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UPPER–STRUCTURE ANALYSIS OF BTS TOWER ON HIGH WIND SPEED AREA TO SUPPORT FUNCTIONAL SUSTAINABILITY

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ABSTRACT

Media transmission (Telcom) tower could be a media transmission building structure that employments a combination of steel outlines as its development fabric. Media transmission towers work as a back for a few media transmission types of gear for transmitting signals that back the cellular communication frameworks that we continuously utilize so remote. Communication. In tower planning, the prevailing powerful stack is wind stack since wind may be a sidelong stack that encompasses a tall affectability to steel development buildings (incorporates a mass that tends to be light). The tallness of the tower that's made depends on the area of the tower itself. The most issue in this inquire about is how to dissect the tower upper–structure in arrange to determine whether it is solid or not to preserve Wind load analysis on BTS (Base Transceiver Station) towers is one of the important aspects in the design of telecommunication tower structures. Wind load can affect the stability and strength of the tower, mainly due to the height of the tower and the nature of the load which tends to change according to the wind speed and the shape of the tower. Study in this research will is about "Upper–Structure Analysis of Bts Tower on High Wind Speed Area to Support Functional Sustainability" as a solution to the problems that often occur in the field and until now still often appear structural infeasibility in the selection of construction systems for BTS Towers planning. Results for anlaysis for each joints are : Anchor Bolt Dimensions : 32 mm X 130 cm X 9 units ; Base Plate Dimensions : 50 cm X 50 cm X 32 mm ; Bolts Dimensions for Anchor Joint Type 1 : 16 mm X 40 mm X 5 units ; Bolts Dimensions for Anchor Joint Type 2 : 16 mm X 40 mm X 4 units ; olts Dimensions for Anchor Joint Type 3 : 16 mm X 40 mm X 5 units ; Bolts Dimensions for Anchor Joint Type 4 : 16 mm X 40 mm X 2 units ; Bolts Dimensions for Anchor Joint Type 5 : 16 mm X 40 mm X 2 units ; Bolts Dimensions for Anchor Joint Type 6 : 16 mm X 40 mm X 2 units ; Couple Plate Dimensions : 60 cm ; Bolts Dimension : L 200 X 15 + L 80 x 8.

Keywords : tower, structure, load, joint, sustain.

INTRODUCTION

Media transmission (Telcom) tower could be a media transmission building structure that employments a combination of steel outlines as its development fabric. Media transmission towers work as a back for a few media transmission types of gear for transmitting signals that back the cellular communication frameworks that we continuously utilize so remote. The improvement of communication innovation in Indonesia is as of now developing quickly. The construction of these towers can be within the frame of tall towers with one recieving wire supplier or brief towers that have numerous recieving wire sets (frequently utilized for shared tower purposes). Subsequently, the innovation engineer builds or re–plans numerous towers to extend the organize or communication flag.

Communication. In tower planning, the prevailing powerful stack is wind stack since wind may be a sidelong stack that encompasses a tall affectability to steel development buildings (incorporates a mass that tends to be light). The tallness of the tower that's made depends on the area of the tower itself. Numerous issues are experienced by the numerous temporary workers with a tower building around the settlement that can collapse at any time, this is often what must be considered in arranging a tower building, we frequently know that a tower can collapse or drop in the event that the tower arranging prepare isn't legitimately dissected considering the area of the tower development is in provincial ranges with moo soil bearing capacity conditions.

The most issue in this inquire about is how to dissect the tower upper–structure in arrange to determine whether it is solid or not to preserve Wind load analysis on BTS (Base Transceiver Station) towers is one of the important aspects in the design of telecommunication tower structures. Wind load can affect the stability and strength of the tower, mainly due to the height of the tower and the nature of the load which tends to change according to the wind speed and the shape of the tower. The following are some common steps in analyzing wind loads on BTS Towers : Determine Wind Location and Zone ; Calculate Basic Wind Speed ; Determine Wind Pressure Coefficient (Cd) ; Calculate Wind Pressure ; Evaluate Structure Stability ; Safety Factor ; Simulation and Modeling. Wind load is calculated based on TIA / EIA – 222 – F Standard. Telecommunication (Telcom) towers can be distinguished by the shape and type of construction. There are four kinds of tower shapes :

1. MT Tower (Mini Tower)
2. SST Tower (Self Supporting Tower)
3. Minipole Tower
4. Monopole Tower

Of the four shapes of tower over the foremost habitually and commonly utilized for arranging BTS Towers, BTS Towers are SST towers. Because the SST tower may be a tower that contains a bar design that's orchestrated and associated to create a outline that stands alone w any other bolster. So it is outlined to be able to acknowledge overwhelming loads such as radio wire loads, cables and stairs (dead stack), people (live stack), seismic tremors and wind. The tallness of the BTS Towers ranges from 20 meters to 120 meters based on the arrange sending arrange by the important cellular merchant, concerning organize scope and transmission frameworks, these two things are too related to the encompassing natural conditions (territory, interferrence, fresnel zone, etc. And based on the sort of area, the tower can be classified into two sorts, that as :

1. Roof Top (Tower that stands on roof of a building).
2. Green Field (Tower that stands directly on the ground).

Figure 1. Green Field SST – 3 Legs BTS Tower at Tiirto Yudo Village by PT. Protelindo – Indosat Company

Study in this research will is about ”Upper–Structure Analysis of Bts Tower on High Wind Speed Area” as a solution to the problems that often occur in the field and until now still often appear structural infeasibility in the selection of construction systems for BTS Towers planning. So that analytical and structural choices are obtained for tower planning that so strong and able to withstand all types of loading according to predetermined constructions standards that used in Indonesia that are : *SNI 8460 : 2017 Persyaratan Perancangan Geoteknik, SNI 1729 : 2020 Spesifikasi Untuk Bangunan Gedung Baja Struktural, SNI 1727 : 2020 Beban Desain Minimum dan Kriteria Terkait untuk Bangunan Gedung dan Struktur Lain, SNI 2847 : 2019 Persyaratan Beton Struktural Untuk Bangunan Gedung, and SNI 1726 : 2012 Tata Cara Perencanaan Gempa Untuk Struktur Bangunan Gedung dan Non Gedung.*

REFERENCES

1. STEEL STRUCTURES AND TOWERS

Steel could be a fabric that's commonly utilized in development. Its fundamental reason is to make the outline of the building as well as to tie other basic components. Steel development has numerous points of interest compared to other building auxiliary materials such as concrete, wood, and the most up to date fabric, composites. (Berman, 2012). One of the buildings that utilize steel structures is the transmitter tower. Transmitter towers used in general can be classified into three sorts, namely :

1. Self-Supporting Tower, could be a tower that features a bar design that's orchestrated and connected to make a outline that stands alone without any other back. There are two sorts of SST towers : three-legged and four-legged.
2. Guyed Tower, could be a sort of tower that's backed by cables that are secured to the ground, this tower is organized on the same pole design as the self-supporting tower, but the guyed tower sort has littler pole measurements.
3. Monopole, could be a sort of tower that comprises of as it were one pole or one post raised specifically into the ground. From its cross area, this sort of monopole tower is partitioned into two sorts, specifically Circular-pole and Tapered-pole.

2. DETERMINING LOCATION AND WIND ZONES

1. Wind Zone Classification : Indonesia has a standard that refers to SNI 1727-2013 on minimum loads for the design of buildings and other structures, where the country is divided into several wind zones with different speeds. These zones need to be considered in the analysis.
2. Site Topography : The height of the place, the contour of the land surface, as well as the presence of other buildings in the vicinity will also affect the wind load.

3. Calculating The Basic Wind Speed

The basic wind speed is determined from applicable standards, for example from climatological data or based on wind zones in SNI or local regulations. This basic wind speed is then multiplied by correction factors that depend on tower height, wind duration, and environmental factors.

4. Determining The Wind Pressure Coefficient (Cd)

The wind pressure coefficient (Cd) is determined by the shape and type of structure. In BTS Towers that are usually triangular or square steel frames, the Cd value can vary depending on the shape and cross-sectional size of the structural elements.

5. Calculating Wind Pressure

Wind pressure is calculated using the basic fluid pressure equation :

$$P = 0.5 \; x \; \rho \; x \; V2 \; x \; Cd \quad (1)$$

Where :

P = Wind pressure (N/m^2)

ρ = Air density (about 1,225 kg/m^3 at sea level)

V = Wind speed (m/s)

Cd = Wind pressure coefficient

6. Wind Load Distribution

Once the wind pressure has been calculated, the wind load acting on the tower needs to be distributed along the height of the tower. Usually, the wind load is taken as a function of height, where the greater load occurs at the top of the tower.

1. Wind Load on Tower Structure The wind load calculation on the tower according to TIA / EIA – 222 – F standard is :

$$F = zq \; x \; Gh \; x \; (Cf \; x \; Ae + \sum (Ca \; x \; Aa) \quad (2)$$

$$F \leq 2qz \; xx \; GH \; x \; Ag \quad (3)$$

2. Wind Load on Antenna The calculation of wind load on a parabolic shape antenna according to TIA / EIA – 222 – F is as follows :

$$Fa = Ca \; x \; Ax \; Kz \; x \; Gh \; x \; v^2 \quad (4)$$

$$Fa = Cs \; x \; Ax \; Kz \; x \; Gh \; x \; v^2 \quad (5)$$

$$M = Cm \; x \; A \; x \; D \; x \; Kz \; x \; Gh \; x \; v^2 \quad (6)$$

7. Evaluation Of Structure Stability

Bending Moment and Shear Force : Wind loads cause bending moments and shear forces on the tower which should be accounted for in the analysis of the strength of the materials and connections of the structure.

Stiffness of Structure : It should be ensured that the tower has sufficient stiffness so that the deformation due to wind load does not exceed the permissible limit.

8. Safety Factor

In the design of a structure, it is necessary to use an appropriate safety factor, which usually depends on the applicable standards. This factor is to ensure that the structure remains safe despite extreme winds that may be greater than calculated.

9. Simulation and Modeling

Numerical analysis and simulation, such as the finite element method, are often used to model the behavior of towers under the influence of wind loads. This helps engineers understand stress distribution and deformation in greater detail.

10. Standards Used

SNI 1727-2013 : Minimum loads for the design of buildings and other structures.

ANSI/TIA-222-G : Standard for the structural design of steel towers and antennas.

RESEARCH METHOD

The MS Tower Analysis Method is a widely used software-based approach for designing and analyzing communication towers, including transmission line towers and telecommunication (BTS) towers. MS Tower, developed by PLS-CADD (Power Line Systems), offers structural analysis, optimization, and design solutions for lattice towers and pole structures. Here’s a breakdown of the analysis method used in MS Tower :

1. Input Data Requirements

To perform the analysis of a tower in MS Tower, several data inputs are required :

1. Tower Geometry : The overall dimensions, member details, and lattice structure configuration (triangular, square, etc.).
2. Member Properties : Cross-sectional properties of tower members, such as area, moment of inertia, and material properties (steel grade, Young's modulus, etc.).
3. Loading Conditions : Includes self-weight, environmental loads (wind, snow, ice), and dynamic loads such as earthquake or vibration from wind.

2. Load Cases and Combinations

MS Tower allows for multiple load cases to be defined, such as :

1. Dead Load (Self-Weight) : The gravitational force due to the mass of the tower and any attached equipment.
2. Wind Load : Wind pressure acting on tower faces, calculated using various standards (such as ASCE, Eurocode, or SNI). Wind loads vary depending on tower height, region, and structure type.
3. Seismic Load : In seismic regions, earthquake forces can be applied based on design codes.
4. Ice and Snow Load : For cold climates, ice accumulation or snow load needs to be considered.

Load combinations such as wind + dead load, or wind + earthquake, are set up to simulate real-world conditions. The software automatically combines these loads to find the critical conditions.

3. Buckling Analysis

For lattice towers, particularly slender members, buckling is a major concern. MS Tower performs buckling analysis to check whether members will fail due to compressive forces. This is done by calculating the critical buckling load for each member and comparing it with the actual applied loads.

4. Design Optimization

One of the key features of MS Tower is its ability to optimize the tower design. After the analysis, the software can suggest changes to member sizes, materials, or configurations to reduce the overall weight or cost of the tower while maintaining structural integrity and safety. Optimization parameters include : Minimum Weight (Reducing the overall material usage) ; Cost Efficiency (Finding the balance between material costs and structural strength) ; Safety Margins (Ensuring that all members have sufficient factors of safety under all load conditions).

5. Deflection and Stability Checks

MS Tower evaluates the maximum deflections of the tower under each load case to ensure that the structure remains within allowable deflection limits. Excessive deflections can lead to failure of connections or antennas mounted on the tower. Stability checks include :

1. Overall Tower Deflection : Ensuring the structure remains stable and does not sway excessively.
2. Member Deflection : Checking individual members for bending or deformation.

6. Reporting and Documentation

Once the analysis is complete, MS Tower generates detailed reports on :

1. Member Forces and Stresses : The internal forces, stresses, and moments in each member.
2. Deflection and Displacement : Nodal displacements and overall deflection of the structure.
3. Safety Factors : The factor of safety for each member, indicating how much reserve capacity exists before failure.

7. Summary of Ms Tower Analysis Process

1. Input Tower Data : Geometry, material properties, and loads.
2. Define Load Cases : Dead load, wind load, seismic load, etc.
3. Perform Finite Element Analysis : Solve the global stiffness matrix to find member forces and deflections.
4. Check Buckling and Stresses : Ensure members do not fail under compression or excessive stress.
5. Optimize Design : Adjust member sizes and materials to achieve cost efficiency and strength.
6. Code Compliance : Verify the design against international or local standards.
7. Reporting : Generate documentation of the analysis and design.

The MS Tower Analysis Method is a comprehensive tool for structural engineers to design and optimize communication towers. It leverages finite element analysis, buckling checks, load combinations, and optimization techniques to ensure safe, cost-effective, and compliant tower designs.

RESULTS AND DISCUSSION

1. 3 LEGS BTS TOWER DIMENSION PLAN

The design basis of the tower applied is TIA/EIA–222-F standard "Structural Standards for Steel Antenna Tower and Antenna Supporting Structure." The fabrication and materials of the tower will be according to the relevant Indonesian Standard and / or Japanese Industrial Standard. The self-supporting tower has Angular legs cross sections. All bracings are made of equal legs angle steel. All the connections in the field are made with Steel Bolts, each fitted with one spring washer and nut. Structural design of self supporting tower shown in the following Table 1 :

Table 1. Legs BTS Tower Dimension Plan

```
Height                  = 60 meter
Basic wind speed        = 120 km/hour  = 33.3 m/sec
Operational wind speed  = 84 km/hour   = 23.3 m/sec
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- ✓ Maximum sway = 0.5°
- ✓ Maximum twist = 0.5°
- ✓ Maximum displacement = H/200

} At operational wind speed

- ✓ Tower verticality = H/2000

Source : Data Analysis

2. LOAD CARRIED

According to EIA Standard EIA – 222 – F, only the following load combination shall be investigated when calculating the maximum member stresses and structure reactions. The unit stresses in the structure members do not exceed the allowable unit stresses for the materials as specified in the EIA Standard EIA – 222 – F. Load design of the tower shown in the following Table 2 :

Table 2. Load Carried by Tower Structure

Type of Antenna	Dimension of Antenna (m)	Mass (kg)	Quantity (Pcs)	Elevation (m)
GSM 2G	2.580x0.262x0.116	19	6	58.5
GSM 3G	1.314x0.155x0.070	6.2	6	58.5
Microwave	Ø 0.6	20	6	58.5

Source : Data Analysis

3. MATERIALS

Steel materials to be used for the tower and appurtenances conform to the relevant Indonesian standards and or Japanese Industrial Standard. Steel materials to be used for the tower shown in the following Table 3 :

Table 3. Materials to be Used by Tower Structure

Type of Material	Standard	Grade
Steel Shape & Plate	ASTM A36 / JIS G3101	fy = 245 Mpa
Bolt & Nuts	ASTM A325 / JIS B1180	fy = 560 Mpa
Anchor Bolts	ASTM A307	fy = 240 Mpa
Steel Pipes	ASTM A53 / JIS G3444	fy = 235 Mpa
Welding	AWS D1.1 E60XX	fy = 345 Mpa
Hot dip galvanized	ASTM A123	75 micron thicness

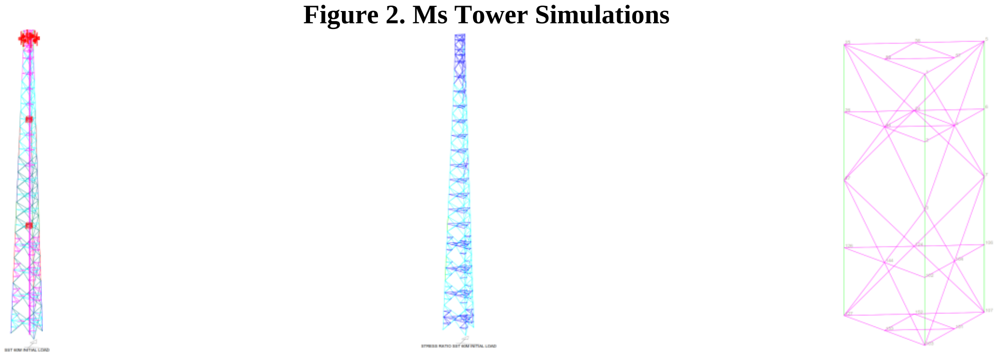
Source : Data Analysis

4. ANALYSIS ON MS TOWER SOFTWARE

The purpose of structural analysis is to find the joint translations the design axial loads in all members of the tower. Loads are applied and separate load cases combined to give the most severe design conditions at various section.

The analysis for the wind load in the tower is made by MS. Tower software. The program will perform static analysis of a space truss of arbitrary geometry by the stiffness method. The truss may be subjected to loads consisting of forces acting on the joints in any directions in space. The program output consists of the joint translations, the member forces and the support reactions. Load analysis on Ms Tower Software of self supporting tower shown in the following Figure 2 :

Figure 2. Ms Tower Simulations



Source : Data Analysis

5. MAXIMUM LOADING RESULTS THAT OCCUR IN MS TOWER SOFTWARE

In Ms Tower software, the maximum loading results typically refer to the highest value of forces or displacements that occur during the analysis of a structural model under various load cases. These results are crucial for identifying the peak demands on a structure, such as maximum bending moments, shear forces, axial forces, or deflections.

These results are essential for evaluating the structural safety, stability, and performance under extreme conditions shown in the following Table 4 :

Table 4. Load Carried by Tower Structure

Maximum stress ratio				
a.	Leg	= 0.989	< 1.0	Panel 16
b.	Bracing	= 0.905	< 1.0	Panel 9
c.	Horizontal	= 0.486	< 1.0	Panel 18
d.	Redundant	= 0.941	< 1.0	Panel 17
e.	Hip	= 0.069	< 1.0	Panel 18
Maximum slenderness				
a.	Leg	= 115	< 150	Panel 3
b.	Bracing	= 196	< 200	Panel 9
c.	Horizontal	= 192	< 250	Panel 14
d.	Redundant	= 244	< 250	Panel 17
e.	Hip	= 195	< 250	Panel 18
Maximum Twist, Sway & displacement				
a.	Twist & Sway	= 0.3594	< 0.50	
b.	Displacement	= 0.2071	< h/200 = 0.30 m	
Maximum Support Reaction				
a.	Compress	= 786.893 kN		
b.	Uplift	= 616.739 kN		
c.	Horizontal Force	= 75.298 kN		

Source : Data Analysis

6. Anchor Bolts

The calculation results for the shear force and tension force on the anchor bolts indicate safe resistance values, demonstrating the capability to withstand the tower's load, as follows :

Table 5. Anchor Bolts Analysis

CHECKING

☞ shear

$$fv = \frac{P\ horizontal}{As\ tot} = \frac{10304.485}{57.272495} = \mathbf{179.92}\ kg/cm^2 < \mathbf{958}\ kg/cm^2 \quad \underline{\textbf{OK}}$$

☞ CheckingTension

Fts = 1.4 Ft - 1.6 fv
= 2681.28 - 287.873
= 2393.407 kg/cm^2

Take smaller value beetween Fts and Ft
used Ft = 1915 kg/cm^2

$$ft = \frac{P\ tension}{As\ tot} = \frac{82502.653}{57.272495} = \mathbf{1440.53}\ kg/cm^2 < \mathbf{1915}\ kg/cm^2 \quad \underline{\textbf{OK}}$$

☞ combined tension and shear load

$$\frac{fv}{Fv} + \frac{ft}{Ft} = \frac{179.92}{957.6} + \frac{1440.53}{1915.2}$$
$$= 0.18789 + 0.75216 = \mathbf{0.940} < \mathbf{1} \quad \underline{\textbf{OK}}$$

☞ Length of anchor bolt

Shear pons (Fcv)
Fcv = 10 kg/cm^2

Le min = 2 x 0.06 x D x fy
= 921.6 mm
= 92.16 cm

$$Le = \frac{P\ tension}{Fcv\ .\ N\ .\ p.D} = \frac{82502.653}{904.32} = \mathbf{91.232}\ cm$$

use for anchor dimension 9 ϕ 32 mm L= 130 cm

Source : Data Analysis

Shear Force	: 179,920 kg/cm^2	< 958,000 kg/cm^2	➔ Ok
Tension Force	: 1.440,530 kg/cm^2	< 1.915,000 kg/cm^2	➔ Ok
Combined Tension and Shear	: 0,940	< 1	➔ Ok

7. Base Plate

The calculation results for the tension force and momen force on the base plate indicate safe resistance values, demonstrating the capability to withstand the tower's load, as follows :

Table 6. Base Plate Analysis

$$W = \frac{a \times tp^2}{6}$$

$$_{all}\sigma_F = 0.66xFyx1.33 \quad (\text{JIS SM 490 YA})$$
$$= 3177\ kg/cm^2$$

$$all\sigma F = \frac{M}{W}$$

$$3177 = \frac{58668.6}{(12.4 \times tp^2)/6}$$

$$tp = \sqrt{\frac{6 \times 58668.6}{12.4 \times 3177}}$$

$$= 2.989\ cm$$

used base plate dimension 50 x 50 x 3.2 cm

Source : Data Analysis

Tension Force	: 65,360 kg/cm^2	< 42,800 kg/cm^2	➔ Ok
Momen Force	: 58.668,600 kg/cm^2	< Plate Thickness 2,989 cm	➔ Ok

8. Anchor Joint Type 1

The calculation results for the bolt shear capacity, bolt bearing capacity, and bolt shear force on the anchor joint type 1 indicate safe resistance values, demonstrating the capability to withstand the tower's load, as follows :

Table 7. Anchor Joint Type 1 Analysis

Force 2	=	31.791	kN										
	=	3243.98	kg										
Bolt Shear Capacity													
Fv	=	n	x	A	x	0.3	x	Fy	x	1.33			
	=	1	x	2.01	x	0.3	x	5600	x	1.33			
	=	4491.14	kg										
Bearing Capacity													
Fp	=	Øbolt	x	t	x	1.2	x	Fu	x	1.33			
	=	1.60	x	1.60	x	1.2	x	4000	x	1.33			
	=	16343	kg										
Ratio of the bolt													
	=	F / nbolt x Min(Fv,Fp)				=	0.361						
Check Gusset Plate													
A_{netto}	=	(L x t) - (Øhole x nbolt x t)											
	=	(9.6 x 1.6) - (1.8 x 1.5 x 1.6)											
	=	11.04	cm^2										
Fv	=	0.4	x	Fy	x	1.33	x	A_{netto}					
	=	0.4	x	2450	x	1.33	x	11.04					
	=	14389.5	kg	>	3243.98	kg	OK						

Source : Data Analysis

Bolt Shear Capacity : 3.243,980 Kg

Bolt Bearing Capacity : 14.389,500 Kg

Bolt Shear Force < Bolt Bearing Force ➔ Ok

9. Anchor Joint Type 2

The calculation results for the bolt shear capacity, bolt bearing capacity, and bolt shear force on the anchor joint type 2 indicate safe resistance values, demonstrating the capability to withstand the tower's load, as follows :

Table 8. Anchor Joint Type 2 Analysis

Force 2	=	31.791	kN										
	=	3243.98	kg										
Bolt Shear Capacity													
Fv	=	n	x	A	x	0.3	x	Fy	x	1.33			
	=	1	x	2.01	x	0.3	x	5600	x	1.33			
	=	4491.14	kg										
Bearing Capacity													
Fp	=	Øbolt	x	t	x	1.2	x	Fu	x	1.33			
	=	1.60	x	1.60	x	1.2	x	4000	x	1.33			
	=	16343	kg										
Ratio of the bolt													
	=	F / nbolt x Min(Fv,Fp)				=	0.361						
Check Gusset Plate													
A_{netto}	=	(L x t) - (Øhole x nbolt x t)											
	=	(9.6 x 1.6) - (1.8 x 1.5 x 1.6)											
	=	11.04	cm^2										
Fv	=	0.4	x	Fy	x	1.33	x	A_{netto}					
	=	0.4	x	2450	x	1.33	x	11.04					
	=	14389.5	kg	>	3243.98	kg	OK						

Source : Data Analysis

Bolt Shear Capacity : 160,714 Kg

Bolt Bearing Capacity : 1.016,650 Kg

Bolt Shear Force < Bolt Bearing Force → Ok

10. Anchor Joint Type 3

The calculation results for the bolt shear capacity, bolt bearing capacity, and bolt shear force on the anchor joint type 3 indicate safe resistance values, demonstrating the capability to withstand the tower's load, as follows :

Table 9. Anchor Joint Type 3 Analysis

Force 2	=	27.32	kN
	=	2787.76	kg

Bolt Shear Capacity

Fv	=	n	x	A	x	0.3	x	Fy	x	1.33
	=	1	x	1.13	x	0.3	x	5600	x	1.33
	=	2524.87	kg							

Bearing Capacity

Fp	=	Øbolt	x	t	x	1.2	x	Fu	x	1.33
	=	1.20	x	1.60	x	1.2	x	4000	x	1.33
	=	12257.3	kg							

Ratio of the bolt

$$= \frac{F}{\text{nbolt x Min(Fv,Fp)}} = 0.552$$

Check Gusset Plate

A_{netto}	=	(L x t) - (Øhole x nbolt x t)								
	=	(6 x 1.6) - (1.4 x 1.5 x 1.6)								
	=	6.24	cm^2							
Fv	=	0.4	x	Fy	x	1.33	x	A_{netto}		
	=	0.4	x	2450	x	1.33	x	6.24		
	=	8133.22	kg	>		2787.76	kg		OK	

Source : Data Analysis

Bolt Shear Capacity : 2.787,760 Kg

Bolt Bearing Capacity : 8.133,220 Kg

Bolt Shear Force < Bolt Bearing Force → Ok

11. Anchor Joint Type 4

The calculation results for the bolt shear capacity, bolt bearing capacity, and bolt shear force on the anchor joint type 4 indicate safe resistance values, demonstrating the capability to withstand the tower's load, as follows :

Table 10. anchor bolts analysis

Force 1	=	28.878	kN
	=	2946.73	kg

Bolt Shear Capacity

Fv	=	n	x	A	x	0.3	x	Fy	x	1.33
	=	1	x	1.13	x	0.3	x	5600	x	1.33
	=	2524.87	kg							

Bearing Capacity

Fp	=	Øbolt	x	t	x	1.2	x	Fu	x	1.33
	=	1.2	x	0.80	x	1.2	x	4000	x	1.33
	=	6128.64	kg							

Ratio of the bolt

$$= \frac{F}{nbolt \times Min(Fv,Fp)} = 0.584$$

Check Gusset Plate

A_{netto} = (L x t) - (Øhole x nbolt x t)
= (6 x 0.8) - (1.4 x 1.5 x 0.8)
= 3.12 cm^2

Fv = 0.4 x Fy x 1.33 x A_{netto}
= 0.4 x 2450 x 1.33 x 3.12
= 4066.61 kg > 2946.73 kg OK

Source : Data Analysis

Bolt Shear Capacity : 2.946,730 Kg

Bolt Bearing Capacity : 4.066,610 Kg

Bolt Shear Force < Bolt Bearing Force ➔ Ok

12. Anchor Joint Type 5

The calculation results for the bolt shear capacity, bolt bearing capacity, and bolt shear force on the anchor joint type 5 indicate safe resistance values, demonstrating the capability to withstand the tower's load, as follows :

Table 11. anchor bolts analysis

Bolt Shear Capacity

Fv = n x A x 0.3 x Fy x 1.33
= 1 x 1.13 x 0.3 x 5600 x 1.33
= 2524.87 kg

Bearing Capacity

Fp = Øbolt x t x 1.2 x Fu x 1.33
= 1.2 x 0.60 x 1.2 x 4000 x 1.33
= 4596.48 kg

Ratio of the bolt

$$= \frac{F}{nbolt \times Min(Fv,Fp)} = 0.076$$

Check Gusset Plate

A_{netto} = (L x t) - (Øhole x nbolt x t)
= (2 x 0.6) - (1.4 x 0.5 x 0.6)
= 0.78 cm^2

Fv = 0.4 x Fy x 1.33 x A_{netto}
= 0.4 x 2450 x 1.33 x 0.78
= 1016.65 kg > 190.918 kg OK

Source : Data Analysis

Bolt Shear Capacity : 190,918 Kg

Bolt Bearing Capacity : 1.016,650 Kg

Bolt Shear Force < Bolt Bearing Force ➔ Ok

13. Anchor Joint Type 6

The calculation results for the bolt shear capacity, bolt bearing capacity, and bolt shear force on the anchor joint type 6 indicate safe resistance values, demonstrating the capability to withstand the tower's load, as follows :

Table 12. anchor bolts analysis

Force 1 = 1.871 kN
= 190.918 kg

Bolt Shear Capacity

Fv = n x A x 0.3 x Fy x 1.33
= 1 x 1.13 x 0.3 x 5600 x 1.33
= 2524.87 kg

Bearing Capacity

Fp = Øbolt x t x 1.2 x Fu x 1.33
= 1.2 x 0.60 x 1.2 x 4000 x 1.33
= 4596.48 kg

Ratio of the bolt

$$= \frac{F}{\text{nbolt x Min(Fv,Fp)}} = 0.076$$

Check Shear Plate

A_{netto} = (L x t) - (Øhole x nbolt x t)
= (2.5 x 0.6) - (1.4 x 0.5 x 0.6)
= 1.08 cm^2

Fv = 0.4 x Fy x 1.33 x A_{netto}
= 0.4 x 2450 x 1.33 x 1.08
= 1407.67 kg > 190.918 kg OK

Source : Data Analysis

Bolt Shear Capacity : 190,918 Kg

Bolt Bearing Capacity : 1.407,670 Kg

Bolt Shear Force < Bolt Bearing Force ➔ Ok

14. COUPLE JOINT

The calculation results for the momen force on plate, momen bearing on plate, bolt shear capacity, bolt bearing capacity, bolt shear capacity, bolt bearing capacity, and bolt shear force on the couple joint indicate safe resistance values, demonstrating the capability to withstand the tower's load, as follows :

Table 13. anchor bolts analysis

$$I\ net = \frac{1}{12}\ 1.6\ \ 10^{3} - 2 \times 1.8 \times 1.6 \times 2.5^{2}$$

= 97.333 cm^4

W net = I net / y = 19.47 cm^3

A net = 10.24 cm2

Momen = (L/2) * d

= 2245.13 x 5.5 = 12348.2 kgcm

$$s = \frac{M}{W\ net} = 634.326 \text{ kg/cm2}$$

$$\tau = \frac{L/2}{A\ net} = 219.251 \text{ kg/cm2}$$

$$\sigma i = \sqrt{634.326^{2} + 3\ (\ 219.251\ )^{2}}$$

= **739.312** kg/cm2 < **1600** kg/cm2

Design of Bolt

Force on Bolt due to Moment = 12348.2 / 5 = 2469.64 kg
Force on Bolt due to Shear = 2245.1 / 2 = 1122.56 kg

$$F\ bolt = \sqrt{2469.64^2 + 1122.56^2}$$

$$= 2712.8\ kg$$

Shear bolt Capacity

$$\tau = 0.6 \times \sigma$$

$$= 2218\ kg/cm^2$$

$$\overline{\tau}baut = 1 \times 1/4\ \pi\ d^2 \times \tau$$

$$= 4456.49\ kg > 2712.80\ kg \quad \textbf{OK}$$

Bearing bolt capacity

$$\sigma = 1.2 \times \sigma$$

$$= 1978\ kg/cm^2$$

$$\sigma_{tu} = \varnothing \times t \times \sigma_{tu}$$

$$= 5063.63\ kg > 2712.80\ kg \quad \textbf{OK}$$

Source : Data Analysis

Momen Force on Plate : 739,312 Kg/cm^2

Momen Bearing on Plate : 1.600,000 Kg/cm^2

Bolt Shear Capacity < Bolt Bearing Capacity ➔ Ok

Bolt Shear Capacity : 2.712,800 Kg

Bolt Bearing Capacity : 5.063,630 Kg

Bolt Shear Force < Bolt Bearing Force ➔ Ok

CONCLUSSION

1. This study concludes the following design requirements for a 3 Legs BTS Tower capable of withstanding the applied loads : Anchor Bolt Dimensions : 32 mm X 130 cm X 9 units, Base Plate Dimensions : 50 cm X 50 cm X 32 mm, Bolts Dimensions for Anchor Joint Type 1 : 16 mm X 40 mm X 5 units, Bolts Dimensions for Anchor Joint Type 2 : 16 mm X 40 mm X 4 units, Bolts Dimensions for Anchor Joint Type 3 : 16 mm X 40 mm X 5 units, Bolts Dimensions for Anchor Joint Type 4 : 16 mm X 40 mm X 2 units, Bolts Dimensions for Anchor Joint Type 5 : 16 mm X 40 mm X 2 units, Bolts Dimensions for Anchor Joint Type 6 : 16 mm X 40 mm X 2 units, Couple Plate Dimensions : 60 cm ; Bolts Dimension : L 200 X 15 + L 80 x 8.
2. The research on the "Upper-Structure Analysis of BTS Tower in High Wind Speed Area to Support Functional Sustainability" highlights the critical importance of designing telecommunication towers that are both structurally robust and functionally reliable in extreme environmental conditions with the findings underscore several key implications
3. Enhanced Structural Resilience : High wind speed areas impose significant dynamic and static loads on the upper structures of BTS Towers. The study provides insights into the behavior of the tower under such conditions, emphasizing the necessity for materials and designs that ensure resilience against these loads to prevent structural failure.
4. Operational Continuity :By analyzing the functional sustainability, the research connects structural integrity with uninterrupted service delivery, which is vital in telecommunications, especially during adverse weather events when communication is most needed.
5. Economic and Safety Considerations : Failures in high wind speed areas can lead to costly repairs and pose risks to human safety. The study informs stakeholders about the importance of preventive design improvements to reduce long-term operational and maintenance costs.

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