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A full-scale experiment of a lattice telecommunication tower under breaking load

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ABSTRACT

The main aim of this paper is to present results of a full-scale pushover test of a 40 meter telecommunication tower under breaking load. A detailed description of the studied tower has been presented with emphasis on the geometrical imperfections of the selected members of the structure. The results of the experiment consisting of the axial forces in the tower's members, as well as the displacements of the observed nodes as a function of external load have been presented. A comparison of a wind load based on the current standards with the load based on the experimental breaking force has been discussed for a typical set of telecommunication equipment. The main conclusion was that the structure's overall carrying capacity depended on the buckling resistance of the legs. Additionally, theoretical buckling resistances (based on standards) of the tower's legs made with round solid bars were smaller than the experimental axial forces in compression.

1. Introduction

The recent advancements in data transmission technology [1], recurring modernizations of telecommunication equipment, and marked increase in technological requirements and consumer demands [2] significantly influenced the way supporting structures for modern telecommunication equipment are produced and raised. From the point of view of civil engineering, the replacement of transmission equipment, such as various antennas or radio units, which takes place every five years on average, requires respective bearing capacity analyses so telecommunication towers utilized by mobile network operators are becoming subjects to various research activities, experiments, and academic works. Research and development in data transmission techniques and signal quality, as well as introduction of progressive telecommunication services like wireless high-speed internet, impact the design process of communication objects such as masts or towers. The improvements of telecommunication structures have several areas of focus: optimization of manufacturing process, complex FEM analyses, modification of analytical descriptions and regulations specified by standards, or experimental research on different kinds of laboratory models and full-scale testing.

Full-scale tests should be carried out taking into consideration several factors. Birkemoe, in [3], notes that the role of experimental research is linked directly to development of specialized hardware, computer software, and analytical possibilities in civil engineering. The decisive factor for successful experiments; apart from measurements of imperfections, stresses, and displacements; is supplementing the data with material properties. The scientific literature, with accurate advice and best practices on structural testing, i.e., [4,5,6], may provide support in performing the experiments.

Full-scale tests have been carried out in the past with notable successes. Albermani et al., in [7], used results of a study on a 1:1 scale transmission tower (there are several similarities between telecommunication and transmission towers, i.e., eccentrically connected angle section members) to create a numerical model which allowed for prediction of transmission tower failure. An investigation on joint effects in lattice transmission towers can be found in the work of Jiang et al. [8]. Lee and McClure also performed a full-scale experiment [9], namely a pushover test of a single 10 meter transmission tower section consisting of angle beams with typical eccentric connections, in order to depict the phenomenon of large deformations. Chan and Cho, in [10], compared the use of numerical methods utilizing first and second order analyses for designs of angle trusses in lattice structures with angle members. The proposed design method was validated by laboratory tests of trusses using single members of slenderness ratio of about 150. In that case, the experiment constituted the starting point for the assumptions of a subsequent numerical analysis. Taillon et al. also

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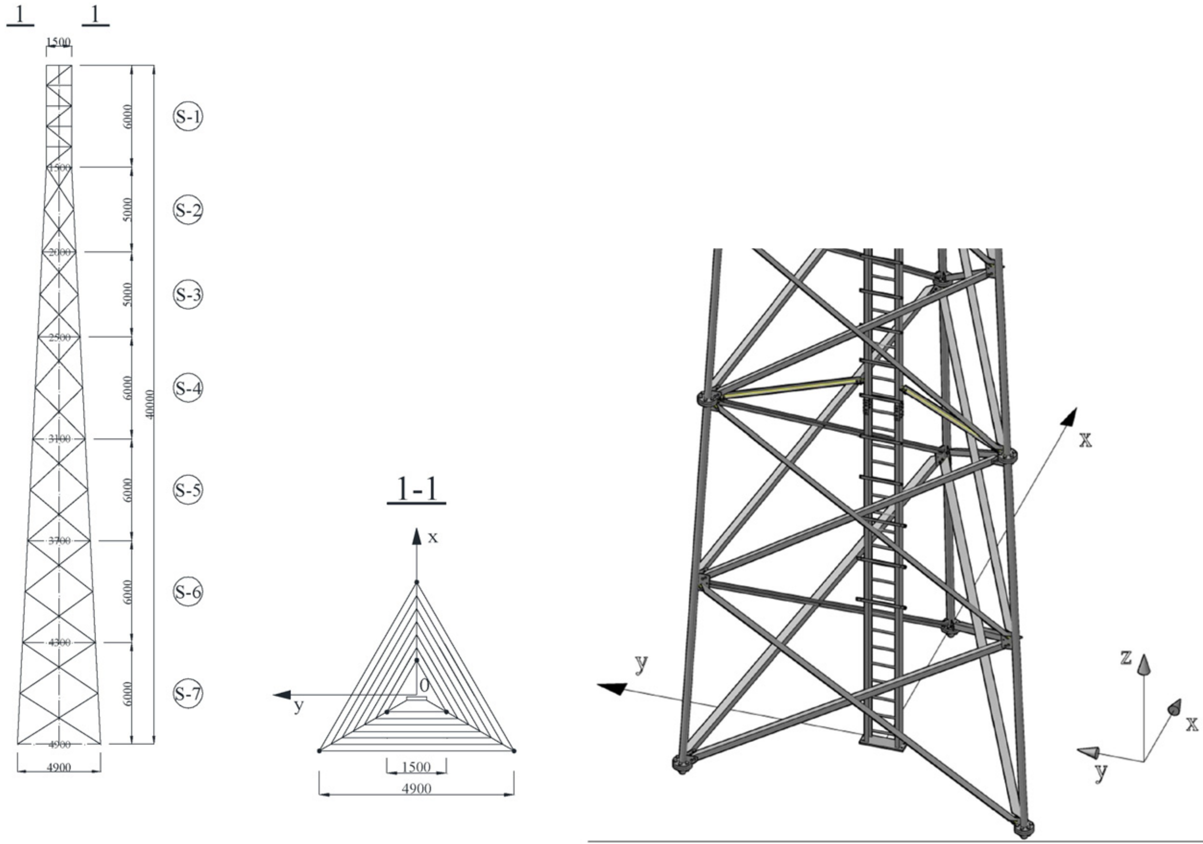

Fig. 1. Static scheme of the tower (left) and 3D view for section S-7 (right), unit is mm.

contributed to static and dynamic tests of lattice structures [11]: an 8 meter transmission tower was subjected to a pushover test and a sudden release of stresses in order to record its free vibrations. Mills et al., in [12], carried out experiments where selected elements of transmission towers were strengthened. The results allowed for verification of solutions used in engineering practice. Similar topics were discussed by Zhuge et al. [13]. Generally, behavior of angle sections (both symmetrical and non-symmetrical which are often used as bearing elements of towers) attracts particular interest of research programs [14,15].

One issue concerning steel lattice telecommunication towers, that has been recently thoroughly discussed and developed, is reliability modeling. Results of research in this area can be found in [16–18]. A valuable contribution, from the perspective of bearing capacity assessment for existing telecommunication towers, was made by Carril Jr. et al. [19]. They discussed the impact of wind action on square cross-section lattice towers. Moreover, Smith, in [20], widely presented the subject of design, construction, and maintenance of telecommunication structures. The publication included reflections on strength, forms of structures, aerodynamic resistance and much more.

Full-scale testing of the engineering structures produces results that may serve in modifications and corrections of analytical descriptions, computational modeling, and standard regulations. Obviously such experiments are difficult to realize due to several reasons such as destruction of the tested object so the experiment cannot be repeated, need for terrain adaptation at the site, use of suitable measurement instruments and research infrastructure, or sometimes purely financial reasons. However, considering how useful results of such tests are, their value cannot be overstated.

This paper is fully devoted to a description of a pushover test on a 40 meter lattice steel telecommunication tower and to presentation of the obtained results. A simplified analytical model of wind loading based on standard regulations has been presented in the second part of the manuscript. Additionally, a typical set of antennas and supporting

Fig. 2. Connections of diagonal bracing members with legs at section's span centers.