CLIMBING HIGH

Structural Engineers Reach New Heights

By Madison J. Batt, P.E., S.E.

Like telephone lines and power poles, communication towers often blend into the urban landscape as necessary but overlooked infrastructure elements. Often, they are brought to the public's attention only when there is a failure in the tower and someone is killed, or there is a public debate about a new tower's construction.

But take a closer look. Such towers are becoming more and more prevalent in nearly every community in the world, with the tallest towers reaching upwards of 2,000 feet. As some of the tallest structures in the world, communications towers rely on a specialized group of structural engineers that are highly skilled in their design, upkeep and repair.

These towers – tall, narrow steel structures to which high-tech communications equipment for transmitting information is attached – range in height from 500 to more than 2,000 feet, with most around 1,000 feet tall. The tallest of the towers are commonly used by broadcasting companies to house TV and FM radio antennas. These types of communication require height to get the best population coverage. Other tall towers are used by agencies such as the Navy and U.S. Coast Guard to hold navigational systems and emergency communications equipment.

AM radio equipment towers are not usually as tall and are mostly guyed towers under 500 feet. They are found in low-land areas or near water in the communities they serve.

Fast-evolving technology in the field of digital communications means the equipment typically found on communications towers is rapidly changing. The advent of high-definition television, for example, means new equipment must be added to existing towers, requiring an inspection of the tower to ensure its infrastructure can support the additional weight. This has increased the demand for tower engineers – specially trained engineers who parlay their rock climbing or mountain climbing experience with their knowledge of structural engineering.

Types of Towers

Most communication towers are constructed of steel framing, although a few may be made from aluminum, wood or concrete. There are two primary types of towers: guyed and self-supporting. A third type combines these two types.

Guyed towers are the tallest structures in the world. The tallest is 2,063 feet in height, located

Tower Engineer Inspecting 500 foot Guyed Tower near Fargo, North Dakota. Guyed towers are completely dependent on the guying system; without the guys – or supportive wires – these tall towers could not stand. Guyed towers are generally three-sided and have solid round or pipe legs. Some have angle legs. Bracing schemes vary between manufacturers. Some use tension-only rods, while others use angle bracing. These towers have face widths that are generally no greater than 12 feet. Guyed towers need considerable land area, so most are built somewhere outside the city of license. Where towers were once located mainly in farming or rural land, they are now often being crowded by the development and growth of the communities they serve. It is not unusual to see homes and businesses built right next to a communication tower's guy wire anchors.

There are two types of self-supporting towers: free-standing towers that use braces or trusses for support, and monopole towers. The tallest free-standing towers usually have large face widths at their base – between 50 and 60 feet – to support their height. The tallest are usually around 1,000 feet tall. Monopole towers are now prevalent in every city and range in height from 20 to 250 feet. Many of these tower types were erected primarily for the cell phone industry.

Combined guyed and self-supporting towers are usually government communication towers that are generally clustered in large groups at military compounds.

Tower Troubles

The major issues regarding towers revolve around the age of the structures, the rates of failure and the codes and standards used to design them.

Currently, towers in the United States can be upwards of 60 years in age, marking when television and FM radio first began. A large number of the tall guyed towers were built about 40 years ago when the majority of FM radio and UHF TV stations were licensed.

Because of their age – and sometimes, lack of maintenance – older towers are failing at a rate of about 2 or 3 per year. The rate of deterioration is caused by a number of factors. The weather and the location of a tower can greatly affect the structural integrity of towers. Salty, coastal air can cause corrosion, and cold, snowy locations can cause ice build-up and increase the risk of a tower's failure. Human error, such as a lack of maintenance, can also influence the structural stability of a tower. Errant aircraft and vandals also add to towers' demise. When these structures fail, the destruction of the steel members with twisted steel in pretzel shapes can be amazing to see.

Most U.S. towers were designed under the earlier codes that had simplified wind loading. Wind loading in the Electronic Industries Association standards (EIA 222- C, B, A and RETMA in newest to oldest) was listed as wind pressure (for example, 33/50) in pounds per square foot. The loading was uniform over the complete height of the tower for towers under 300 feet and over 650 feet. Towers from 300 to 650 feet tall had about a 12 percent increase in wind pressure for the portion over 300 and up to 650 feet. The country was divided into three wind pressure zones - A, B and C. There was no consideration for the dynamic effects of the wind, and there was no gust coefficient. The location with respect to the coastline was not included and there was no recognition of the speed-up effect for towers located on mountains and escarpments. The only modification was to reduce the pressure at round members; hence the 33/50 with 33 pounds per square foot for round and 50 for flat members. Ice loading was not required.

Tower Debris After Failure of a 1000 foot Guyed Tower

continued on next page

In recent years, much has been done to ensure the safety and structural integrity of communications towers and the equipment on them. The current standard used by the industry is the Structural Standard for Antennas Supporting Structures and Antennas ANSI/TIA 222-G standard. This standard moved the design and analysis to a more current, state-of-the-art way of thinking. Towers are evaluated per the AISC LRFD and ASCE 7 standards, using three-second gust loading for winds. The standard is written so that it can be adopted as part of the International Building Code (IBC). Ice and wind loading maps for the entire U.S. are included. The new ice loading maps are written to more realistically represent true ice loading. In the previous standard, ice loads were generally listed as ½ inch thickness over the complete height of the tower at about 75 percent of the design wind speed.

Another problem in the tower industry is the lack of qualified workers performing inspection and maintenance work. This work can be quite dangerous; especially for the inexperienced and those unfamiliar with safe practice and structural engineering principles.

The proliferation of towers to support the booming cell phone industry has added to the danger. When the explosion of cell phone tower work occurred, there was a large influx of tower workers directly out of high school. They worked for numerous small and large companies installing antennas and building the infrastructure we have today. When that work was complete, these workers gravitated to the tall tower work when TV stations added the HDTV antennas to their towers. There was too much work for traditional tall tower workers, so the small and more inexperienced companies won numerous tall tower modification projects throughout the U.S. Most accomplished their tasks.

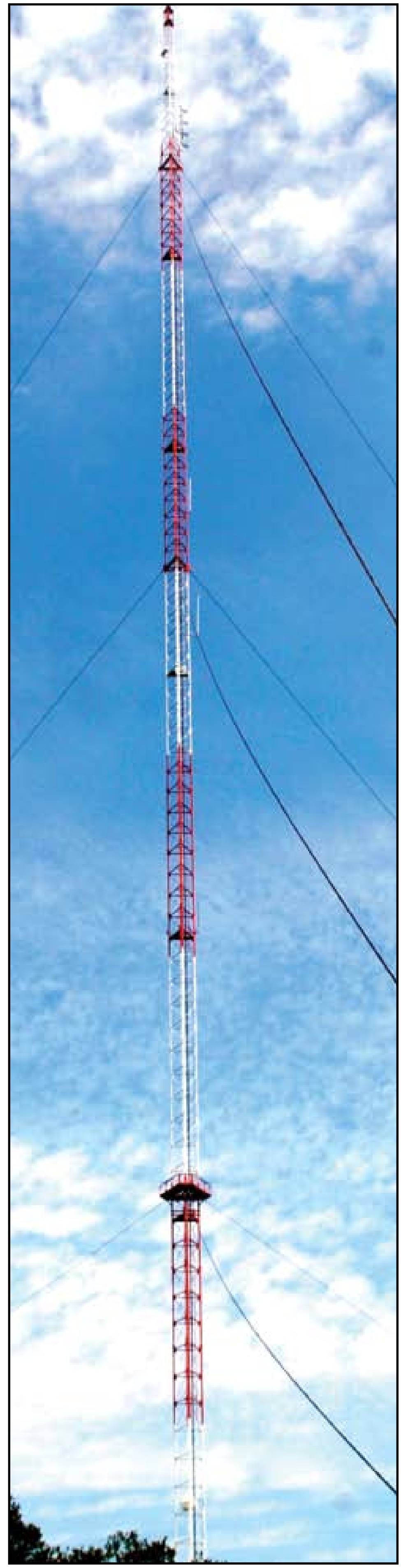
There were tower workers that weren't so lucky. It wasn't uncommon to hear of towers that collapsed when horizontal and diagonal bracing members were removed without a temporary member to take its place. These failures have led to lawsuits over who was at fault, including engineers who in some cases performed work as the general contractor and were responsible for the design of the upgrades.

Communications towers are sometimes the focus of controversy before they are even built. When a new tower is needed to replace an existing tower or if a new tower is to be built, it will generate an enormous reaction from the local community. In many areas, the public process hinges on several issues that are irrelevant to the effects or purpose of the towers. Self-interest groups have effectively blocked new towers in certain areas based on misinformation about lighting or radio frequency (RF) from the broadcast antenna. Often, the misinformed will claim guy wires can defy gravity and act as large whips. This is just a glimpse of the conflicts that go on in every city and town when new towers are proposed.

The Tower Team

While the infrastructure work required to support the cell phone industry has slowed,

The Author Inspecting a 500 foot Self Supporting Tower



1649 foot Guyed Tower in Florida

Self Supporting Towers at Mt. Wilson, CA

demand for towers to serve growing residential communities remains high. In mountainous regions, the towers are not as tall as in the flat regions of the country. These towers at one time were well above the community. Now, there are multi-million dollar homes being developed higher in the communities throughout the country.

Along with the demand for new towers comes the need for qualified designers, builders and inspectors. The engineering of these towers is done by a variety of firms in the U.S. New tower designs are mostly performed by the manufacturers of the towers. Several tower manufacturers use different consulting firms to execute the design. The designers in the consulting firms and the manufacturers are mostly professional civil engineers, with the exception of a few firms that use licensed structural engineers.

Engineering evaluation of existing towers – including the analysis and retrofit design – is performed by the tower manufacturers and consultants that specialize in tower work.

Design of new towers and upgrades follows conventional AISC steel fabrication standards. In the past, some steel fabricators fabricated steel building framing as well as the tower framing members. Analysis is performed with specialized software that takes into account the non-linearity of guy wires. There are several programs available to accomplish this task, while some of the manufacturers and consultants have written their own specialized proprietary software.

The Importance of Inspections

Having good information about the tower members, the foundations, the steel grade, the antennas, transmission lines and the all the other equipment on the tower is critical. Getting this information is another matter. There are numerous older towers that were manufactured by companies that are no longer in business. Ownership has changed and all the documentation has been lost on numerous towers. Searching for information requires patience, skill and some luck. Drawings of towers have been found in the ceiling rafters of transmitter buildings or in the basement of old studio buildings.

When no information is available, a last resort is to climb the tower to document the structure. Ultrasounds are used to measure pipe legs and foundations are sometimes exposed. An estimate of steel grade is made based on the vintage of the tower and on who the manufacturer was. Steel grades vary from 33 ksi to 95 ksi, so some investigation is necessary.

Towers are inspected for numerous reasons. Often, owners or insurers require an annual

continued on next page

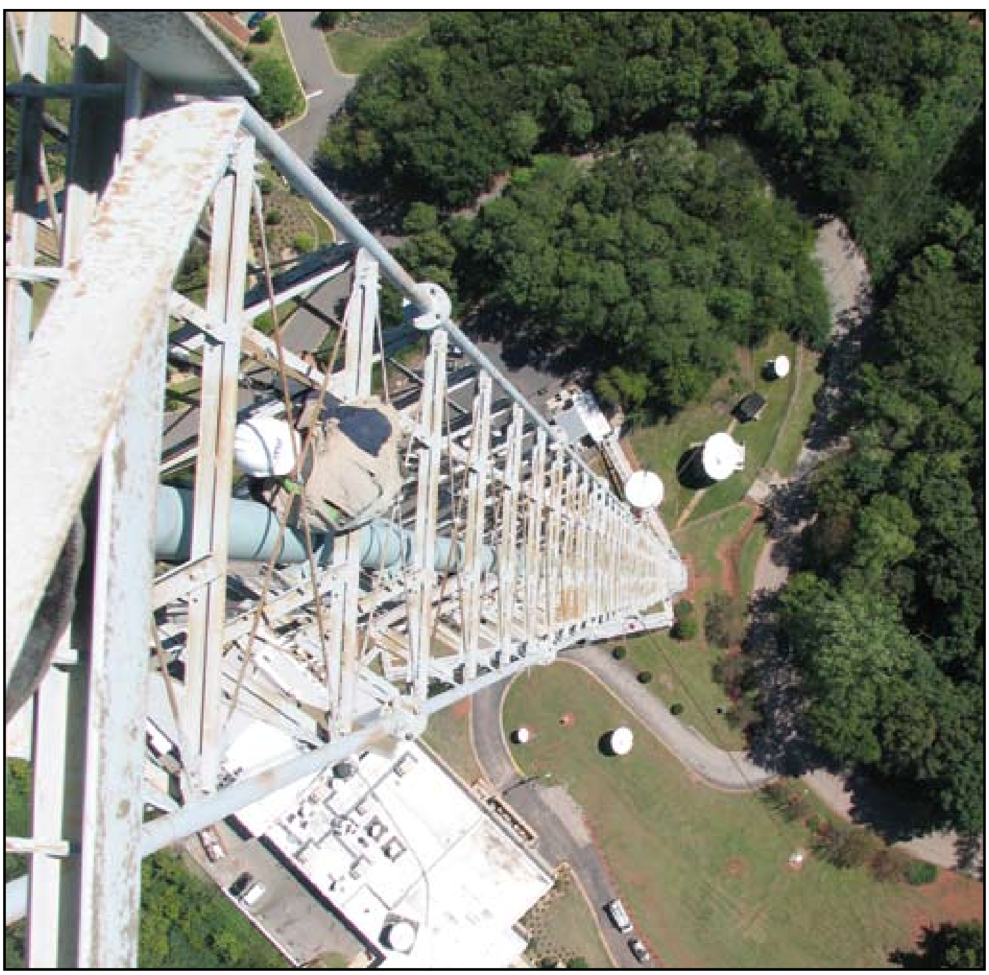
inspection to ensure the tower is stable and safe. Inspections may also be ordered following a significant windstorm or cold snap, as well as during and after construction work. Inspections may also occur if further information is needed on the antennas and other equipment installed on the towers.

The tower climbing, observation and inspection work is done by a variety of individuals. Tower contract workers do a significant portion of the inspection work, since finding engineers who also climb towers can be difficult. While tower climbing can be a challenge, those who accept that challenge get to travel anywhere there is a tower, often all over the world. Safety is a priority and anyone who climbs should be a certified climber.

Working with communication towers requires a commitment to a specialized type of engineering – one that involves a structural background, an aptitude for the nuances of tower engineering and the willingness to travel anywhere in the world, often at a moment's notice.

With ever-changing technology and a growing population, it is without question that these examples of "vertical real estate" are here to stay in the landscape of today's society.▪

Severe Corrosion on a Tower in Hawaii



Inspection of a 1000 foot Guyed Tower

So You Want to Be a Tower Engineer?

It's not often one can turn a hobby into a fulfilling career, but a turn of events 24 years ago allowed me to do just that.

An avid mountain and rock climber, I was offered an opportunity to climb and inspect a 500 foot self-supporting TV tower. Little did I know at the time, but eventually that would be the total focus of my career.

Tower engineering is truly a specialized area of civil and structural engineering. Currently there are only about five engineers in the United States who are licensed structural engineers specializing full-time in this area. Most engineers in this industry are professional engineers who work directly for tower manufacturers and tower consultants.

So what is it about tower engineering that is so different from other engineering disciplines? Tower engineers generally work directly for their clients, not for architects or other consultants. They get to work outdoors and, at times, high in the air. And of course there is some specialized lingo, such as VSWR (Voltage Standing Wave Ratio) or SBE (Society of Broadcast Engineers). VSWR is a term used by the broadcasters as a measure of how well a load is impedance-matched to a source.

Tower engineering work is quite varied and can be challenging. The opportunity to climb the tallest structures in the world affords numerous business and travel experiences. Because there are few structural engineers that climb towers, there is a large demand for professionals to do this work. It makes for a well-rounded engineer who can climb a tall tower, perform an analysis on the tower and then write an evaluation report or provide upgrade or maintenance documents for the tower's owner.

Besides having a good background in structural engineering principles, a tower engineer must be physically fit, not be afraid of heights, and be trained in fall safety and Radio Frequency (RF) exposure (this is the expression for the non-ionizing radiation that broadcast antennas radiate).

Since this type of work is done all over the country, the lead structural engineer needs to be licensed in every state in which the work is performed.▪

Madison J. Batt

*Madison J. Batt is Director of Tower Engineering at KPFF Consulting Engineers in Seattle. He can be reached at **madison.batt@kpff.com**.*