hollow Sections*" since it was both structurally stiffer and more economical.

8 - Reasons.

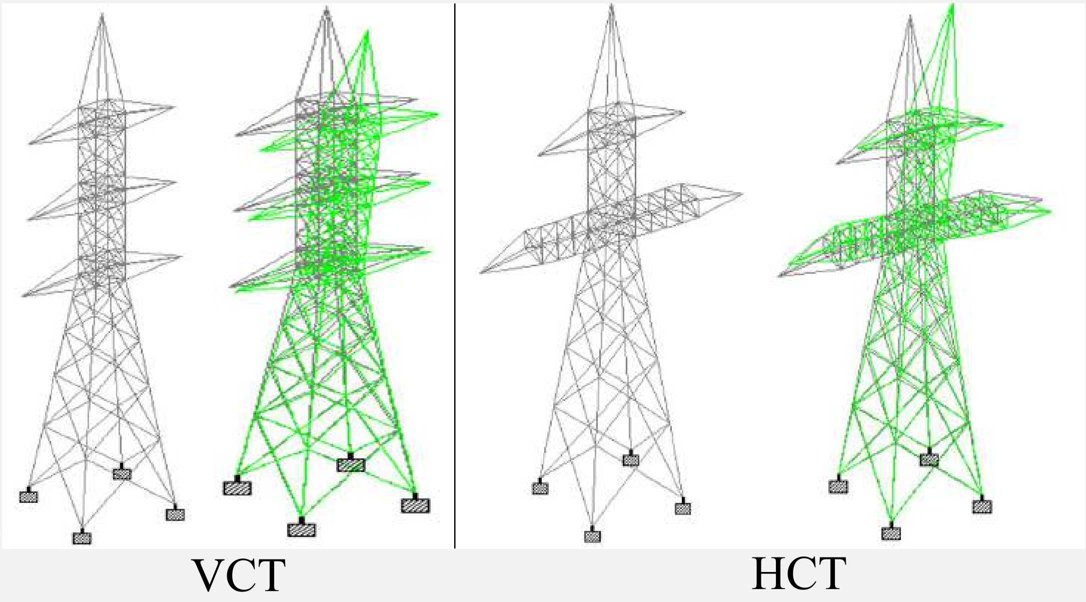
9 - Challenges with Hollow Sections.



5.2 - CONFIGURATION TYPES[2].

1. Tower Specifications.

Type	-	132 kV double circuit self-supporting angle tower.
Height	-	HCT = 38.83 m & VCT = 44.85m
Span	-	200 m
Base Width	-	7.6 m for both VCT and HCT.
Material	-	Mild steel and High tensile steel.
Configuration	-	Vertical Configured Tower and Horizontal configured tower.



2. Tower Analyses.

- Linear Static Analysis.

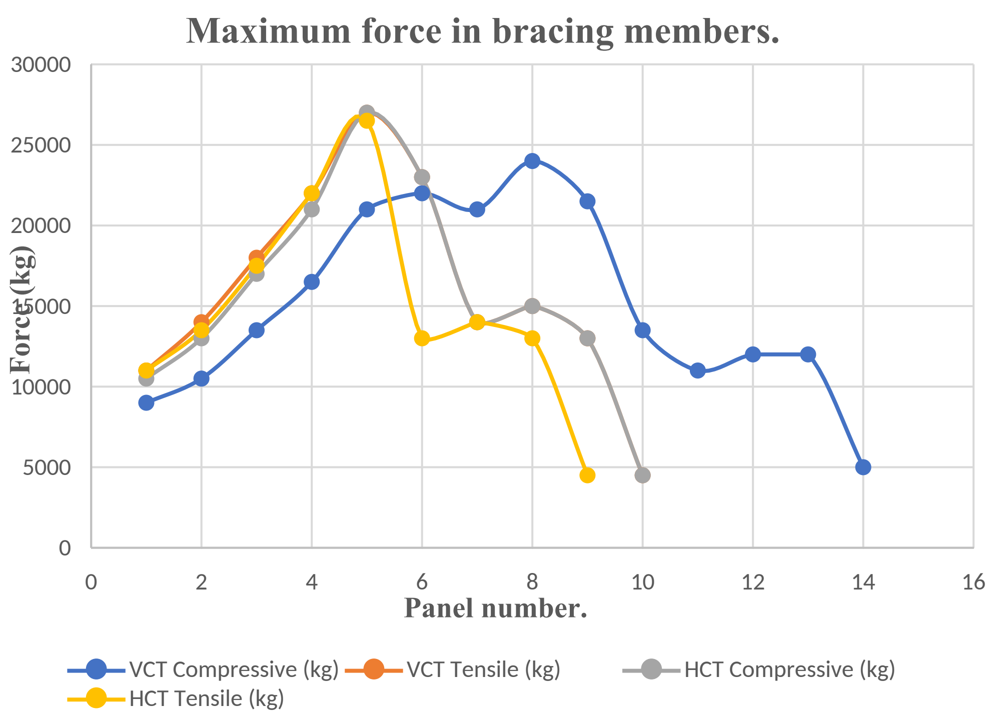
Soft ware Used

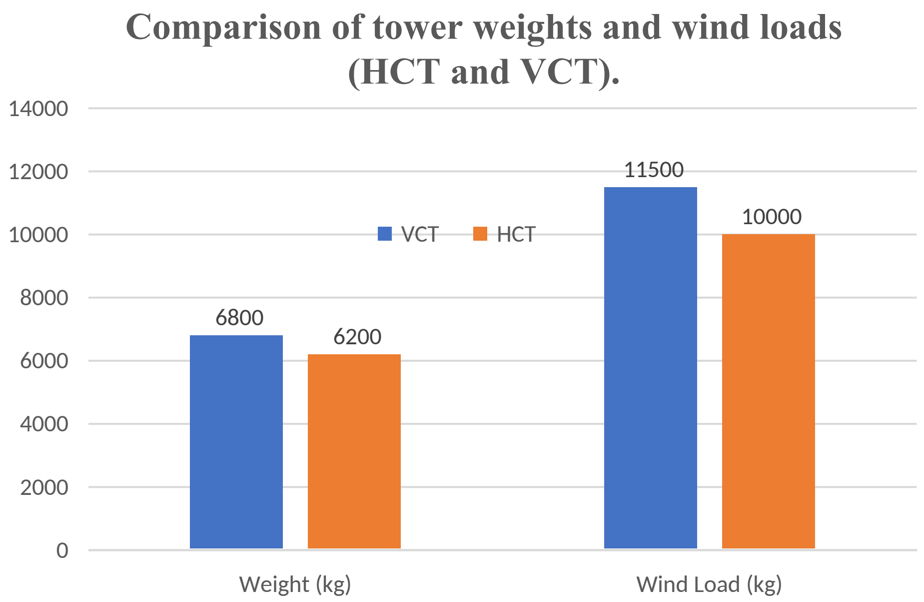
- STAAD Pro for 3D modeling and analysis.

3. Loads Considered.

- Self-weight (Dead load)
- Conductors & Hardware load
- Wind load on tower and conductors
- Ice/Snow load (if applicable)
- Earthquake/Dynamic load

4. GRAPHS.





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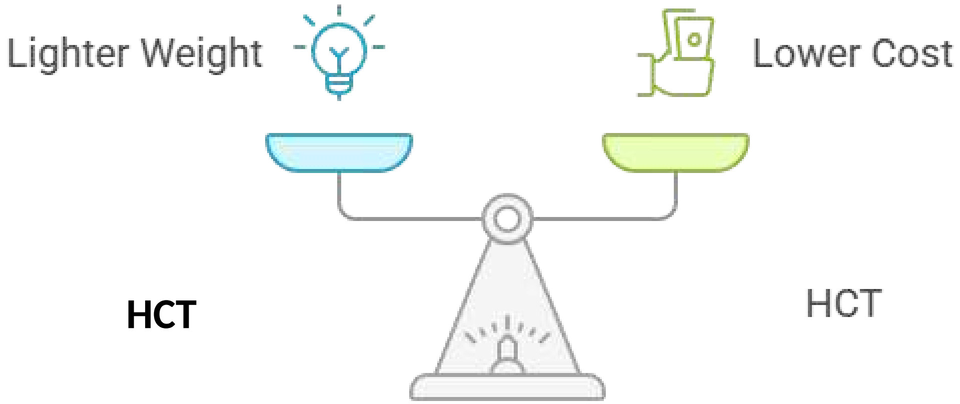
5. OBSERVATIONS.

Choose between weight and cost savings.



6. REASONS.

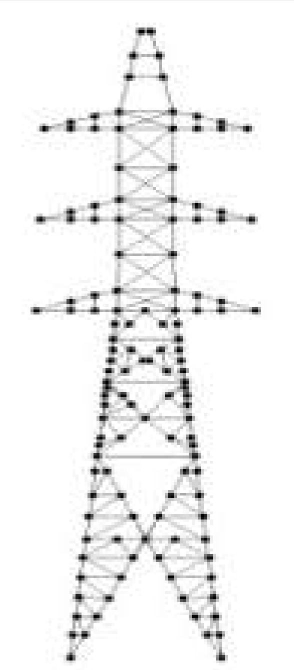
Vertical vs Horizontal Configuration.

	Vertical Configuration (VCT)	Horizontal Configuration (HCT)
Wind Load	Higher	Lower
Steel Weight	Lighter	Slightly Heavier
Steel Type	HT Steel	MS Steel
Axial Forces	Higher	Lower
Structural Stability	Lower	Higher

5.3 - BASE WIDTH COMPARASION[3].

1. Tower Specifications.

Type	-	Self-supporting lattice steel transmission tower
Height	-	34.120 m
Top width -		0.5 m
Base Width	-	6.307 m
Cross arm length	-	9.2 m
Material	-	Steel (Fe415)
Sections used	-	ISA



2. Tower Analyses.

- **Linear Static Analysis:** For base comparison under normal loads.

3. Loads Considered.

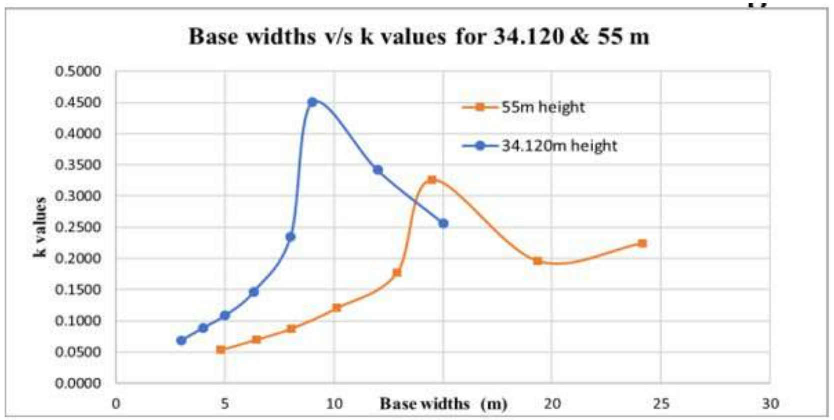
- Self-weight (Dead load)
- Conductors & Hardware load
- Wind load on tower and conductors
- Ice/Snow load (if applicable)
- Torsional & Longitudinal wind effects

4. Soft ware Used

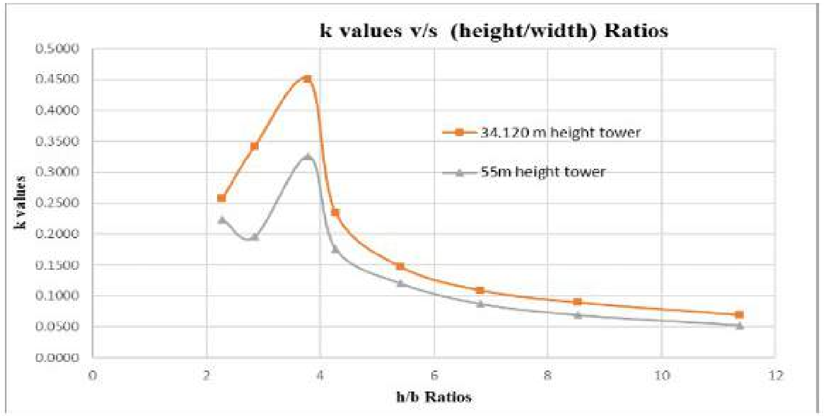
- STAAD Pro for 3D modeling and analysis.

5. GRAPHS.

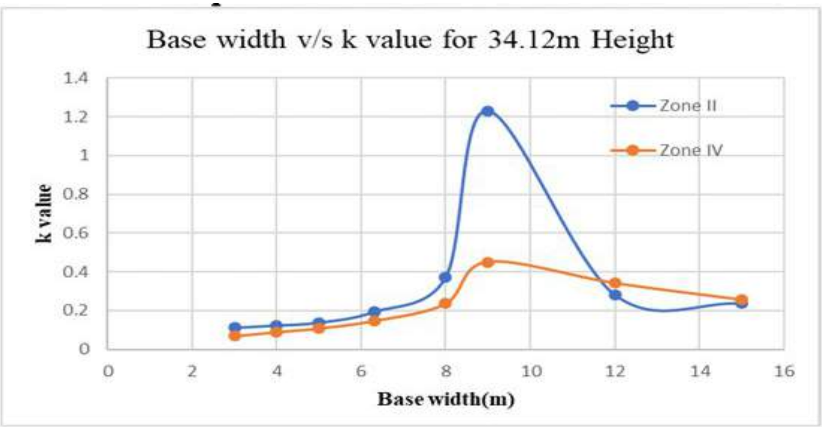
5.1 Graph between k values and base widths for 34.120m and 55m heights.



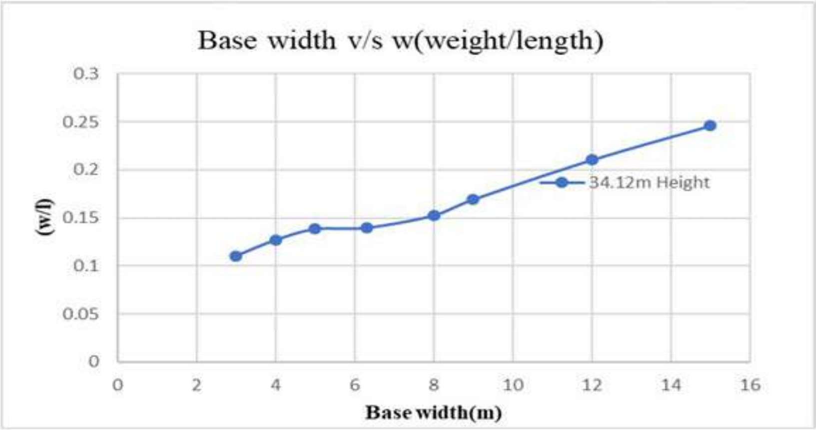
5.2 Graph between k values and height to width ratios for 34.120m and 55m heights.



5.3 Graph between base widths and k values for 34.12m height.

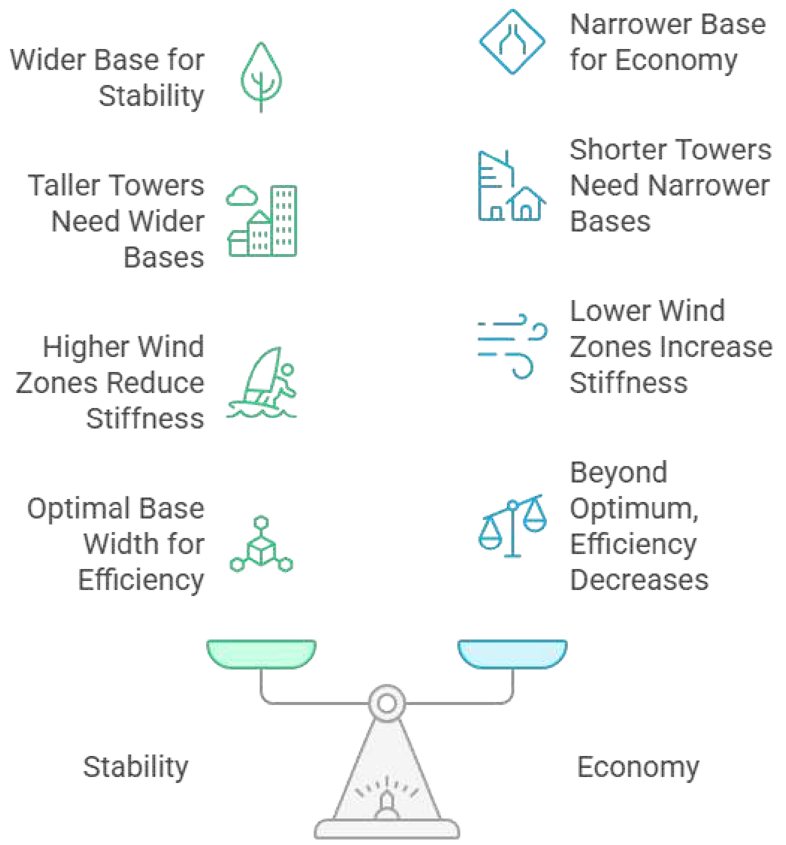


5.4 Graph between base widths and (weight/length) values for 34.12m Height.



Cont.

6. OBSERVATIONS.



- **9 m** for 34.12 m tower (k = 0.45).
- **14.5 m** for 55 m tower (k = 0.345).
- Towers in **higher wind zones (Zone IV)** require **slightly wider bases** for the same height compared to **Zone II**.

7. REASONS.

1. Optimum Stability vs. Economy:

- Wider bases improve tower stability and reduce deflection under wind loads.

2. Height-to-Base Ratio (h/b = 3.79):

- This ratio ensures adequate stiffness while keeping the tower design economical.

3. Wind Zone Adaptability:

- Base widths are chosen to suit different wind zones, increasing slightly for higher wind speeds.
- This provides better resistance to lateral loads without overdesigning for low-wind areas.

Cont.

5.4 - BRACING COMPARASION[4].

1. Tower Specifications.

Type - Self-supporting lattice tower.

Height - 27 m – 55 m (up to 75 m for 500 kV).

Height range - 27 m – 55 m (up to 75 m for 500 kV).

Base Width - 4 m – 10 m (varied for optimization).

Material -

Configuration- K, X, Diamond (D), Single Diagonal, Cross-Diagonal, KD, Y, YD, XBX, Pratt, KX.

2. Loads Considered.

Dead Load, Wind Load, Longitudinal Load, Vertical Load, Seismic Load, Temperature Load and Dynamic Load.

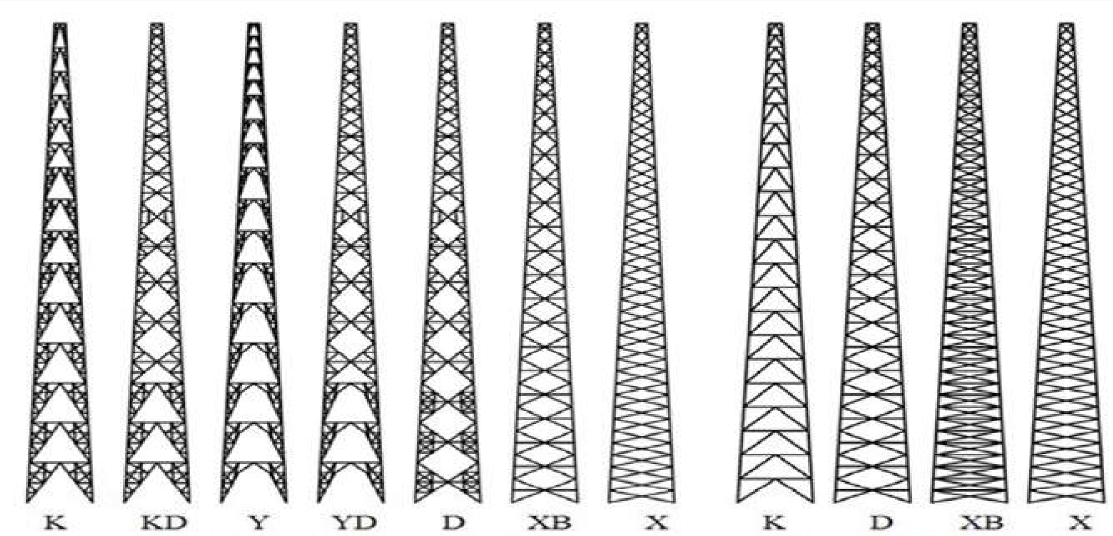
3. Tower Analyses.

- Linear and non linear Static Analysis.

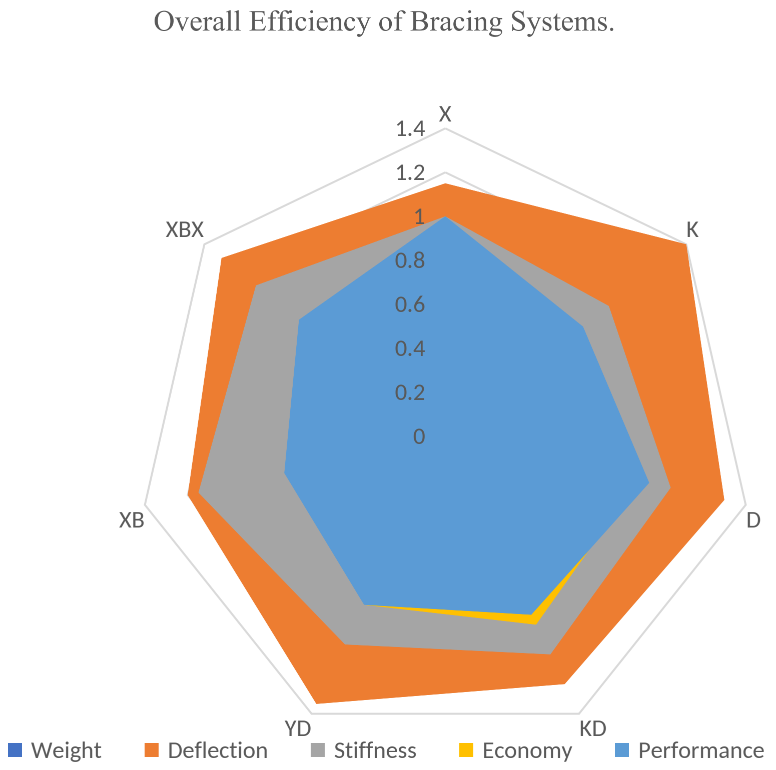
Soft ware Used

- STAAD Pro for 3D modeling and analysis

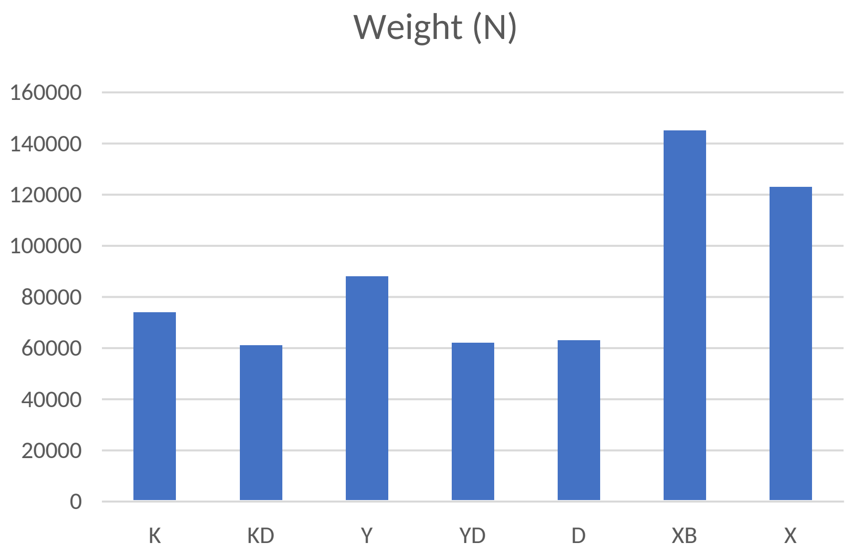
4. Bracing considered.

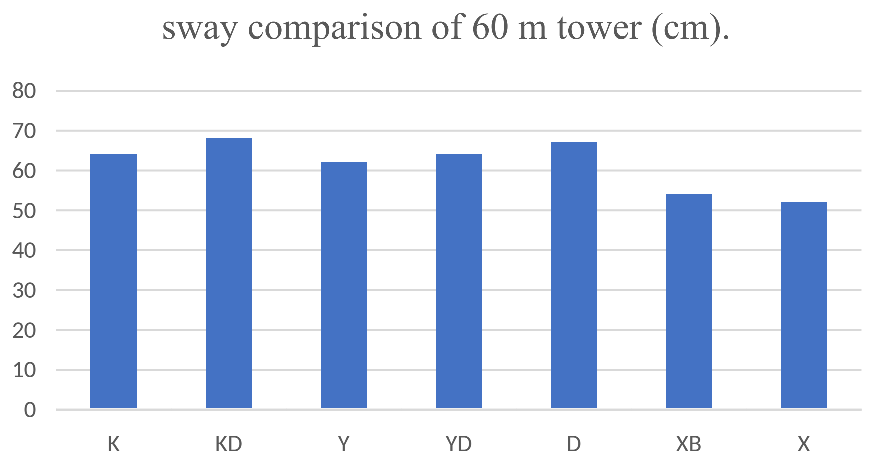


5. GRAPHS.



Radar graphs.





Cont.

6. OBSERVATIONS.

- Bracing configuration governs both economy and stiffness.
- X-bracing generally yields minimum weight and uniform force distribution.
- K-bracing offers higher stiffness but adds steel.
- Diamond (D) and Cross-diagonal are good compromises.
- KD/YD suitable for telecom towers (tall, slender).

7. REASONS.

Bracing	Structural Behaviour	Reason for Efficiency
X-Bracing	Direct tension–compression path; symmetrical load transfer.	Minimum deflection & weight → most economical.
D / Diamond	Secondary diagonal reduces unbalanced forces.	Stable, uniform stress distribution.
K-Bracing	Redundant members, higher stiffness.	Lower deflection but heavier; useful in high-wind zones.
KD / YD	Combined K & diagonal system.	Good economy for tall slender telecom towers.
XBX / Cross-Diagonal	Multiple load paths.	Balanced between stiffness & weight.

5.5 - CODE COMPARASION[5].

1 Tower Specifications.

Type -	220 kV Double-Circuit Lattice Tower
Height -	40 m
Span -	200 m
Base Width-	5.95 m (Square Base)
Material-	Equal-Angle Steel Sections (Mild and High-Tensile Steel)
Configuration-	X-Bracing and K-Bracing Patterns

2 Loads Considered.

- Self-weight (Dead load)
- Conductors & Hardware load
- Wind load on tower and conductors
- Ice/Snow load (if applicable)
- Torsional & Longitudinal wind effects
- Earthquake/Dynamic load
- Cyclonic (gust) load factors (IS 875 Part 3: 2015)
- Load combinations for extreme conditions

3 Tower Analyses.

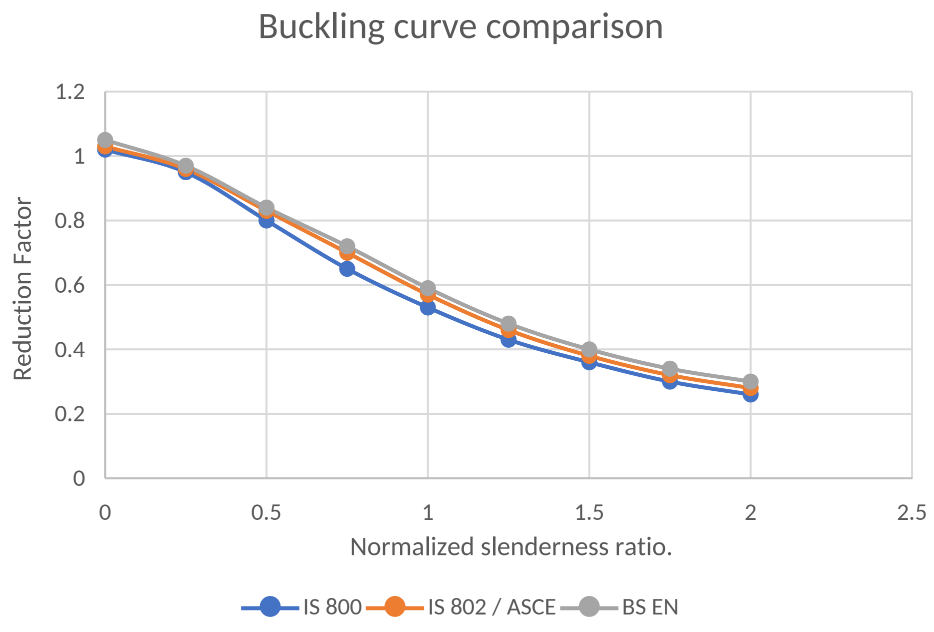
- **Linear Static Analysis** - For base comparison under normal loads.
- **Dynamic Analysis** - Time-dependent and seismic response.

4 Soft ware Used

- STAAD Pro for 3D modeling and analysis
- ANSYS for validation and parametric optimization

5 - GRAPHS.

1



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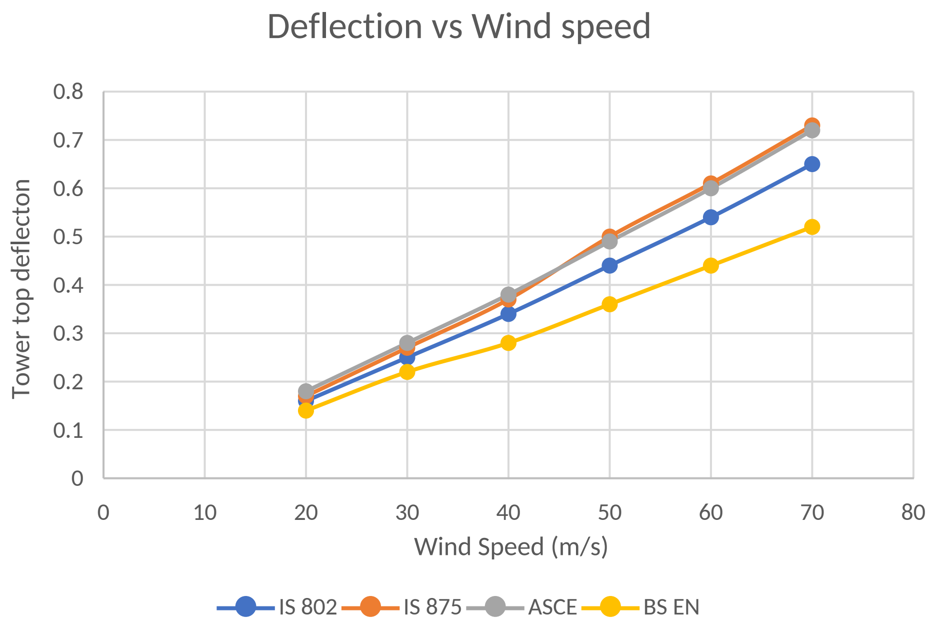


Cont.

6 - OBSERVATIONS

1. **Wind load** is the most critical factor in tower design, especially in cyclone-prone regions.
2. **IS 802 (2015)** needs revision to include **k_4 factor** for cyclonic safety (as adopted in IS 875 (2015)).
3. **IS 802 (2015)** is adequate for normal zones but **unsafe in coastal Wind Zone 5** without modification.
4. **ASCE 10-97/10-15** and **BS EN 1993-3-1** give more accurate and reliable load estimations for extreme winds and slender members.

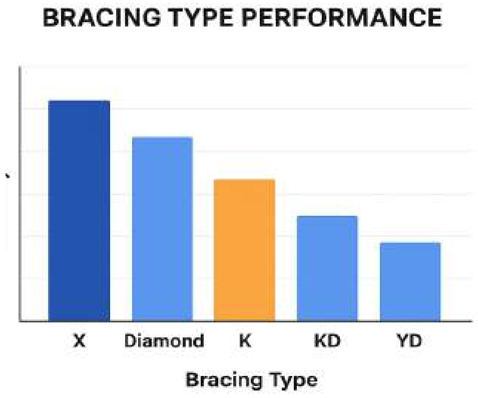
7 - Recommended / Best Code and Reasons.

- **Best Performing Code: IS 875 (Part 3): 2015 + ASCE 10-15 combination** (or IS 802 revised with k_4 factor = 1.3).
- Reasons:
  - Accounts for cyclonic gust effects via importance factor (k_4).
  - Harmonized with international reliability-based design methods.
  - Produces safe, economical, and performance-based results in high wind zones.
  - Reflects current understanding of fluctuating and directional wind loading on lattice towers.

1. Efficient bracings.

X-bracing offers the most efficient balance of stiffness, strength, and economy by uniformly distributing loads and minimizing deflection.

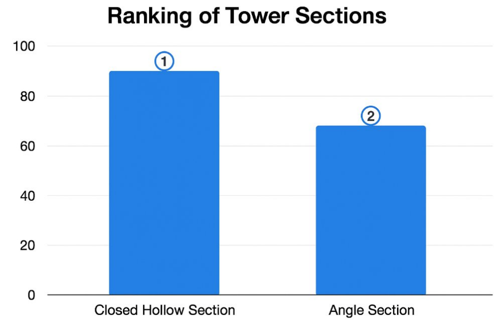
Compared to K, Diamond, and KD patterns, it ensures greater stability with lower steel consumption, making it the most suitable choice for transmission tower design.



2. Efficient section.

Closed hollow sections are more efficient than traditional angle sections, offering higher stiffness and lower deflection under wind and seismic loads.

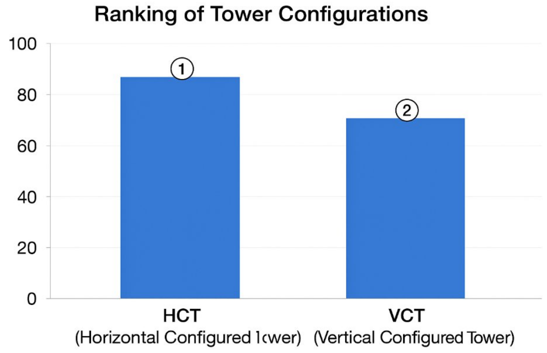
Despite slightly complex fabrication, they provide superior strength-to-weight performance and improved overall structural efficiency.



3. Efficient configuration.

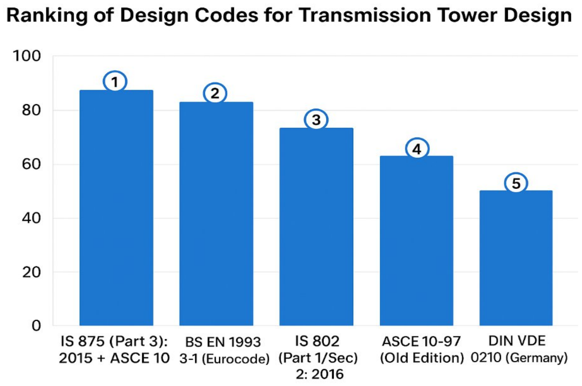
The **horizontal configuration (HCT)** is the most economical and practical design, offering stable performance with lower wind loads.

Although slightly heavier, it allows the use of mild steel instead of high-tensile steel, resulting in significant cost savings.



4. Efficient code for design.

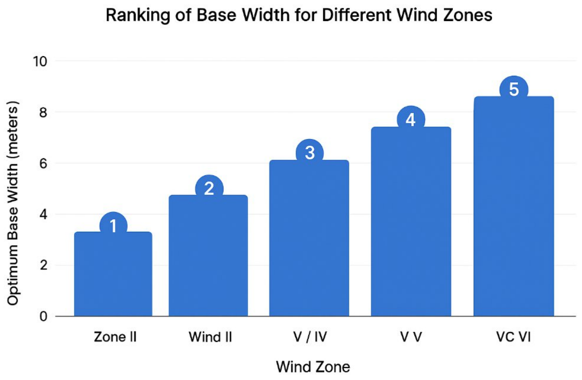
The **IS 875 (Part 3): 2015 + ASCE 10-15** combination ensures safe and economical tower design by incorporating the k_4 factor for cyclonic and directional wind effects. A **revised IS 802** with $k_4 = 1.3$ is essential for achieving reliable performance in coastal and high-wind regions.



5. Efficient base width.

The **optimum base width** depends on tower height and wind zone, balancing both stability and economy.

An ideal **height-to-width ratio** maximizes structural efficiency while minimizing excess steel and cost about **9 m** for **34.12 m towers** and **14.5 m** for **55 m towers** offer the best performance.



[1] *Comparative Study of Four-Legged Lattice Transmission Tower Having Angle and Hollow Sections,* International Journal of Advance Engineering and Research Development (IJAERD), vol. 4, 2017.

[2] Analysis and Design of Vertical and Horizontal Configurations of Cross-Arms in a Transmission Line Tower, IJERT, vol. 4, 2015.

[3] M. N. Shyamenahalli and C. D. M. Determination of Economic Base Width of Transmission Tower for Different Wind Zones, *International Journal of Research in Engineering and Science (IJRES),* vol. 9, 2021.

[4] Abdulaqder M. Tah, Kamiran M. Asilevani, & Mustafa Özaçka. (2017). *Comparison of Various Bracing System for Self-Supporting Steel Lattice Structure Towers. American Journal of Civil Engineering.*

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