Journal of Constructional Steel Research 71 (2012) 111–118

Contents lists available at SciVerse ScienceDirect

Journal of Constructional Steel Research

Variation of damping and stiffness of lattice towers with load level

Jean-Yves Taillon, Frédéric Légeron *, Simon Prud'homme

Dept. of Civil Engineering, Université de Sherbrooke, 2500 boul. de l'Université, Sherbrooke, QC, Canada, J1K 2R1

ARTICLE INFO

Article history:
Received 20 May 2011
Accepted 16 October 2011
Available online 25 November 2011

Keywords:
Rigidity
Damping
Lattice steel structures
Load level
Numerical modeling
Non linear structural behavior

ABSTRACT

Steel lattice structure design is often controlled by dynamic loads such as wind, earthquake or shocks resulting from broken components such as guy cables or conductors. In order to properly evaluate the response of these structures under this type of loads, it is necessary to model accurately the structure. However, there is a lack of data in the literature to guide the designer to select adequate assumptions for stiffness and damping. Also, if a variation of these characteristics with the level of load was observed experimentally, this variation has not been researched in detail.

In order to provide additional data and guidance on the modeling techniques to be used for lattice structures, and specifically to evaluate the relation of stiffness and damping with the load level, an 8 m long section of a transmission line tower was erected, pulled at different levels of solicitation and left to vibrate freely after the load was suddenly released. Numerical modeling was also conducted and compared to the experimental results. In this study, engineers will find practical information on modeling techniques to be used for lattice structures.

1. Introduction

Steel lattice towers are very common for transmission lines, antenna and sign structures. Their design is often controlled by dynamic loads such as wind, earthquake or shocks resulting from broken component such as guy cables or conductors. To accurately predict their response to dynamic loadings, it is necessary to model properly their stiffness and damping.

Very few studies on behavior of lattice towers have been conducted in the past [1]. Kitipornchai et al. [2] reported that the behavior of lattice towers is non linear. This can be attributed to the connection slippage. Up to the connection slippage load, connections behave fairly linearly, but slippage results in a local non linearity. The bolt slippage load is related to its pre-tension [3] which is a parameter that is not very well controlled in practice due to bolting techniques used. The connection slippage results in a loss of stiffness and increasing level of damping. This highlight the possible dependency of the behavior of lattice towers to the load level.

Glanville et al. [4] have tested telecommunication towers and damping ratios of 0.5% to 1% were measured on the free vibration response following low level forced vibration. Ostendorp [5] tested a 30 m tall lattice microwave tower. In the test, the tower was loaded up to a force of 40% of the theoretical capacity and released. The damping ratio was measured on the free vibration following release of the force and ranged from 0 to 40% with an average of 17%. This study highlighted the variation of damping for different load levels without providing clear indications on how they are related.

For steel buildings, similar experimental observations on the variation of damping with load level have been reported by Ref. [6]. In that research, the damping of a tall building increased from 0.4% to 1.1% with an increase of displacement amplitude. Tamura and Suganuma [7] have also shown a dependency of frequency and damping to stress amplitude on steel frames. They measured the damping with two different methods, and found values ranging from 0.4 to 1.2% with one method, and from 0.8 to 1.8% with the other method. With both methods they found a modification of damping ratio with the stress amplitude. Fukuwa et al. [8] have also noticed a strong dependency of damping and natural frequency on response amplitude of steel buildings. They attributed this strong dependency to the participation of non-structural elements.

The relation between the level of load and damping is also recognized in codes by providing different values, depending on the type of loading. ASCE [9] recommends, in its commentary, to use a value between 0.15 and 0.5% for wind effect on steel towers, and 5% for earthquake. ASCE [9] commentaries recognize that damping can be influenced by the level of structural response. For elastic dynamic analysis, AASHTO [10] recommends a damping ratio of 1% for bolted and welded structures. The Canadian Bridge Standard [11] recommends the use of damping ratio of 0.75% to 1% for wind analysis of sign structures and vibration of pedestrian bridges. The code AISC [12] proposes values of 3% to 5% for a steel structure under earthquake loading. The Eurocode 1 part 1-4 [13] defining the wind action provides values of structural damping of 0.32% for welded lattice steel

* Corresponding author. Tel.: +1 819 821 7395; fax: +1 819 821 7974.
E-mail addresses: Jean-Yves.Taillon@USherbrooke.ca (J.-Y. Taillon), frederic.legeron@usherbrooke.ca (F. Légeron), Simon.Prudhomme@USherbrooke.ca (S. Prud'homme).

0143-974X/$ – see front matter © 2011 Elsevier Ltd. All rights reserved
doi:10.1016/j.jcsr.2011.10.018