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Artikel: Structural updating of steel television and radio broadcast towers in the USA

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1. Structural Updating of Steel Television and Radio Broadcast Towers in the USA

The soaring vertical lines of television and radio broadcast towers are familiar sights around the outskirts of cities and throughout the countryside of North America. Their tall, slender trusswork sways, bends and twists imperceptibly in the wind, reined by the ever-undulating sweeping lines of the guy cables spread out in three directions to remote anchorages.

As a result of the extensive development of electronic communications, these towers are routinely designed, rapidly built and some of them soon become packed with equipment. Space on existing towers is often leased to other users for mounting their communications equipment such as microwave dishes with their coaxial cables and attendant hardware. The proliferation of communication devices on some towers makes them reminiscent of skinny Christmas trees.

The mounting of new equipment, wear-and-tear, deterioration with age, weathering, structural problems arising from original design deficiencies or from construction errors, occasional collapses, changes in code requirements, local laws for checking, inspecting and recertifying structures, and even changes of ownership of towers necessitate the review at one time or another of nearly every tower. As a result, a whole sub-industry of inspection, analysis, strengthening and rehabilitation of existing towers has developed in the USA.

Field inspection procedures and check lists have been established by inspecting and consulting firms as well as by some owning companies. Special-purpose computer programs, some embarrasingly crude, others highly sophisticated, have been developed by engineering firms, researchers and certain US government agencies to perform efficient and reliable gravity and wind analyses. Some of the most frequently used strengthening and corrective procedures and devices are almost industry standards. However, the work still requires sound engineering knowledge and a great deal of imagination and practical innovation.

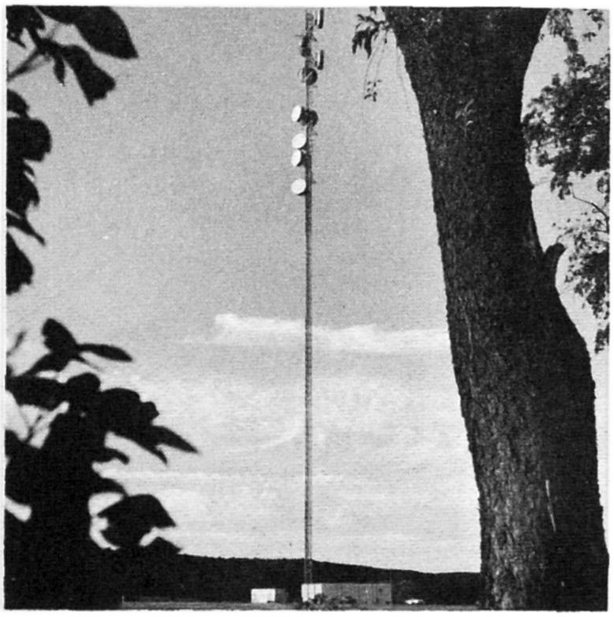

Fig. 1 147-meter guyed tower in West Chester, Pennsylvania. (Courtesy of ITT/United States Transmission Systems, Inc.)

The causes of structural problems with otherwise properly designed and well built towers are created mainly by lack of maintenance and consequent deterioration; addition of wind catching equipment; loss of cable tension; high-frequency low-amplitude vibration of cables; and low-frequency high-amplitude vibration (galloping) of cables.

Typically, a program of thorough investigation of a tower, for whatever reason, includes the following tasks:

- review of the history of the tower,
- review of available drawings (if drawings are not existing, accurate field measurements are made for the purpose of making new structural drawings),
- close visual inspection of all members, connections, bolts and welds, guy pull-offs, guy cables, foundations and anchorages, platforms, antenna mountings, elevators, ladders, and other appurtenances,
- structural analysis, consisting of:
  determination of the material properties of the tower trusswork and guy cables,
  calculation of wind areas of the tower trusswork, platforms, antennas, coaxial cables, ladders and other appurtenances,
  determination of wind design pressures from the governing code (s) or by special analysis,
  calculation of gravity and wind loads,
  analysis (usually by computer) of the guyed mast to determine horizontal sway, shears, bending and torsional moments along its height, as well as guy cable forces, This analysis it performed in one, two or three directions, with the wind into the face, into the apex and along a face of a triangular tower,
  dynamic analysis, if the time and expense are justified,
  evaluation of the internal forces in the tower legs, girts, diagonals, connections and guy cables,
  determination of allowable stresses and forces by the AISC (American Institute of Steel Construction) specifications,
  comparison of the internal forces to allowables and identification of overstressed members, connections and cables,
  evaluation of the acceptability of drift, tilt, and twist of the tower.

This investigation, when necessary, is followed by:

- development of construction details for reinforcing or replacing overstressed members and connections,
- development of solutions to the control of guy cable vibrations and selection of devices,
- preparation of construction drawings, specifications and cost estimates.

A good example of a thorough investigation is the 147-meter guyed microwave tower in West Chester, Pennsylvania. As part of a program of structural review of their towers, ITT/United States Transmission Systems, Inc., commissioned a comprehensive structural analysis, supplemented by field inspection, of this tower. It is a slender triangular trusswork, has five levels of guy cables with torque stabilizers at the top three guy levels. It supports twelve large-diameter microwave dishes and several small antennae (Fig. 1). The work was performed under the author's direction. The calculations, computer print-outs, graphical presentation of results, discussions, conclusions and recommendations were presented in a five-volume report.

The design conditions that most significantly affect the cost of construction of a new and the cost of strengthening of an existing tower are the design wind pressure and thickness of icing. (The latter is the formation of ice on the surfaces which drastically increases the effective wind areas, thence the wind load on the tower as well as the wind loads and weights of the guy cables.) The major current US codes that specify design wind velocities and/or pressures for buildings, towers and other structures are the [1]ANSI A58.1-1982, [2]UBC-1982 and for towers only the [3]EIA RS-222-C 1976. None of these codes specify ice thickness for design. Past experiences, some local codes and building officials determine the icing to be used for each particular case. (The ASCE Guide for the Design of Steel Transmission Towers makes limited recommendations for icing.) Depending on the topography of the terrain where the tower is located, these three current codes are in reasonable agreement on the *average* wind design pressure along the height of a tower. They do, however, result in quite different *distributions* of pressure along the height.

The changing requirements between 1953 and 1983 of the ANSI, UBC and EIA codes, as well as the local building code, were evaluated by the author for the 290-meter guyed tower of KMBC-TV in Kansas City owned by The Hearst Corporation, as part of an in-depth structural review (Fig. 2). The study traced the major events in the history of the tower: original construction, later changes of equipment, subsequent structural modifications and recent changes of ownership. It was found that at each event during those thirty years the codes required considerably different wind pressures: increasingly greater by the ANSI, EIA and local code and slightly decreasing by the UBC. This points up the situation that a tower standing for 30 or 40 years may become structurally inadequate and need to be reinforced because of changes in codes.

The most common items of structural maintenance, reinforcing, and controls of tower sway and cable vibrations are the following:
- repainting,
- local reinforcing around new and existing equipment,
- reinforcing of legs and leg splices in zones of high tower bending moments,
- reinforcing of girts and diagonals in zones of high tower shear and tower torsion,
- reinforcing of connections at ends of girts and diagonals,
- addition of torque stabilizer arms to reduce tower twists,
- increasing guy tensions to reduce lateral sway of tower,
- «Tuning» the tower by modifying guy cable tensions to move the zones of maximum moment and shear up or down along the tower,

[1] American National Standards Institute
[2] Uniform Building Code
[3] Electronic Industries Association

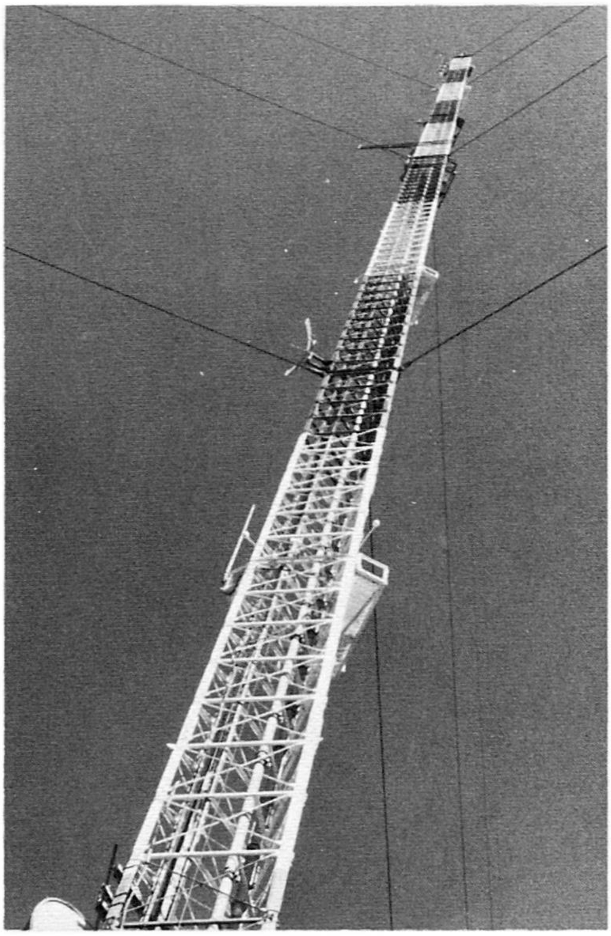

Fig. 2 290-meter guyed tower in Kansas City, Missouri. (Courtesy of The Hearst Corporation)

- addition of Stockbridge dampers to attenuate high-frequency low-amplitude (aeolian) vibrations of the guys,
- installation of snubber/damper systems for controlling low-frequency high-amplitude vibrations (galloping) of the guys,
- reducing guy tensions for greater factor of safety in the cables,
- «Bundling» of coaxial and power lines to reduce wind areas.

A recent example of this kind of updating is the 35-year old 345-meter guyed tower of KMOX-TV near St. Louis, owned by CBS Inc. Prompted by the accumulation over the years of mounted equipment, the tower was analyzed and strengthened to safely support the accumulated equipment and to meet the higher wind pressure requirements of contemporary codes. The work included reinforcement of the tower legs and some girts, replacement of several diagonals, changing of a number of standard bolts to high-strength bolts, installation of high-frequency vibration attenuators and galloping vibration damping systems on the guy cables.

Many other towers across the US have undergone such extensive structural rehabilitation at costs (1985 prices) of up to 250 000 US Dollars.

(Robert T. Ratay)