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FULL-SCALE BEHAVIOUR OF A TELECOMMUNICATION LATTICE TOWER UNDER WIND LOADING

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ABSTRACT: The aim of this paper is to investigate the full-scale behavior of a 50m tall triangular freestanding lattice tower located in Sânnicolau Mare, Romania. The tower has been equipped with an ultrasonic anemometer, a temperature sensor, two triaxial anemometers and six strain gauges to measure both wind as well as structural parameters. The response to a synoptic wind event that has been recorded on May 18th 2021 is presented and compared to results obtained from the Finite Element Analysis of the tower, results showing good agreement.

Keywords: telecommunication lattice tower, full-scale measurements, wind loading, structural response

1. INTRODUCTION

Telecommunication lattice towers are lightweight structures that support equipment for signal transmission being used mainly in the mobile networking field. Typically, freestanding lattice towers do not exceed 200m in height whereas guyed towers may reach heights up to 600m. Due to their reduced weight, they are generally designed by wind rather than seismic requirements, the design methodology involving the summation of wind forces corresponding to the bare structure to those corresponding to the ancillary elements as specified for example in Eurocode 3 Part 3-1 (Szafran, 2015).

Full-scale measurements presented in literature show approximately the same order of magnitude of the response in both the alongwind as well as the crosswind direction (Hiramatsu and Akagi,1988; Ballio et. al, 1992; Glanville and Kwok, 1995) whereas wind tunnel tests of lattice towers provide quite different results from those obtained from field measurements showing drag coefficients much larger then lift coefficients (Bayar, 1986; Carril et. al, 2003, Calotescu et. al, 2021).

The aim of this paper is to investigate the full-scale behavior of a 50m tall freestanding lattice tower to wind loading. The monitored tower is located in Sânnicolau Mare, Romania. The tower has been equipped with full-scale instrumentation to measure both wind as well as structural parameters. The response to a synoptic wind event measured on May 18th 2021 is presented and compared with results obtained from the Finite Element Analysis (FEA) of the structure.

2. THE MONITORING SYSTEM

The monitored structure is a 50m high triangular telecommunication lattice tower (Fig. 1a) with the base span of 12.0m and top span of 2.30m. The tower is divided into 10 sections and is tapered up to 39.40m with a 3.72deg inclination with respect to the vertical. From 39.40m up to 50m the tower has parallel legs. All members have circular hollow cross-sections. Along the height there are two resting platforms at 15m, 27.5m and two working platforms at 40m and 47.5m. Three panel RF antennas are installed at 50m and one parabolic antenna is installed at 17m. The ladder is positioned in the center of the tower.
The monitoring system includes a GILL ultrasonic anemometer, a temperature sensor, two PCB triaxial accelerometers, six strain gauges, a datalogger and a video surveillance system made up of four cameras (Fig. 1b). The ultrasonic anemometer (Fig. 1c) was installed at 50m on a leg member together with the temperature sensor, the triaxial accelerometers were installed at 50m and at 27m respectively (Fig. 1c) and the strain gauges were installed at the base of the tower, three on the legs and three on diagonals (Fig. 1e).

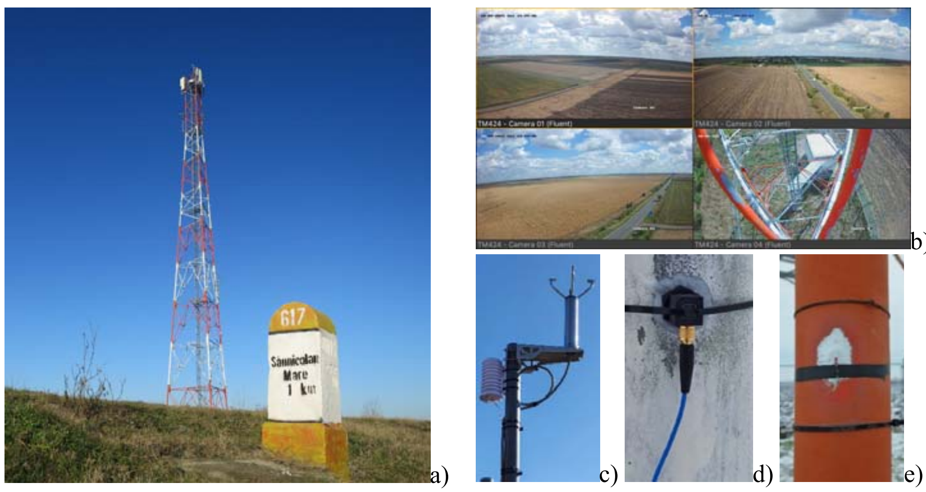


Fig. 1. a) The tower, b) video system c) anemometer and temperature sensor, d) accelerometer and e) strain gauge.

3. WIND CHARACTERISTICS

The event that was recorded on May 18th 2021 is a typical synoptic event being characterized by a Gaussian distribution of wind velocities as seen in Figure 2. The 10minutes average wind velocity is 11.60m/s whereas the peak velocity reached 15.34m/s. During the event, the measured wind direction was 270 degrees which is perpendicular to the face of the tower on which the accelerometers and strain gauges are installed. This direction will be considered as the alongwind direction for the purpose of this study. The temperature was constant in the ten minutes interval centered around the peak velocity.

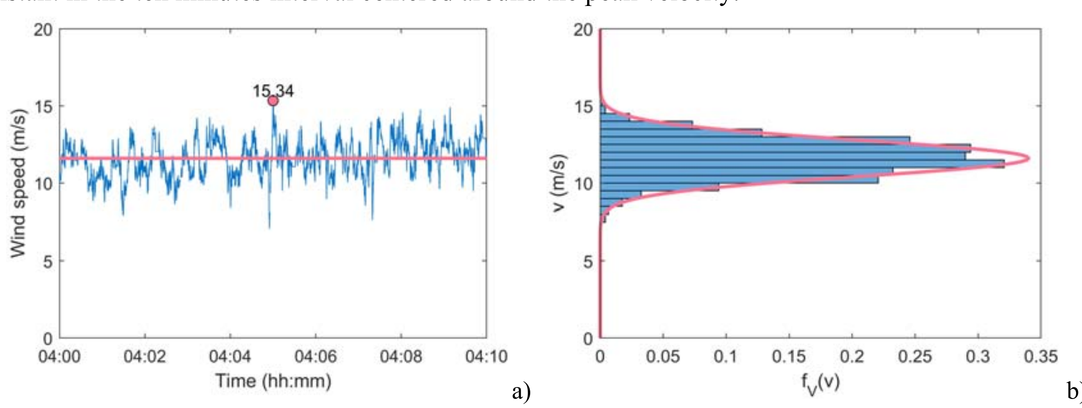


Fig. 2. a) Wind velocity and b) histogram and fitted normal distribution for the May 18th 2021 event.

4. RESPONSE CHARACTERISTICS

The Finite Element Analysis (FEA) of the monitored tower was performed in order to evaluate the dynamic properties of the structure. The first modes of vibration are flexural coupled modes with fundamental frequency 1.72Hz, the third mode is a torsional one having a fundamental frequency of 3.71 Hz, the fourth and fifth modes of vibration are coupled flexural modes with frequency 5.20Hz whereas the sixth mode is a torsional mode with frequency 6.62Hz (Fig. 3).

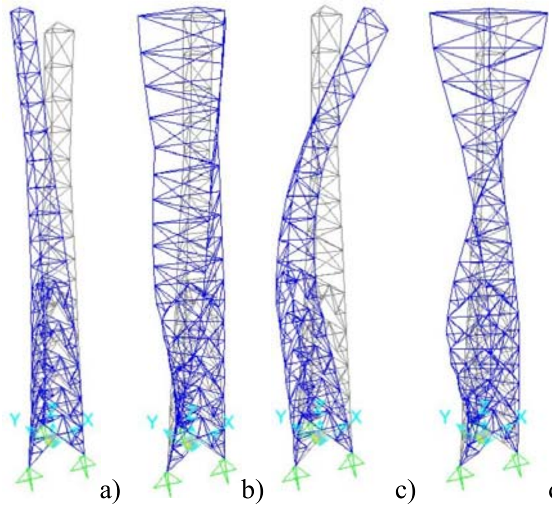


Fig. 3. Mode shapes of the monitored tower a) mode 1, b) mode 3, c) mode 4 and d) mode 6

Figures 4 and 5 show the time histories and Power Spectral Density (PSD) functions of the acceleration measured at 50m in the alongwind and crosswind direction, respectively. At it may be seen, there is a good agreement between the full-scale results and the FEA results with respect to the first flexural mode of vibration, the PSD function of acceleration showing a peak value at 1.70Hz for both directions. The third mode of vibration is not so clearly emphasized. However peak values around 4.2Hz may be noticed for both directions which is slightly larger than the torsional frequency obtained from the FEA. The same is valid for the sixth mode which is again a torsional one. The fourth and fifth flexural modes may be identified on the PSD function corresponding to the crosswind direction where a peak value may be seen around 5.1HZ.

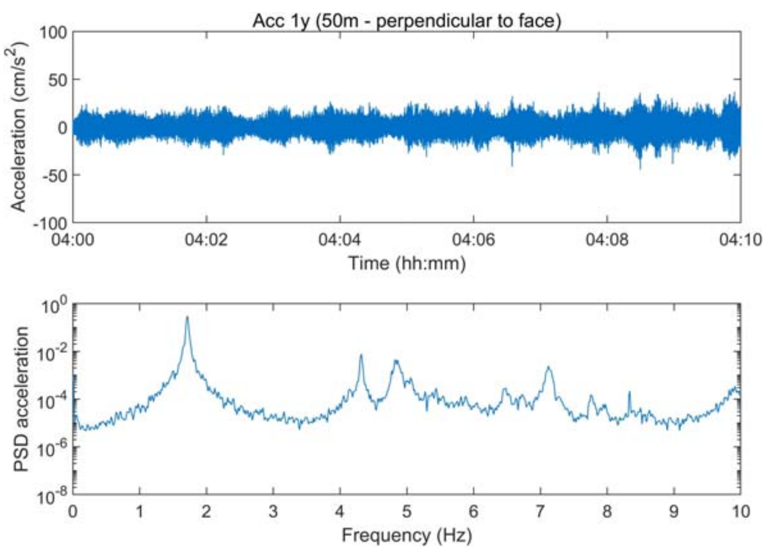
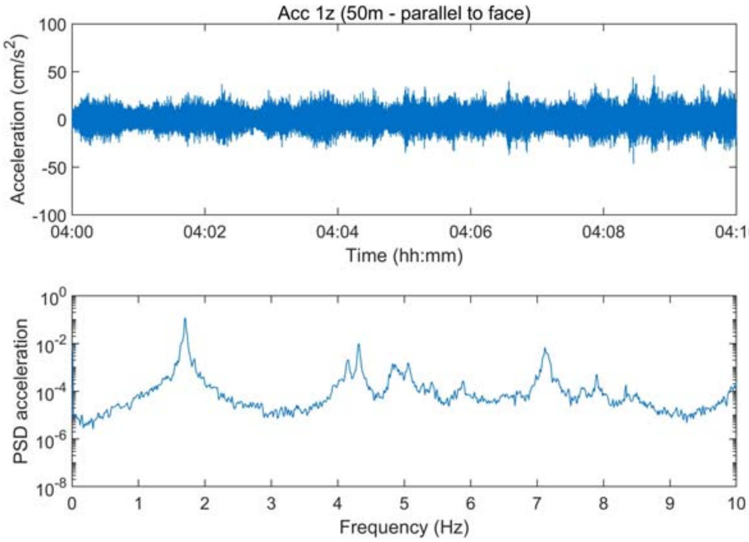


Fig. 4. Time history and corresponding PSD function for acceleration in alongwind direction



b)

Fig. 5. Time history and corresponding PSD function for acceleration in crosswind direction

5. CONCLUSIONS

In this paper, the full-scale behavior of a 50m tall triangular lattice tower was investigated by comparing results obtained from acceleration data measured on May 18th 2021 during a synoptic wind event with FEA results of the monitored tower. Results show good agreement in terms of the dynamic characteristics of the lattice tower, with PSD functions emphasizing peaks around the fundamental frequencies of the structure.

ACQNOLEDGEMENT

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REFERENCES

Ballio, G., Maberini, F., Solari, G., 1992. *A 60 years old, 100 m high steel tower: limit states under wind actions*. In J. Wind Eng. Ind. Aerodyn. (43): 2089-2100.

Bayar, D.C. 1986. *Drag coefficients of latticed towers*. In J. Struct. Eng. (112): 417-430.

Calotescu, I., Torre, S., Freda, A., Solar, G. 2021. *Wind Tunnel Testing of telecommunication lattice towers equipped with ancillaries*. In Engineering Structures (241): 112526.

Carril, C.F., Isyumov, N., Brasil, R.M.L.R.F. 2003. *Experimental study on the wind forces on rectangular latticed communication towers with antennas*. J. Wind Eng. Ind. Aerodyn. (91): 1007-1022.

Eurocode 3 – Design of Steel Structures - Part 3-1: Towers, masts and chimneys – Towers and Masts. 2008. European Committee for Standardization, Brussels.

Glanville, M.J. & Kwok, K.C.S. 1995. *Dynamic characteristics and wind-induced response of a steel frame tower*. In J. Wind Eng. Ind. Aerod. (54/55): 133-149.

Hiramatsu, K. & Akagi, H., 1988. *The response of latticed steel towers due to the action of wind*, In J. Wind Eng. Ind. Aerodyn (30): 7-16.

Szafran, J. 2015. *Analytical determination of aerodynamic resistance of the skeletal telecommunication towers.* In Structure and Environment, Kielce University of Technology (7): 5-14.