Available online at www.sciencedirect.com
SCIENCE DIRECT
Thin-Walled Structures 41 (2003) 167–177
THIN-WALLED STRUCTURES
www.elsevier.com/locate/tws

Numerical simulation of structural behaviour of transmission towers

F.G.A. Albermani [a], S. Kitipornchai [b,*]

[a] Department of Civil Engineering, University of Queensland, Brisbane, Queensland, 4072 Australia
[b] Department of Building and Construction, City University of Hong Kong, Kowloon, Hong Kong

Abstract

Transmission towers are a vital component and management needs to assess the reliability and safety of these towers to minimise the risk of disruption to power supply that may result from in-service tower failure. Latticed transmission towers are constructed using angle section members which are eccentrically connected. Factors such as fabrication errors, inadequate joint details and variation of material properties are difficult to quantify. Consequently, proof-loading or full-scale testing of towers has traditionally formed an integral part of the tower design. The paper describes a nonlinear analytical technique to simulate and assess the ultimate structural response of latticed transmission towers. The technique may be used to verify new tower design and reduce or eliminate the need for full-scale tower testing. The method can also be used to assess the strength of existing towers, or to upgrade old and aging towers. The method has been calibrated with results from full-scale tower tests with good accuracy both in terms of the failure load and the failure mode. The method has been employed by electricity utilities in Australia and other countries to: (a) verify new tower design; (b) strengthen existing towers, and (c) upgrade old and aging towers.

1. Introduction

Overhead transmission lines play an important role in the operation of a reliable electrical power system. Transmission towers are a vital component and management needs to assess the reliability and safety of these towers to minimise the risk of disruption to power supply that may result from in-service tower failure. One of the problems facing tower designers is the difficulty in estimating wind loads as they

* Corresponding author. Tel.: +852-2788-8028; fax: +852-2788-7612.
E-mail address: bcskit@cityu.edu.hk (S. Kitipornchai).

0263-8231/03/$ - see front matter © 2002 Elsevier Science Ltd. All rights reserved.
doi:10.1016/S0263-8231(02)00085-X

are based on a probabilistic approach. Another is tower strength, which in contrast, could be deterministic provided a proven-reliable analytical tool is available for the specified design load conditions. In practice, factors such as fabrication errors, inadequate joint details and variation of material properties are difficult to quantify and they are often used to justify the use of full-scale tower testing. Strictly speaking, however, test results are only valid for the particular tower under the particular test loading conditions, and they may not predict exactly how a tower may behave in practice under different loading conditions.

This paper describes a computer simulation technique for predicting the ultimate structural behaviour of self-supporting and guyed latticed transmission towers under static loading. The technique can predict accurately the failure load and the failure mode of towers, and may thus be used to replace or reduce the need to carry out full-scale tower testing. The method has been employed by electricity utilities in Australia and other countries to: (a) verify new tower design; (b) strengthen existing towers, and (c) upgrade old and aging towers.

Three case studies are presented: (i) a calibration case study, (ii) a case study involving the strengthening of existing towers, and (iii) a case study involving upgrading old towers. For commercial reasons, ownership of the towers will not be revealed.

2. Current analytical techniques

Latticed transmission towers are constructed using angle section members which are eccentrically connected. Towers are widely regarded as one of the most difficult form of lattice structure to analyse. Consequently, proof-loading or full-scale testing of towers has traditionally formed an integral part of the tower design. Stress calculations in the tower are normally obtained from a linear elastic analysis where members are assumed to be axially loaded and, in the majority of cases to have pinned connections. In practice, such conditions do not exist and members are detailed to minimize bending stresses. Despite this, results from full-scale tower tests often indicate that bending stresses in members could be as high as axial stresses (Roy et al. [1]). EPRI [2] compared data from full-scale tests with predicted results using current techniques and concluded that the behaviour of transmission towers under complex loading conditions cannot be consistently predicted using the present techniques. They found that almost 25% of the towers tested failed below the design loads and often at unexpected locations. Furthermore, available test data showed considerable discrepancies between member forces computed from linear elastic truss analysis and the measured values from full-scale tests.

3. Nonlinear analytical techniques

In the proposed nonlinear analytical technique, the tower is modelled as an assembly of beam-column elements. Linear, geometric and deformation stiffness