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Experimental study of the effects of dish antennas on the wind loading of telecommunication towers

Patricia Martín [a], Vivian B. Elena [a,*], Acir M. Loredo-Souza [b], Edith B. Camaño [c]

[a] Departamento de Estructuras, Instituto Superior Politécnico José Antonio Echeverría, Cujae, 19390 La Habana, Cuba
[b] Laboratório de Aerodinâmica das Construcões, Universidade Federal do Rio Grande do Sul, Brazil
[c] Instituto de Pesquisas Hidraúlicas, Universidade Federal do Rio Grande do Sul, Brazil

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A B S T R A C T

A several number of communication lattice tower collapsed in the past years due to strong winds in Cuba, most of them with a high number of dish antennas. Antennas generate a modification on the wind flow around the tower acting as a screen against wind load and transmitting strong efforts to the tower members. Structural design under wind loads of latticed towers is concerned about the approach to take into account the effect of dish antennas and their interference at different positions in the tower. In this paper, an experimental study in a boundary layer wind tunnel was performed to obtain the drag coefficients and the interference factor on a square section latticed tower with dish antennas. The tower was divided into three sections, which were studied with one and two dish antennas. Results show that interference factor can achieve values smaller and greater than the unity for dependent on the wind direction and relative position of dishes on the tower section. Drag coefficients for sections without antennas are in correspondence with codes.

1. Introduction

In the last years, due to the pass of hurricanes through Cuban territory, a great number of communication towers failed with all the antenna system (Elena Parnás et al., 2011). The antennas, specially the dish antennas, generate a modification of the wind flow that acts as a screen and provokes additional wind forces on the structures. Wind forces acting on the dish antennas must be designed taking into account the effects of their presence on the tower. These effects are considered multiplying an interference factor to drag coefficients of isolated antennas. At times antennas are protected by part of the tower while in some other cases antennas and tower are not overlapped, which implies an increment of the total wind load.

Some published works related with this thematic (Carril et al., 2003; Holmes et al., 1993) and international codes on wind load on structures (AS3995-1994, 1994; BS1800-4, 1995; EC 3: Part 3-1, 2007; ESDU, 1993) give indications of interference factor mainly for one dish antenna located at the same tower cross-section. However, on many real towers two dishes are located at the same level and it is necessary to obtain interference factor for each dish. These cases are complicated because there is interference between the two dishes and the dishes with the tower.

Carril et al. (2003) and Holmes et al. (1993) performed a preliminary study of the effect of two dish antennas located at a same tower cross-section in a wind tunnel. They found great differences in the interference factor according to wind direction and some values greater than 1. Also, they got the interference factor due to a single dish antenna located in the tower cross-section for several wind flow direction. Results varied with wind direction, getting values of interference factor greater than unity and increments on wind load of 30% for a single dish antenna.

Carril et al. (2003) carried out studies to obtain interference factor for a tower with 1–6 dishes antennas located at the same face of the tower and at perpendicular to wind flow. Carril et al. (2003) suggest the use of an interference factor of 1.0 for sections of lattice towers that have solidity of 0.2 or less. For solidity ratios greater than 0.2 interference factor must be calculated as specified in ESDU (1990).

This paper presents an experimental study of the effects of dish antennas on the wind loading on a typical self-supported Cuban design tower of square section made of angle members. Three tower sections of different solidity ratio and different total enclosed area were studied in a wind tunnel for various wind flow directions. Sections were tested to obtain drag coefficients with one and two dish antennas at the same tower cross-section in order to compute wind forces. Interference factors for one dish

* Corresponding author.
E-mail address: vivian@civil.cujae.edu.cu (V.B. Elena).

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attached to a tower section model and interference factor for a second dish when there is already a dish located were also obtained. A qualitative approach was made with the purpose to show when there is an overestimation or underestimation of the total drag coefficients.

2. Wind tunnel test

2.1. Models

The tower geometry and the cross-sectional dimensions of columns (C), bracing members (B) and diagonals (D) are presented in Fig. 1. Three sections of the tower were selected for the wind tunnel test as shown in Fig. 1. Sections present different geometries, solidity (ϕ) and total enclosed area. In this work, total enclosed area is defined as the area limited by the external bars of the tower section models.

Section models were made of wood using a geometrical scale of 1:10 as shown in Fig. 2. The geometrical scale was selected to satisfy that Reynolds number on angle members cross-section models (Table 1) that were greater than 2200 according to Holdo (1993) and Vickery (1982). As a result, drag coefficients are independent on Reynolds number and there is no scale effect. The thickness of angle members was not scaled. Other factors that were considered to define the models were dimension of the test section of the tunnel, appropriate materials for model's construction and wind tunnel blockage. Maximum blockage ratio calculated for section models in this work are equal to 6.5% for section 1, while for sections 2 and 3 blockage ratio is 3%. There is no need of corrections for sections 2 and 3 according to Holmes (2004) and Simiu and Scanlan (1996). For section 1 corrections were made according Maskell method with a blockage factor (m) of 1.3 according to ESDU, 1998.

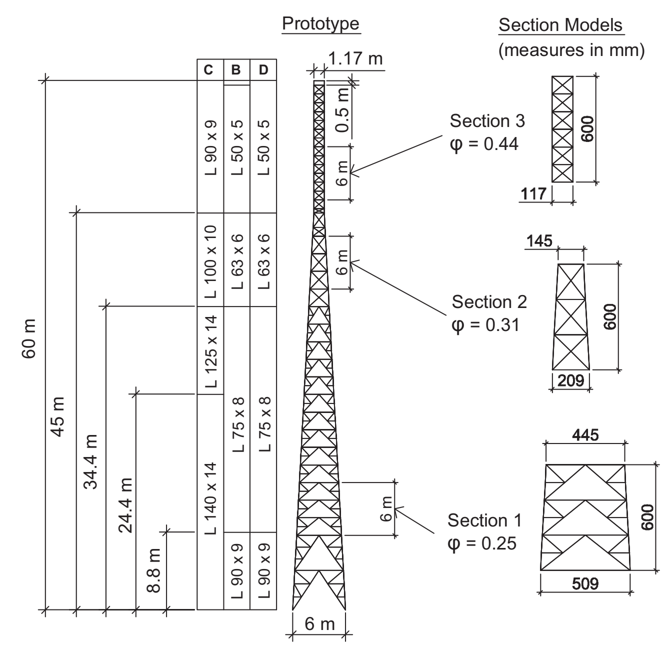

Fig. 1. Sketch of prototype and tower section models studied.

The dish antenna chosen for this work has 2 m diameter and detailed characteristics have been obtained from RFS (2013) Catalog. Their ratio H/D (Fig. 3a) is 0.182. Dish model was made of clay from wooden pattern with a scale of 1:10, the same used for tower section models. Drag coefficients are independent of Reynolds number for dish antenna when it is greater than 10^4 according to White (2011). The value obtained for the model of this study was 200 833.

2.2. Testing facilities

The experimental tests were carried out at the “Prof. Joaquim Blessman” boundary layer wind tunnel of Aerodynamic Laboratory of Construction at the UFRGS, Brazil. The features of this tunnel can be seen in Blessmann (1982).

The models were seated above the tunnel floor on a turntable circular flat plate, which had a force balance attached to its center. The force balance was rigidly connected to the turntable. Drag forces measured were performed with the force balance axis aligned with the tunnel axis. In this approach, the entire assembly was rotated around the central axis of the tower section models to measure the forces at different wind angles.

To obtain higher precision in the experimental method, drag forces due to the wind tunnel test turntable and drag forces from the devices used for measuring were deducted from the total drag forces measured on the model. After installing the force balance in the wind tunnel cross section, the balance was calibrated statically using a set of known masses. Two daily calibrations were performed, at the beginning and at the end of the tests series in order to guarantee a proper function of the measuring cells.

Drag forces were measured with a unidirectional balance coupled with strain gages. The balance was built at the Laboratory of Aerodynamic of Constructions of the UFRGS. Two horizontal rigid plates attached by four vertical stainless steel thin plates compose the balance. The bottom rigid plate is fixed to a tripod set on the floor of the wind tunnel facilities while the top rigid plate is fixed to the turntable (base of the tested models). The test turntable displaces along with the tested models in the flow directions

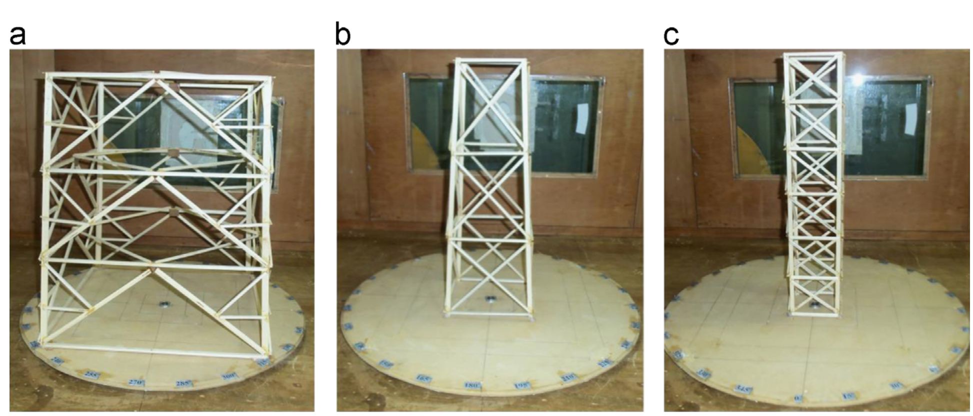

Fig. 2. Tower section models: (a) section 1, (b) section 2, and (c) section 3.