PLANNING ADVISORY NOTICE

Network Performance Impacts vs. Structural Failure

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This Planning Advisory Notice (PAN) is intended to convey information on some of the design considerations for antenna supporting structures (structures). The ANSI/TIA-222 Standard as adopted by the International Building Code is titled "Structural Standard for Antenna Supporting Structures." The key reason these structures exist is to support the network infrastructure deployed upon them. While there are various reasons as to why a structural engineer may assess a "failing" capacity ratio (i.e., the proposed load exceeds what the code allows for a design event), this PAN will focus on two primary categories of failures:

1. Structural Failure
2. Network Performance Impacts

Before analyzing structure failures and network performance impacts, it is imperative to understand the term "design event." A design event is when the structure experiences code-prescribed wind, ice, or seismic loading. An example of a wind design event is a structure in an area where the design wind speed would be 115 MPH; in this location a 115 MPH wind gust pushing against the structure would be considered a design event. Turning to the structural failure classification; a structural failure typically occurs when a primary member or connection exceeds its structural capacity as a part of a design event. For a wind design event, the engineer will analyze the structure for the design loads in an area and if the members are not able to sustain the pressure on the structure from the design requirements, then the winds could stress the members beyond their structural capacity. If this occurs, it may result in a physical "failure" of the structure such as members bending or breaking. It's important to recognize that there are many factors of safety built into the structural analysis of a structure. The wind speed used for an analysis is often a 700-year return period 3-second gust of wind. This wind event is expected to occur on average once every 700 years. Thus, while an analysis by an engineer may report the structure as failing on paper, it does not necessarily mean the structure itself is in imminent danger of collapse. However, the structure does not meet code requirements. It is also possible that a code-compliant structure will experience loads higher than the design loads, such as a tornado, resulting in a structural failure. While not a desired outcome, it is important to recognize that it is a proper application of ANSI/TIA-222.

A network performance impact failure occurs when there is a potential negative impact on network performance due to movement of a portion of the structure, antennas, mounting support, or other equipment installed upon the structure. While a structural failure must be remedied to be code compliant with the authority having jurisdiction, a network performance impact is in more of a gray area as it is based on End User requirements, customer expectations, and preference for the design performance based on the intended use of the structure. An example is a temporary microwave installed on a structure that may have the potential for twist to be exceeded in a design event that might impact the performance of the microwave. Depending on the End User's intent, the microwave may be allowed to have the performance drop, especially in areas where the coverage is not primary or essential.

Engineers are required to ensure the structure has adequate structural strength to support the equipment during a code-prescribed wind, ice, and/or seismic design event. Preventing structural failures during a design event is paramount to ensure the safety, health, and welfare of the public. It should be noted that it

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is permissible for a structure to be designed in a way that exceeds code-prescribed design loads as required by the structure owner or authority having jurisdiction. Additionally, it is important to understand the structure owner's election of intended use which will allow the engineer to properly determine the risk classification of the structure. The TIF White Papers "Risk Categorization in Accordance with ANSI/TIA 222-H and the 2018 IBC" (May 2018), as well as "Reliability of Telecommunications Structures" (Nov. 2020) can be referenced for additional information. Maintenance loads and any fall protection requirements must be considered in accordance with consultation between the engineer and End User and is not a focus of this paper.

Professional Licensed Engineers are beholden to the National Society of Professional Engineers (NSPE) Code of Ethics for Engineers. Two of the fundamental cannons of the Code of Ethics are: 1) hold paramount the safety, health, and welfare of the public; and 2) act for each employer or client as faithful agents or trustees. Engineers acting as faithful agents to their employer or client are obligated to not only consider the safety, health, and welfare of the public but also what options their employer or client have available to economically achieve the same safe outcome.

End Users such as carriers, government bodies (e.g., e911), broadcasters, or the entity engaging a contractor to perform the installation, must be the party to define the acceptable tolerance for potential network performance impact. It is a recommended best practice that the End User also discuss with their engineer what is important to them for their network based on the intended use of their assets. This is where the aforementioned example of the microwave antenna is applicable. If this is a redundant path that carries minimal or intermittent traffic it may be acceptable to the End User to allow installation on a structure where the twist might induce a design event that impacts the microwave path. However, if this is a critical microwave path the End User should ensure that the engineer properly evaluates not only for structural failures, but also for network performance impacts to the microwave path.

The role of a consulting professional engineer is to not only communicate results from a structural analysis, but also to provide the End User with guidance on solutions based on their design intent and intended use. Some solutions may require thinking outside the box, highlighting the importance of understanding the End User's tolerance for potential network performance impacts based upon design events, network redundancy, site history, and ability to respond for adjustments. Potential network service impacts on a single site may be an acceptable condition for the End User given their ability to correct the failure in a timely manner or redundancy in the local region. An allowance for potential network performance impacts may enable the End User to have flexibility financially to build greater redundancy in a network. An example of this would be the possibility of a member rotating during a wind design event that might impact the antenna position. The End User may elect to manage that through storm response vs. investing in upgrading the mounts and connections. Another good example is temporary installations for sporting events or a state fair. It is possible to design with a lower level of network reliability based on the monitoring of the structure and the use. Safety is never to be neglected as a part of these decisions, but use of reduced factors can be considered based on the intended use and reliability requirements.

Many mount systems utilize round or pipe members with connections incorporating U-bolts or threaded clamps. These types of connections are reliant on the installer tightening the connection sufficiently (per AISC requirements) to ensure the U-bolts or clamps do not rotate about the round member. These friction connections may fail by slipping or rotating under a design event based on the load position. However, this failure is not a structural failure if the slipping or rotating of the connection does not result in the mount to yield, rupture, or disconnect in any way. That said, the movement about the round member could result in a failure due to a negative network performance impact provided by that mount during an extreme weather event. If the existing condition is prone to a network performance impact, there are potential cost-effective solutions the engineer can propose to the End User to reduce the risk and potential network performance impacts.

These solutions do come at a cost that may be better used to add more redundancy to the network rather than installing modifications that may never be utilized.

These examples demonstrate the importance of communication and collaboration between the End User and engineer to delineate a structural vs. a network performance impact in order to optimize the End User's allocation of resources for network upgrades. The engineer must consider that while they are being consulted as the expert on structural design, it is the End User who possesses the necessary information and expertise concerning their network redundancy, overlays, degradation, and intended use, as well as monitoring and maintenance programs. Presented next are three illustrative examples commonly occurring in the telecommunications industry which require engineers to evaluate both structural failures and network performance impacts of their designs.

Illustrative Example 1: Stiff Arm Angle

It is very common to see sector frames installed facing different directions rather than being perpendicular to the tower legs; it is mainly due to the End Users' desired azimuth not matching the azimuth of the tower leg. If the difference between azimuths is significant, then it will result in sector frame stiff-arms (tiebacks) being installed outside the designed angle range. Standard manufactured sector frame stiff-arms are typically designed with an angle range of 20 - 25 degrees (i.e., a skewed angle). While it is a common practice to install stiff-arms at such an angle, installing sector frames in this way does impact the designed capacity of sector frames. **Figures 1** and **Figure 2** below show the impact of designed perpendicular angle versus a skewed angle on the stiff-arm from a deflection standpoint.

Significant deflection on stiff-arms can impact the rigidity of the sector frames, allowing it to move more noticeably. In some cases, it is perceived as a structural failure but that might not always be the case. It is structurally acceptable to recommend stiff-arms installation with a skewed angle as long as it meets the slenderness ratio limit and the deflection on the stiff-arms are checked and approved by the engineer. Additionally, when stiff-arms are installed outside of the manufacturer-specified range, considerations should be made for potential network performance impacts. It is important that engineers, acting as faithful agents, communicate these potential impacts with the End User and explore other alternative solutions such as recommending additional bracing across the tower face, when possible, to allow for stiff-arms to be installed within the designed angle range.

Illustrative Example 2: Deflection Based on Stiff Arm Angle

Sector frames are one of the most popular mounts in the telecommunication industry. A sector frame typically includes a V-boom, face horizontals, mount pipes, and connection hardware. Some V-booms consist of a single diagonal bracing on each side of the V-boom designed to carry tension force only. However, a V-boom might be installed upside down in some cases, causing the diagonal bracings to carry compression force instead. When this scenario occurs, the diagonal bracings could be overstressed during a design event in the structural engineering model due to a high slenderness ratio and low compressive strength.

Figure 3 and **Figure 5** depict the sector frame being installed incorrectly as both diagonal bracings are upside down and overstressed. However, when deleting these diagonal bracings directly in the model, the sector frame is passing (see **Figure 4** and **Figure 6**). When the diagonal bracings are overstressed, they will deform and become ineffective. The stress would then be redistributed based on adjacent members' stiffness. The stress of the overall sector frame after diagonal bracings' overstress can be obtained by ignoring the diagonal bracings in the model. Based on the result from **Figure 4**, we could see that the sector frame will still pass without these diagonal bracings. An alternative approach to deleting the diagonal bracings is to set the upside-down diagonal bracings as tension only members. Tension only members have zero

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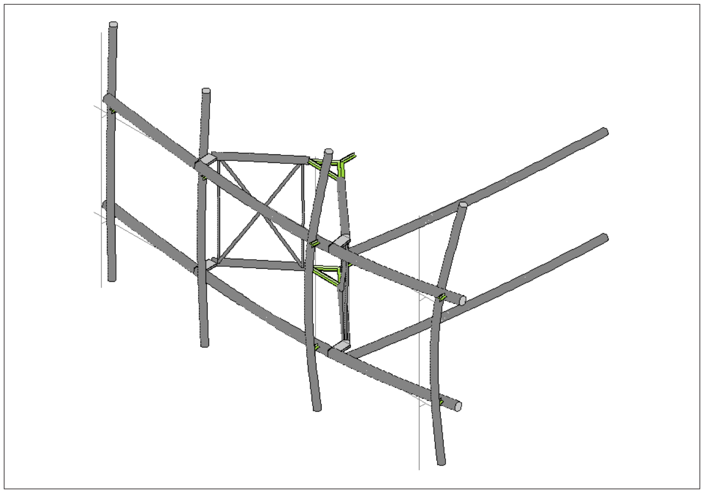

Figure 1 – Deflection on stiff-arms with designed angle

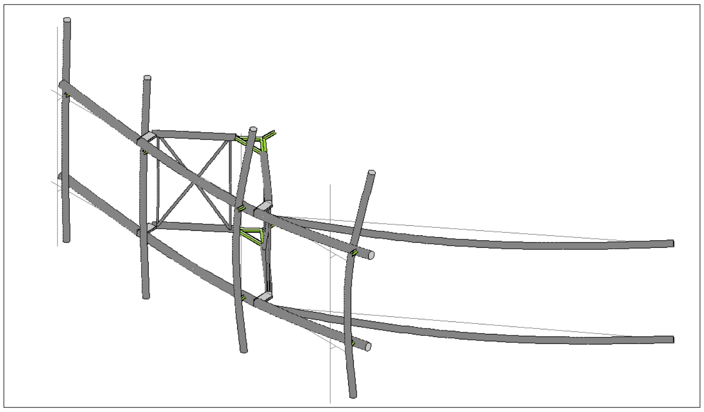

Figure 2 – Deflection on stiff-arms with skewed angle

capacity in compression, which will help to redistribute the stress to simulate the result after these diagonal bracings are deformed. There are additional considerations that may need to be taken into account when modeling the mount based on the design intent of the individual members and/or driving alternative load paths. These approaches reduce the need to modify or replace mounts that in reality do not fail but merely have a member that reflects a failure in analyses that would never be controlling or an intended use of the member.

In summary, a consulting professional engineer shall critically think about results from a structural engineering model and provide necessary adjustment on whether the overstressed members could cause an overall failure of the antenna mount or not. The engineer should reevaluate the results especially when only redundant members are overstressed to ensure a mount's structural integrity. In this case, the incorrect installation of this sector mount will not cause a structural failure, but the local failure on those diagonal bracings could be considered as a potential network performance impact leading to a larger deflection and loss of service. At this point, a discussion between the engineer and End User is warranted.

Illustrative Example 3: U-bolt Rotation

In the telecommunication industry, U-bolts are a widely used component of antenna mounting systems. The strength of a U-bolt connection in transferring forces parallel to the longitudinal axis of a supporting member and rotation about the longitudinal axis of a supporting member has been provided by telecommunication industry association standard, ANSI/TIA-222 Rev H and Rev I. However, there are many unknown factors that could impact the actual capacity of the U-bolt connection, such as installation temperature, humidity, actual pretension by installers, pipe sizes, number of U-bolts, and installation sequence. Due to these unknown factors, it is not possible for the engineer to determine an accurate capacity of the U-bolt connection. However, ANSI/TIA-222 Rev H and Rev I does provide guidance for determining torsional resistance for U-bolt connections. While this standard mentions that the U-bolt connections shall not be utilized to transfer torsion to a

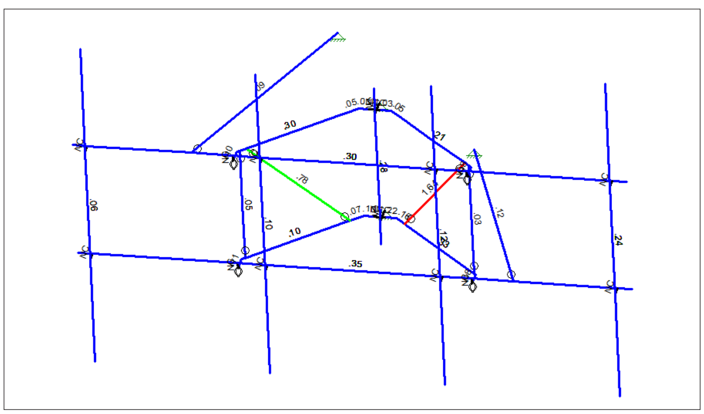

Figure 3 – Failing Sector Frame

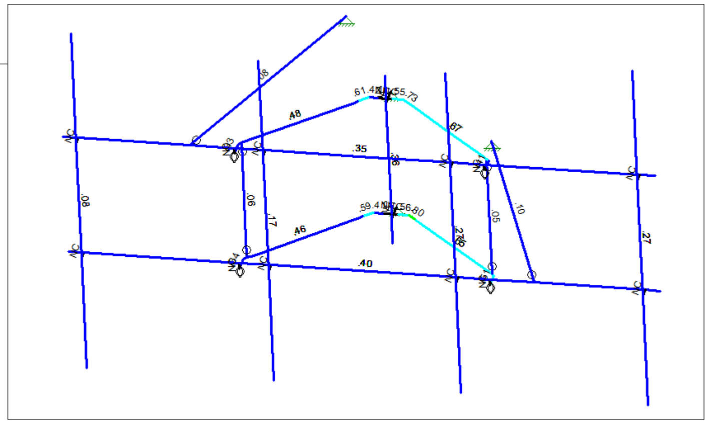

Figure 4 – Passing Sector Frame

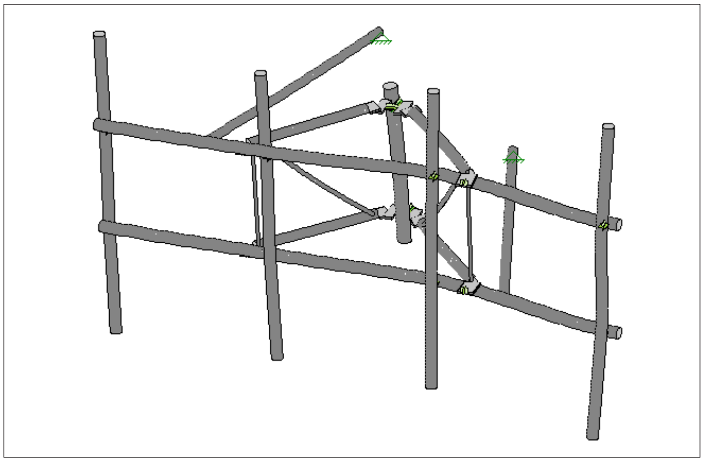

Figure 5 – Failing Sector Frame (Deflection)

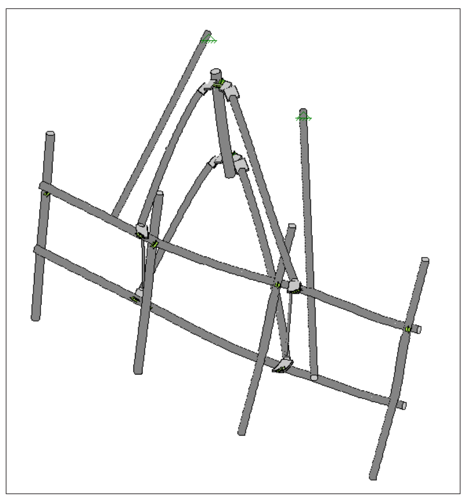

Figure 6 – Passing Sector Frame (Deflection)

round supporting member required to maintain strength and stability of a structure, the limitation under this loading condition shall not apply to connections used for appurtenances (e.g., a mount).

When thinking about the capacities of U-bolt connections, both sliding and torsional capacities are determined by the friction between the U-bolt and supporting member with crossovers. Proper selection of crossover connections is critical to limiting potential network performance impacts. U-bolt connections with crossover channels (see **Figure 8**) are recommended rather than regular crossover flat plates (see **Figure 7**) at connections for appurtenances, especially if only a single attachment is applicable to allow for increased frictional capacity. An example of this would be at the connection of a stand-off member of a T-Arm to the mount face, or the connection of the mount pipe to the horizontal member.

Without a support member, frictional resistance of the connection is the primary component preventing the rotational resistance of the mount. While rotation of the mount may not be considered a structural failure, it could cause network performance impacts. The End User should be notified about the potential network performance impact resulting from mount rotation and sliding under a design event. At that time, the End User may choose to accept a passing mount deliverable understanding that horizontal rotation may occur and network performance should be monitored. It should be noted that there are a substantial number of mounts currently in use with a documented history showing no issues with this type of connection. The End User should be aware of the concern while also being made aware of other guidance that may be developed for a network. One example would be where the antennas are centered on the T-Arm allowing for equal pressure on the antenna above and below the connection. In **Figure 9** and **Figure 10**, the mounts all had the antenna centerlines offset vertically from the mount (cheated up) which increases the risk of rotations significantly, leading to a potential network performance impact.

Figure 7 – Regular Crossover Flat Plates

Effective communication between the engineer, End User, and contractor can allow for an effective means to accomplish a quality, code-compliant, safe installation that meets the End Users' intended use and network reliability requirements. In designing these quality and safe installations, it is best practice for engineers to evaluate both the structural acceptability and network performance impacts of a design, while giving deference to what is constructible.

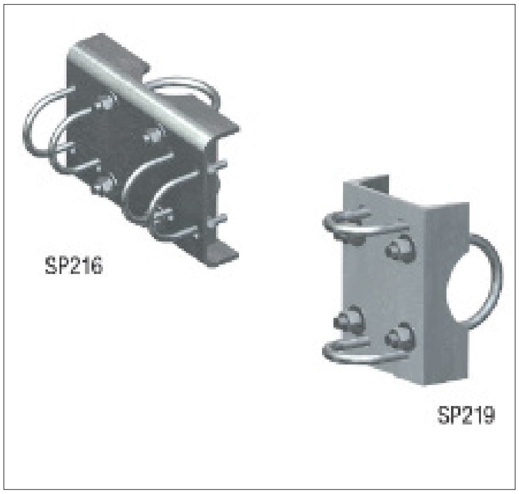

Figure 8 – Crossover Channels

Figure 9 – T-Arm Mount Face Rotation

Figure 10 – Single Mount Pipe Rotation

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