Tower Engineering & Analysis

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Tower Engineering & Analysis

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Standards and Building Codes

- Building Codes are legal, standards are not. Standards must be referenced by the governing building code to be legally binding.
- Current Tower Engineering & Analysis Standards
  - TIA-222-H currently most widely adopted by building codes, took effect in 2006
  - TIA-222-I took effect on January 1, 2024, but not adopted by many building codes yet.
- Standard Changes
  - TIA-222-F (1996) to TIA-222-G (2006): Drastic overhaul of previous standard, introduced new wind speed and ice maps, new classification system, exposure categories, topographic effects…wind loads increased 10% to 30%+ in some locations.
  - TIA-222-G (2006) to TIA-222-H (2017): Change not as impactful as previous update, refined wind speed and ice maps, refinement and consistency with current building codes, minor changes to loading, general slight reduction in wind loading.
  - TIA-222-H (2017) to TIA-222-I (2024): Tornado loading for Risk Category III and IV structures stronger focus on mounts and mount-tower interface, expanded focus on when to analyze existing towers, generally same loading as TIA-222-H.
- Currently Adopted Building Codes
  - Washington DC: Currently using 2015 International Building Code, references TIA-222-G
  - Maryland and Virginia: Currently using 2021 International Building Code, references TIA-222-H
  - Most jurisdictions have their own supplements/amendments to these building codes

Risk Categorization

- Risk Categorization…defines how important a structure (tower, mount, etc) is, typically decided between discussions with structure owner and engineer.
- Risk Category (I, II, III, and IV) grouping:
  - Risk Category I: Agricultural facilities, certain temporary facilities, minor storage facilities.
  - Risk Category II: Normal structures with redundancy, structures that due to use or location represent a moderate risk to human life and/or damage to surrounding facilities in the event of failure.
  - Risk Category III: Applies to communication structures that in the event of their collapse could impact surrounding facilities that support operations that are necessary for day-to-day civilian life or when the services provided by a communication structure for such operations are not available by other means and there is a contractual agreement to provide and maintain a hardened communication site.
  - Risk Category IV: Applies to communication structures where a failure may impact an entire community as opposed to a failure that would have a limited local impact.
- The higher the risk categorization, the higher the wind, ice, and seismic loading (greater recurrence interval).
  - Risk Category I, II, III, and IV: 300 year, 700 year, 1,700 year, and 3,000 year return periods.
  - Latest TIF White Paper: Risk Categorization in Accordance with ANSI/TIA-222-H: https://tifonline.org/wp-content/uploads/2022/09/White-Paper-Risk-Categorization-in-Accordance-with-ANSITIA-222-H.pdf

Tower and Foundation Analysis

- What is a communication tower? A structure that's primary purpose is to support antennas and other wireless communication equipment.
- What is a foundation? The structural base of the tower, typically constructed below ground, that transfers loads into the soil and keeps the tower stable.
- Common tower types include:
  - Monopoles: Single-pole structure (large cantilever beams).
  - Self-Supporting Towers: Freestanding lattice towers that do not require guy wires.
  - Guyed Towers: Typically tall towers stabilized with tensioned guy wires anchored to the ground.
- The design and analysis of communication towers is governed by TIA-222.
- TIA-222 provides procedures on:
  - Determining environmental loads such as wind, ice, and earthquakes.
  - Defining acceptable tower movement, including deflection, sway, and twist.
  - Calculating the strength of tower components, including structural members (legs and bracing), connections (bolts and welds) and foundations.
- Loading determined by TIA-222 is applied to a 3D model to determine forces in members, connections, and base/foundation, and then those forces are checked against the member's capacities in determining their demand-capacity ratio (towers with 100% demand-capacity ratio are at capacity under those design loads, etc).

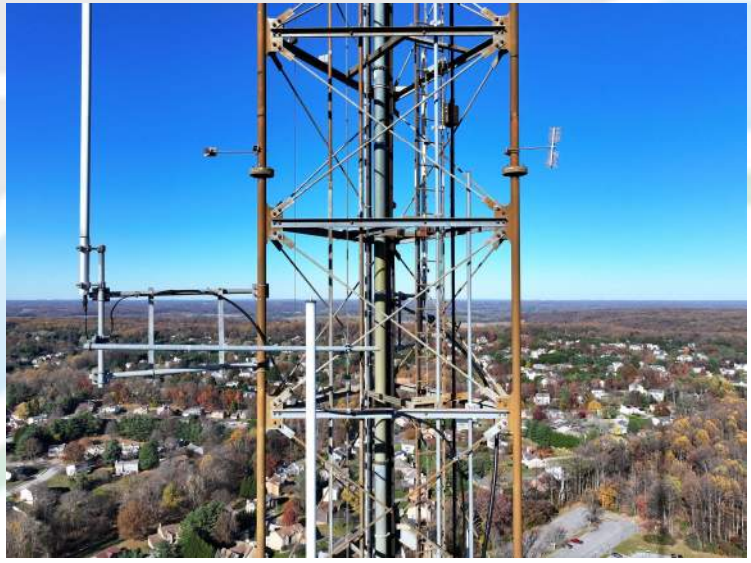
Tower Types

Foundation Types

Mount Analysis

- What is a mount analysis? Gained nationwide attention circa 2013, with larger commercial wireless carrier equipment (i.e. RRHs) being installed. Became nationally accepted circa 2017 and formally introduced through TIA-5053. A formal mount analysis/design section was issued as part of TIA-222-H.
- What is a mount? The structure that connects an antenna/RRH/TMA/etc to the tower is considered the mount…aka sector frames, platforms, sidearms, standoffs, etc.
- Specific loading requirements for climbing loads, more sensitive to localized loads than broader tower analysis.
- Beware! Easy to order mounts from catalog (pull from TESSCO or Talley), but many of these mounts have little to no engineering backing, especially for loading required by current standards. Smaller tenants often have limited budgets and don't have funding for a mount analysis, but we always recommend an engineer at least review before ordering off-the-shelf components.
- Good rules of thumb regarding typical mounts you're familiar with, specifically sidearms:
  - Should have two rails (not one single standoff)
  - At least one well-triangulated tieback (sometimes two, for long omni/dipole antennas)
  - Long omni and dipole antennas should have top stabilizers to reduce mount demand
- Current standards are less reliant on friction-type connections that rely on connection tightness, hard to quantify and check adequacy, tiebacks will be more dependent in upcoming standard releases.

Mount Types

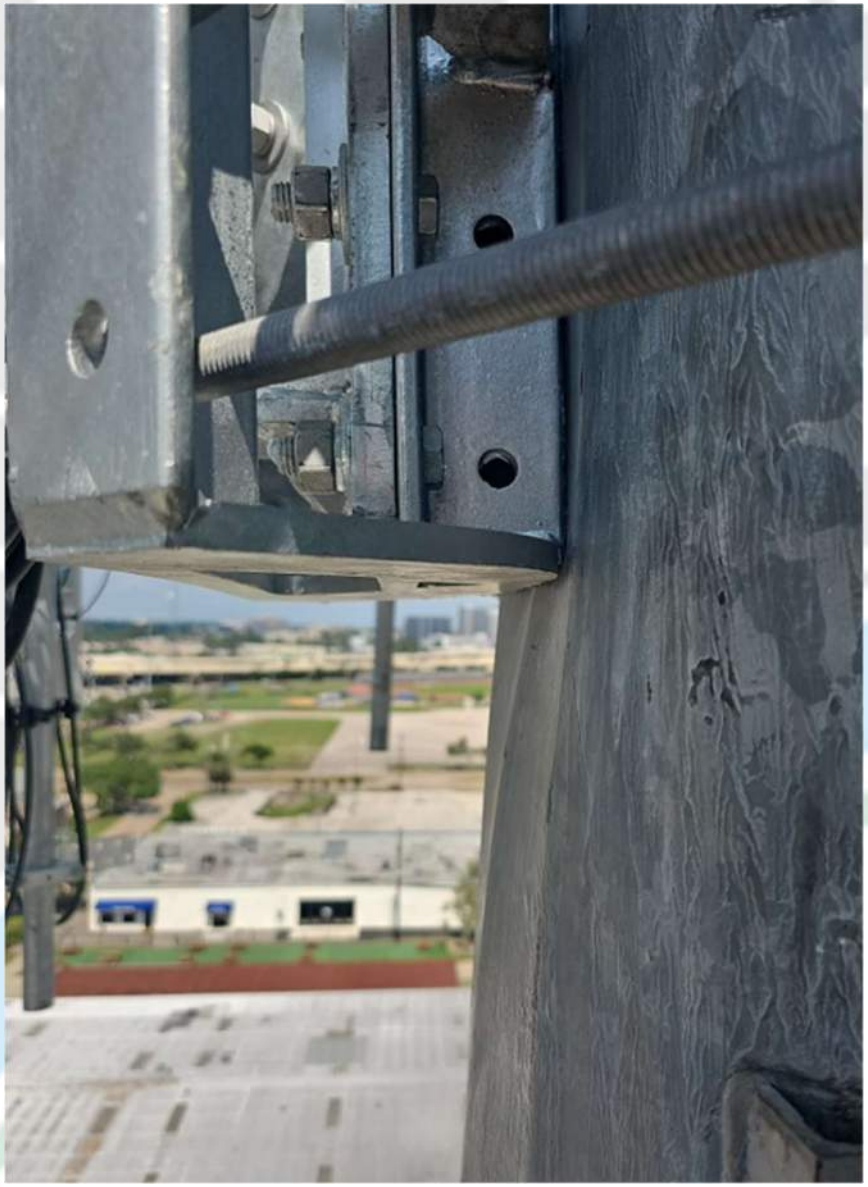


Mount Types (Cont'd)

Mount-Tower Interface Analysis

- What is this? Became nationally recognized in TIA-222-H, further elaborated upon in TIA-222-I.
- A mount-tower interface analysis is an analysis of the localized impact of a mount on the tower. Examples include:
  - Interface where platform collar is connected to a monopole.
  - Sector frame or sidearm connected to a tower leg.
  - Tieback connected to tower bracing.
- In the past, it wasn't clear who's responsibility it was, whether the mount or the tower analyst, but the latest TIA-222 standards have clarified that it's the responsibility of mount analyst.
- Mount-Tower Interface can significantly impact global tower load-carrying capacity.
- Important to connect to strong points of the tower:
  - Mount attachments connected at or near panel points. Panel points are leg/bracing intersections.
  - Tiebacks connected to bracing intersections (not in the middle of bracing)

Mount-Tower Interface Failures



Mount-Tower Interface Failures (Cont'd)

Tower and Foundation Analysis

- When is a tower analysis required? Changed Conditions requiring evaluation:
  - A change in type, size, or number of appurtenances such as antennas, radios, transmission lines, mounts, platforms, ladders, etc.
  - A change in the risk category of a structure to a higher risk category.
  - A change in serviceability requirements (i.e. more stringent twist or sway limitations due to a change involving microwave antennas).
  - A change to the geometry of the structure or to the strength of structural components (i.e. an extension in height of the structure, a change in the guying configuration of a guyed mast or a change to structural members resulting in lower strengths, etc.).
- When is a foundation analysis required?
  - Original tower drawings typically provide original foundation loads. If calculated foundation loads are less than original foundation loads, then a foundation analysis typically isn't required, and can simply compare to the original design loads. However, if exceeded or foundation capacity not calculated previously, a foundation analysis is typically required.
- Is a tower analysis always required when adding new appurtenances on your tower…NO!
  - Like-for-like replacements do not require a tower analysis.
  - Changed conditions must consider size and weight of antennas, mounts, and cables (cables more impactful than you may expect)
  - Typically default to the judgement of a qualified engineer/tower analyst of record.

Tower and Foundation Analysis (Cont'd)

- Is a tower analysis required to use the latest standard…NO! There are exceptions:
  - Under the current standard, towers designed under previous, less stringent TIA standards (such as TIA-222-F) are not immediately overloaded as a result of higher loading required by the current standards.
  - If tower designed under a previous standard, or if tower was modified/reinforced under a previous standard, that specific loading is defined as the baseline loading. Analysis using the latest standard is not required if increase in demand-capacity ratio of any member in the structure exceeds 5% over the baseline loading. In other words, if a tower is loaded to 140% under the current standard under the baseline loading, permitted to be loaded to up to 145% using loads from latest standard.

Tower Reinforcement

- Monopoles
  - Bolting or welding steel to the pole faces
  - Adding stiffeners to baseplates
  - Adding anchor rods
  - Guying the pole (if sufficient real estate)
- Lattice (Self-supporting and guyed towers)
  - Clamping steel to reduce unbraced lengths of members
  - Replacing bolts and members
  - Adjusting guy wire pretension

Tower Reinforcement (Cont'd)

- Reinforcement Considerations
  - Many reinforcement activities temporarily alter how the structure carries load. Whenever a tower's stability is reduced, even briefly, the contractor must develop a rigging and construction plan, and a qualified engineer must review the proposed sequence to verify the structure remains safe throughout construction.
  - Clamping is most preferred (no penetrations), bolting less preferred, and field welding is least preferred (due to increased complexity and quality control requirements).
- Creative Engineering! Site-Specific Wind and Ice Studies
  - What is a Site-Specific Wind and Ice Study? A collection and statistical interpretation of historic data from nearby airports that considers wind speeds, terrain, and topography specific to that site.
  - Wind and ice loading provided in the codes are often overly and compoundingly conservative.
  - Codes recommend site-specific wind and ice studies over the data they provide…cost more than pulling data from tables, but construction cost savings are often significant…allows tower owners to squeeze additional, safe capacity out of their towers for additional co-location opportunities.
  - In this area, often provides lower wind loading, but higher ice loading. Sometimes comes back with higher wind loading due to extreme topographic changes where it's difficult to quantify with code methodology, etc.

Types of Tower Reinforcement

Types of Tower Reinforcement (Cont'd)

Types of Tower Reinforcement (Cont’d)

Foundation Reinforcement

- Monopoles
  - Drilled Pier: Increasing size of drilled pier at grade
- Lattice (Self-supporting and guyed towers)
  - Pad and Piers: Tying foundations together with grade beams or concrete mat, adding rock anchors
  - Concrete Mat (Buried or at Grade): Adding concrete weight (yes, more weight is better) or enlarging mat
  - Guy Anchors: Adding soil or concrete above buried guy anchor blocks
- Reinforcement Considerations
  - Foundations are often governed by soil strength. Geotechnical reports and provided parameters are often overly conservative, always a good idea to get a second opinion of boring logs to see if reserve capacity available in soils before designing expensive foundation modifications.
  - As with tower reinforcement, anytime structure is made less stable (soil removed, etc), even for a short period of time, a rigging plan by contractor as well as rigging review/construction analysis by qualified engineer is required.

Types of Foundation Reinforcement

Types of Foundation Reinforcement (Cont’d)

Foundation Repair

- Foundation Repair
  - Foundations often need repair due to lack of routine maintenance, poor initial construction conditions, environmental damage (lightning strikes).
  - Grout at the base of self-supporting towers is often troublesome (prevents water drainage), can be removed without significantly reducing anchor rod capacity, in most cases.
  - Fiberglass wraps can be helpful if cracks/efflorescence present, to prevent further water migration to underlying rebar.

Foundation Repair

Maintenance and Condition Assessments

- Maintenance and Condition Assessments
  - What is this? Routine inspections and evaluations of towers. Are these required? NO! (highly recommended), although some insurance companies will tell you YES!
  - They are recommended by TIA-222 to be completed every 5 years for self-supporting and monopole structures and every 3 years for guyed towers. Some owners have tighter inspection cycles.
  - Monopoles/Self-Supporting Towers
    - Tower Plumbness
  - Guyed Towers
    - Guy Wire Pretension (in accordance with latest tower analysis)
  - Make sure your tower climbers and engineers communicate…tower climbers aren't often engineers and don't know the specifics of the latest tower analysis, which is key, especially on guyed towers.
  - My recommendation is that tower climbers should collect the data, provide to the engineer, and the engineer should review and prepare inspection report, with focus on which items need to be repaired immediately, in the near future, or not at all (provide level of severity).
  - Routine maintenance and condition assessments and an associated maintenance plan allows you to apply factor to reduce wind and ice load on your tower (only applies to Risk Category II structures)…somewhat of a financial benefit for taking care of your tower.

Rigging Plans, Reviews, and Construction Analyses

- Rigging Plan:
  - Governed by ANSI/ASSP A10.48 standard
  - A systematic and detailed presentation prepared by the contractor showing the equipment and procedures required for construction in accordance with this standard that will provide for the safety of personnel and for the stability of the structure and lifted components.
    - Required when tower structure is used for hoisting
    - Required for Gin Pole operations
    - Required when tower or foundation is made less stable at any time during construction (i.e. removing and replacing bracing, replacing bolts, removing soil for mapping, etc.)
- Rigging Review & Construction Analyses:
  - Structural requirements governed by TIA-322 and TIA-222. TIA-322 dictates wind speeds to use in Construction Analyses for particular construction timelines.
  - A rigging review and construction analysis is a signed and sealed document completed by a Qualified Engineer to ensure the structure remains safe during each phase of construction, based on the length of time it takes for each phase, that is dictated by the contractor. Contractor provides length of time for each phase during construction.
  - Why is this helpful? Often forego the use of expensive temporary bracing
  - Qualified Engineer is typically hired by contractor.
  - Contractor must have plans in place to act if construction analysis wind speeds are exceeded.

Tower Inspections and Mappings

- Types of Inspections
  - Climbing Inspections
    - Thorough, but costly and time-consuming
    - Hands on and allows measurement of steel and bolts
  - Drone Inspections
    - Limited mainly to visual and thermal inspections
    - Can’t measure thicknesses of bolts and hollow members
    - Can't fly drones, without extensive unlock codes, within a 15 mile radius of Washington DC. Also restrictions at military installations.
- Tower (Structural) Mappings
  - Required when original or modification drawings, or previous analyses are not available.
  - Tower manufacturers often have drawing database and can locate based on model number on tower or address.
  - Typically involves a full-height, hands-on climb to measure tower geometry, member sizes, bolt sizes, etc.

Tower Inspections and Mappings (Cont'd)

- Appurtenance Mappings
  - Required to document antenna, mount, and cabling configuration. Can often be completed by drone, but may require tower climbers depending on level of detail needed.
- Foundation Mappings
  - Usually involve excavation around below-grade portions of foundation, as well as geotechnical investigations to determine soil strength.
  - Usually requires contractor to engage engineer as part of Rigging Review/Construction Analysis.

Good Tower Management Practices

- Important to use the same engineer for all tower and foundation analysis effort. Many engineers have varying opinions, so it's important to require the same engineer for all tower analysis work for consistency. It's often recommended to use same engineer to prepare drawings and analyses for all tenants, as they are all interrelated…consistency is key.
- Tower analyses do not take into account condition, assume like-new condition always. Assume the tower is properly maintained by the owner. Tower analyses are not the same thing as Maintenance and Condition Assessments. Currently no way to reliably reduce tower member capacity based on less-than-like new conditions. Bridge design standards incorporate condition-related effects, but not yet in the buildings and tower world.
- Post-construction drone mappings. Most jurisdictions do not send their inspectors climbing towers to inspect, their jurisdictional inspection focus is typically at grade. Ensure "air" inspections are completed, have engineers drone inspect and coordination with contractors to obtain the information needed to complete at least a visual inspection of the topside install.
- Good idea to implement bird deterrent devices for all tenants…nothing stops routine antenna or tower maintenance for all tenants (including tower owner) during bird season like an active osprey or eagle nest, February through August. Recommend requiring tenants to install bird deterrents on wide mounts that can collect dropping sticks.