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Effect of ancillaries on the aerodynamic behaviour of freestanding lattice towers

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ABSTRACT: Free-standing lattice towers are structures commonly used in the field of telecommunications, as they support antennas and other equipment necessary for broadcasting as well as signal transmission. Due to their lightness they are particularly sensitive to wind load. An investigation of the influence of antennas as well as linear ancillaries such as ladders and cables has been carried out on the aerodynamic coefficients of a sectional lattice tower model. A series of static wind tunnel tests have been planned and conducted, and three models have been considered. A first model has been tested only considering its structural components (Test 1). Sequentially, linear ancillaries such a ladder and cables (Test 2) and discrete ancillaries such as panel and parabolic antennas (Test 3) were mounted and tested. For each test, aerodynamic data are evaluated at different wind tunnel speeds and angles of attack. The main purpose of the study is to understand the influence of ancillary components on the wind loading of lattice towers.

KEYWORDS: Aerodynamic loading, ancillaries, lattice towers, wind tunnel tests.

1 INTRODUCTION

Free-standing lattice towers are structures used in the field of telecommunications as they support antennas and other equipment, necessary for television and radio broadcasting, as well as signal transmission. The aerodynamic load is the more relevant one for such structures. Lattice towers are also characterized by additional equipment such as ladders, cables and antennas. All these elements greatly increase the wind-exposed area.

It is also important to remember that up to now few similarities have been found between full scale measurements and wind tunnel tests. Full-scale measurements of real lattice towers usually reported almost the same order of magnitude of the alongwind and crosswind response [1, 2, 3, 4], whereas wind tunnel tests on sectional [5, 6] and full scaled models [7] showed values of the drag coefficient often much larger than those of the lift coefficient. This result is consistent with a first run of investigations that were carried out on the sectional model of a 90m high triangular lattice tower [8] in the wind tunnel laboratory at the Department of Civil, Chemical and Environmental Engineering (DICCA) of the Polytechnic School of the University of Genova.

The previous tests considered a model reproducing a bare structure. The legs were realized with circular section elements, whereas two sectional types have been considered for diagonal bracings, i.e. angle and circular (resulting then in two test models). Based on the consideration that significant crosswind forces may arise from the presence of ancillaries, the present paper describes a series of tests that make use of the previously built models equipped with linear and discrete ancillary components, in order to identify the influence of these elements on the wind loading of lattice towers, mainly in the crosswind direction.

2 WIND TUNNEL TESTS

Tests have been carried out in the closed-loop subsonic circuit wind tunnel for aerodynamic and civil experiments of University of Genoa. The wind tunnel has a test chamber with cross section 1.7 x 1.35 m^2 (width x height) and, two test sections: the former is mainly intended for aerodynamic tests in homogeneous flow, whereas the latter is used when a fully developed boundary layer is needed. The present tests have been conducted in the former section of the WT, where the flow uniformity is within 1% and longitudinal turbulence intensity is below 0.25% (smooth flow conditions). A grid has also been used consisting of slender square bars to test models in turbulent flow conditions. For the present campaign, the test section was equipped by a pitot tube to measure the undisturbed wind speed (placed 0.2 m above the wind tunnel roof) and a fast-response multi-hole probe (Cobra probe) to measure the wake characteristics.

The wind tunnel model simulates the intersection between two subsequent sections located close to the top of a 90m tall cellular lattice tower described in [9]. The scale of the models was chosen 1:5.7 due to the availability of commercial components. The tower legs are parallel and arranged in triangular cross-section. The bracing pattern of diagonals consists of X-type bracing. The model was tested using two different types of bracing in order to evaluate their influence on aerodynamic loading. The model with circular leg members and angular diagonal and horizontal members was called *L-Model,* whereas for the *O-model* circular cross-sections have been used both for legs as well as for diagonals. The characteristics of the model are reported in Table 1.

Table 1. Model characteristics

Element	Cross-section [mm]	Length [mm]
Legs	ϕ20x1.5	878
Diagonals, *L*	L 15x15x1.5	640
Diagonals, *O*	ϕ10x1.5	640
Horizontals, *L*	L 15x15x1.5	485
Horizontals, *O*	ϕ10x1.5	485

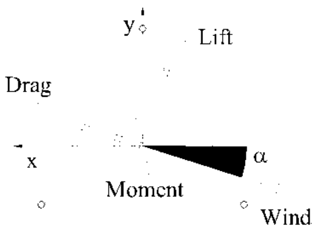

Figure 1. Model position respect to wind direction

Tests have been conducted in both smooth and turbulent flow conditions. The aerodynamic coefficients have been evaluated based on the time history of the forces detected by two rigid balances that support the models at their extremities. The drag, lift and moment coefficients are defined as follows:

$$C_i = \frac{F_i}{\frac{1}{2}\rho U^2 A_{ref}} \quad (i = D, L); \quad C_M = \frac{M}{\frac{1}{2}\rho U^2 A_{ref} L}; \qquad (1)$$

where U is the reference mean wind velocity, A_{ref} is the reference area of the model, ρ is the air density, L = 526mm is the reference dimension of the model, F_D and F_L are the drag and lift forces and M is the torsional moment. The reference area A_{ref} is the solid area projected onto a plane orthogonal to a face which[u1], for both tests, was taken as the face of the bare model corresponding to α = 0° angle of attack[G2]. For Test 1 (Table 2) only a range of angles of attack corresponding to the symmetry of each model was considered. Wind tunnel tests have been carried out at different wind speeds to check the dependence of the aerodynamic coefficients on the Reynolds number, which has been found to be negligible.

Table 2. Test1: Setup characteristics

Model	Angle [deg]	Velocity [m/s]	Flow type
L	0°-120°	8.8, 12.8, 16.7	turbulent
L	0°-120°	9.7, 14.1, 18.5, 22.9	smooth
O	0°-60°	9.7, 14.1, 18.5, 22.9	smooth
O	0°-60°	8.8, 12.8, 16.7	turbulent

The presence of ancillary components such as ladders, cables and antennas can greatly change the aerodynamic behavior of the structures. First of all, it increases the exposed area determining an increase of drag force. However, is it not yet clear what is the effect on cross-wind direction and if ancillaries can be the reason for the strong correlation between alongwind and crosswind response on full-scale measurements.

Two sets of tests have been carried out in order to define the effects of ancillary elements on the aerodynamic behavior (Table 3, Figure 2). The former one (Test 2) is characterized by linear ancillaries, placed within the model perimeter: a ladder, five cables of two different diameters and five support elements of two different dimensions. In the latter set of tests (Test 3), the combined effect of linear and discrete ancillary components is tested. The models of three panel antennas and one parabolic antenna was realized. The three panel antennas was arranged on each leg of the model, while the parabolic antennas was arranged on one face.The models of Test 2 and Test 3 are tested in both smooth and turbulent flows with angular and circular section bracings. The angle of attack is varied by 10° steps by rotating the model in the counter clockwise direction and only one velocity is tested for the full range.

Table 3. Ancillaries elements

	Elements
Linear	Ladder handrail
	Steps
	Support n1
	Support n°2
Discrete	Panel antennas
	Parabolic antennas

Figure 2. Sectional wind tunnel model with ladder, cables, elements support and antennas.

In Figure 3 the mean values of drag, lift and moment coefficients are reported for *O-model* for Test 1, Test 2 and Test 3 configuration, both in smooth and turbulent flow[u3][G4]. At the moment, Test 3 is characterized by linear ancillaries (ladder, support elements and cables) and 3 panel antennas, symmetrically arranged on each leg of the model.

It may be noticed that mean drag coefficients increase from Test 1 to Test 3 and from smooth to turbulent flow. As regards the lift coefficient, it is possible to look at a change of sign of mean coefficient from Test1 to Test 2 and Test 3. Differently, the values of the lift coefficient in the Test 3 and Test 2 are very similar to each other. The moment coefficient is always very close to zero.

Currently, new wind tunnel tests on the sectional model with both linear as well as discrete ancillaries, considering also non symmetric arrangements, are in progress. The results of this test campaign will be reported and discussed in the full version of this paper.

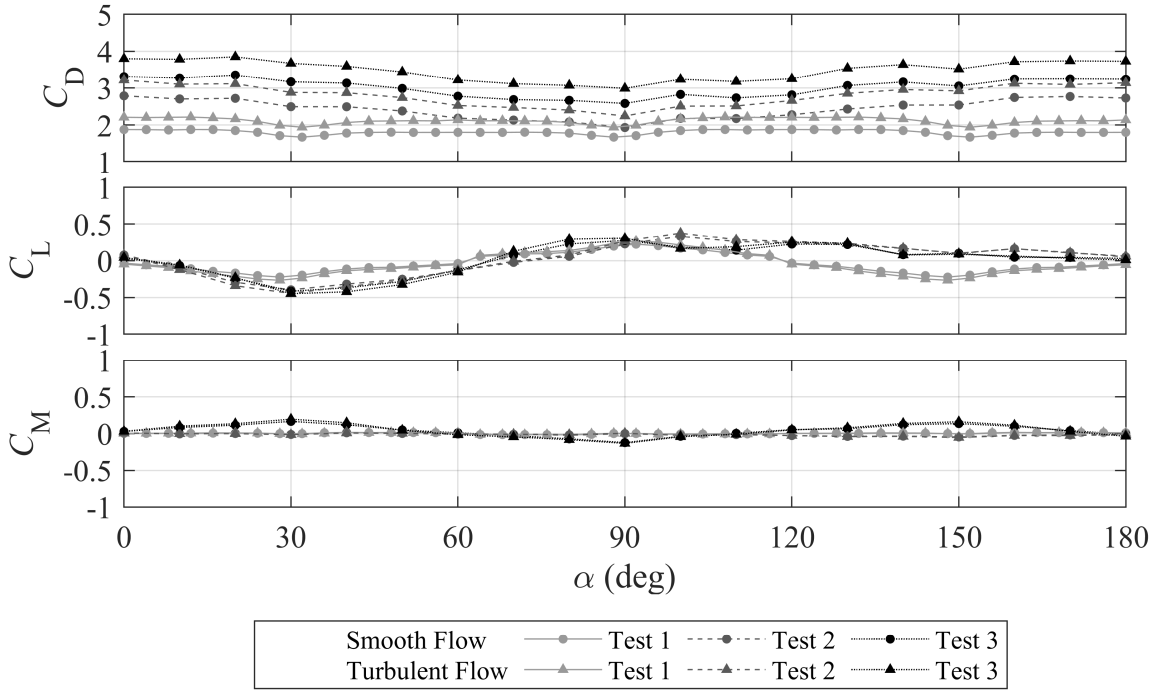

Figure 3: Mean drag, lift and moment coefficients for the *O-model* in smooth and turbulent flow.

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