RENSON
Creating healthy spaces

Wind tunnel measurements of the aerodynamic forces on Renson blade type L.066.01

Intro

Blade type L.066.01 of Renson's Linius® product range, has been tested in the wind tunnel at Vrije Universiteit Brussel.

This report is an assembly of copied parts of the original test report. Some parts are highlighted, others have been removed or blanked out as they don't concern the subject of this note.

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Vakgroep Toegepaste Mechanica

WIND TUNNEL MEASUREMENTS ON DIFFERENT RENSON's SHADING BLADES

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1. INTRODUCTION

This report summarises the wind tunnel testing campaign performed on different shading blades developed by Renson Projects NV. This testing campaign was conducted at the Department of Mechanical Engineering of the *Vrije Universiteit Brussel* (VUB), during the months of October and November 2006. The study was carried out at the VUB low speed wind tunnel (a brief description of the facility is included in annex 1 of this report), on full-scale and scale models of the shading blades, considering different configurations of the models and, in some cases, different yaw angles of the wind.

Although the use of wind tunnel testing is a widely accepted research technique in civil and industrial engineering, the tests to be performed have to be planned and designed according to some preliminary considerations. The use of wind tunnels for aerodynamic studies is based on the principle of dynamic similarity of Fluid Mechanics, which establishes the direct applicability of dimensionless coefficients measured in the wind tunnel on a scale model to the full-scale case (Meseguer et al., 2001). This applicability requires that the following conditions are met:

- The geometrical similarity between the real case and the tested model.
- The equality between the Reynolds and Mach numbers of the flow associated to the flow near the obstacle in the full scale case and in the wind tunnel test.

To satisfy the geometrical similarity condition, an exact scale reproduction of any aerodynamic-significant details in the model is required. Normally as workshops where the models are made can deal with a good level of details.

The second condition is harder to fulfil as it is extremely difficult to reproduce in a wind tunnel test both the Reynolds number (Re) and the Mach number (M_∞). Fortunately, in almost all cases relevant to civil aerodynamics, the following considerations can be made:

- For low speeds (almost incompressible flows, Mach number lower than 0.3), the effects of compressibility of the air are minimal so, once the condition of Mach number lower than 0.3 is met in both cases, real and scaled, the wind tunnel results will not depend on the Mach number.

- Equality of the Reynolds numbers requires equality of the product $U{\cdot}L$ in real and wind tunnel cases (Re = $U{\cdot}L/\nu$, where U is the wind velocity, L is a characteristic length of the obstacle and ν is the kinematic viscosity of the air). This condition means that the stream velocity in the wind tunnel should be increased accordingly to the scale of the model but not exceeding the before-mentioned limit of $M_\infty < 0.3$ ($M_\infty = U/a$, where a is the sound speed in the air). Except in very large wind tunnels, experimental Reynolds numbers are much lower than the real ones. Fortunately, the configuration of the flow in the surroundings of a bluff body, for Reynolds numbers above a critical value, is independent of the Reynolds numbers value and that implies that the distribution of pressure coefficient over the body does not change significantly.

In the case of civil aerodynamics the structures to be studied are normally bluff bodies, with sharp or not very rounded edges which cause a localised and predictable detachment of the boundary layers at low wind velocities. This configuration of detached boundary layers does not change for higher wind velocities, so in most cases of civil aerodynamics it is not necessary to preserve the Reynolds number of the full scale flow once the critical Reynolds number has been exceeded.

In the present testing campaign both full-scale and scale models were tested in the wind tunnel. Full-scale models are composed of Linius®, ® and), whereas scale models are composed of scaled blades (see figure 1.1). The scale used is 1:2.

In previous tests one of the full-scale models (Linius® blades) was tested at two different wind speeds, $U_\infty \sim 19$ m/s and $U_\infty \sim 10$ m/s. As no remarkable differences were observed in the measured forces, all full-scale models were tested with the maximum speed allowed by the wind tunnel ($U_\infty \sim 19$ m/s).

2 EXPERIMENTAL PROCEDURE

In the present testing campaign the wind force coefficients of 29 different blade configurations were measured. As indicated in the previous chapter, the forces were measured considering the testing blade not standing alone in front of the wind, but together with other blades, that is, forming a plane porous barrier made of blades (Renson solar shading structures and Linius® systems –called Continuous Louvres Systems, CLS, in the past–, see figure 2.1).

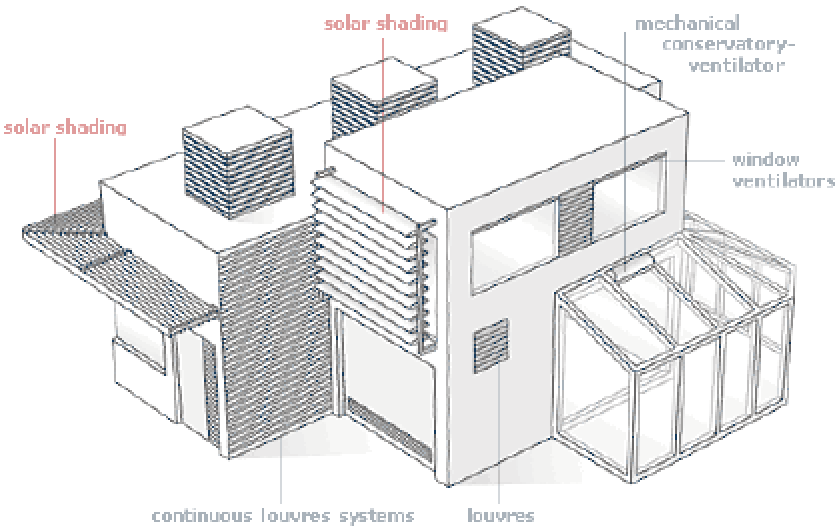
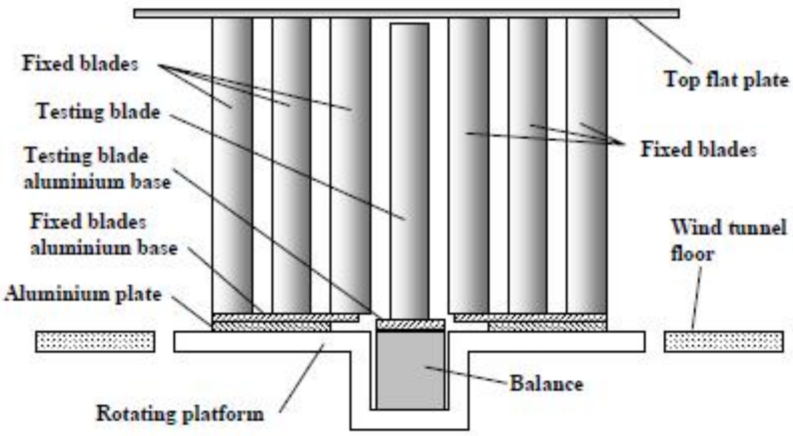


Figure 2.1. Sketch of some of the Renson products. The solar shading and continuous louvres systems, both made of several blades, can be observed in the figure. This image has been taken from the Renson Projects NV web page.

In figure 2.2 one of the tested configurations is shown together with a sketch of the general arrangement designed for these tests. The testing model is composed of several blades, all welded to two floor base plates except the one to be tested, which is fixed to the balance of the wind tunnel using also a base plate. Both plates which are the base for the fixed blades are screwed onto two aluminum plates. This is necessary to avoid any contact between the fixed blades of the model and the testing blade or its base plate. One flat plate, completely horizontal and parallel to the wind direction, was also welded onto the top of the fixed blades in order to better simulate bi-dimensional flow around the blades, that is, to eliminate the effect of the three-dimensional flow at the top of the blades (see figure 2.1).



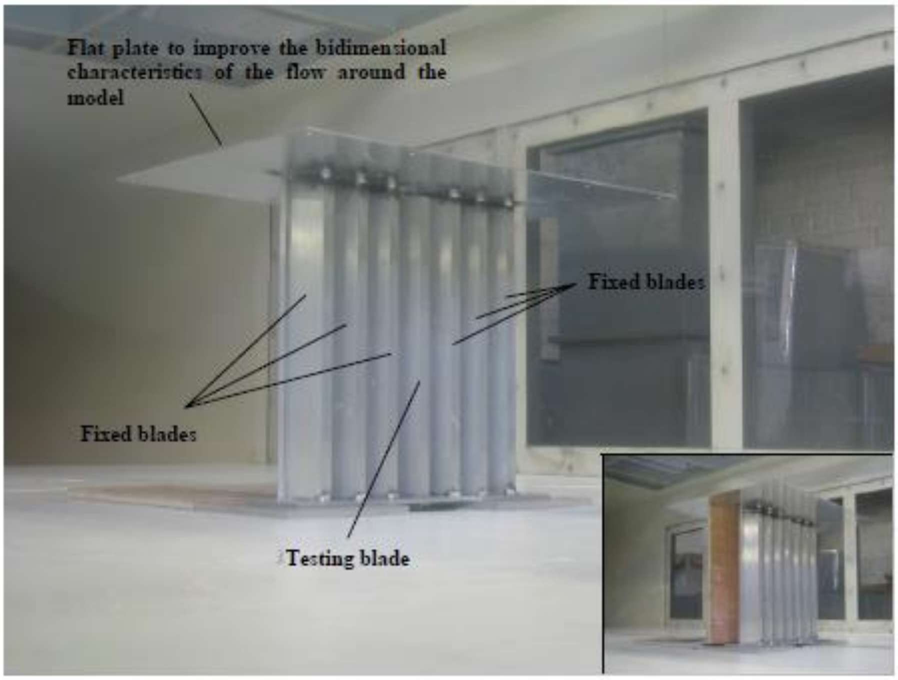


Figure 2.2. General arrangement in the wind tunnel of the model, and picture of a Linius® blades model (see table 2.1). In the down-right corner the wooden plate placed downstream the model to simulate the wall is shown.

As said, 29 different-blade configurations, that is, different models, were tested, all cases are included in table 2.1 (sketches of all different models are included in annex 2). The Linius® blades are designed to be located near a wall, and for this reason four different cases were tested, each one corresponding to a specified distance to a wall. A wooden plate was located downstream to the models to simulate the wall, see lower-right corner of figure 2.2. The distances between the models and the plate are the real ones, d = 20, 46 and 100 mm, the fourth distance ($d = \infty$) corresponds to the case of model tested with no wall placed downstream (see figure 2.3). The blade alone, that is, without the influence of other surrounding blades, was also tested. This decision was made during the experiments to get a more complete analysis which could be useful for Renson Projects NV in the future.

Table 2.1. List of cases studied in the present testing campaign. The blade codes and the description correspond to Renson standards.

Group	Case (blade code)	Description	Wind direction (α)	d
Linius® (CLS)	1.01		-	20/46/100/∞
	1.02		-	20/46/100/∞
	1.03		-	20/46/100/∞
	1.04		-	20/46/100/∞
	1.05		-	20/46/100/∞
	1.06		-	20/46/100/∞
	1.07	L.066	-	20/46/100/∞
	1.08		-	20/46/100/∞
	1.09		-	20/46/100/∞

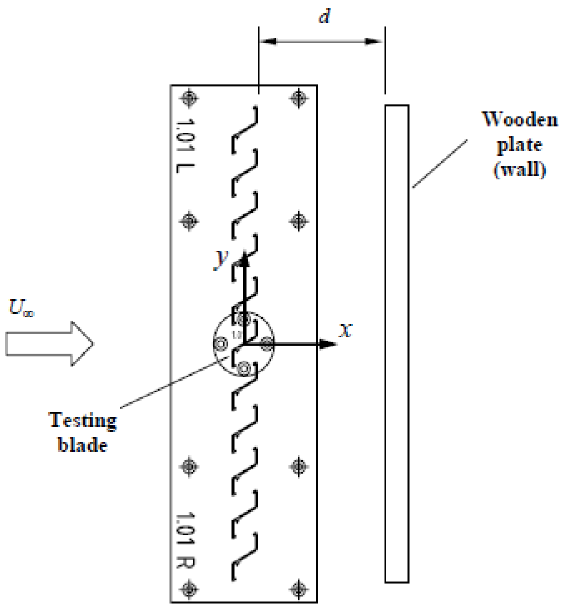


Figure 2.3. Sketch of the arrangement in the wind tunnel of a Linius® blades model. The wind forces direction criterion is indicated in the sketch.

3 RESULTS AND DISCUSION

Dimensionless force coefficients are defined as follows:

$$c_x = \frac{F_x}{q_\infty c l} \qquad (1)$$

$$c_y = \frac{F_y}{q_\infty c l} \qquad (2)$$

F_x and F_y are the forces measured on the blades (see figures 2.3, 2.4, 2.5 and 2.7) by the balance of the wind tunnel (see figures 2.2), q_∞ is the dynamic pressure measured upstream to the model (see annex 1 for more information concerning the wind tunnel), and c and l are respectively width and length of the testing blade. For Linius® and vertical Sunclips® blades c represents the dimension of the blade perpendicular to the wind,

Linius®

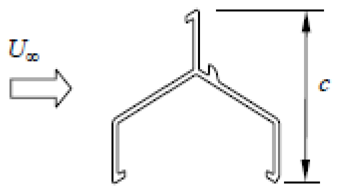


Figure 3.1. Sketches indicating the criteria followed to chose the values of the width, c,

Table 3.1. Values of width, c, and length, l, of the blades used to calculate force coefficients c_x and c_y.

Group	Case (blade code)	Description	c [m]	l [m]
Linius® (CLS)	1.01			
	1.02			
	1.03			
	1.04			
	1.05			
	1.06			
	1.07	L.066	0.0765	0.38
	1.08			
	1.09			

The force coefficients related to Linius®, Sunclips® and Icarus® blades are respectively included in tables 3.2 to 3.8.

The results concerning Linius® blades tested alone are coherent with the drag coefficients known from bi-dimensional square cylinders (see figure 3.2). The maximum load was measured for the case 1.03

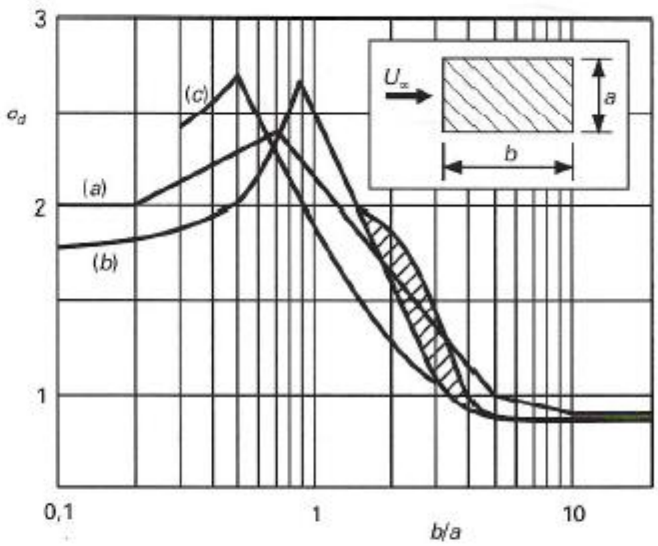


Figure 3.2. Drag coefficient of square cylinders as a function of the shape, that is, the *b/a* ratio (indicated in the figure). Data are taken from Eurocode 1 (a), Simiu & Scanlan (b), and Courchesne & Laneville (c). The data are referred to different levels of air turbulence intensity, I_u. The graphic was taken from Meseguer et al. (2001).

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Table 3.2 (continuation). Forces coefficients, c_x, c_y, and the square mean $(c_x^2 + c_y^2)^{½}$, measured on Linius® blades.

Case	*d* [m]	c_x	c_y	$(c_x^2 + c_y^2)^{½}$
1.06	0.02			
	0.046			
	0.1			
	∞			
	blade alone			
1.07	0.02	0.03	−0.03	0.05
	0.046	0.11	−0.07	0.13
	0.1	0.44	−0.24	0.50
	∞	1.27	−0.71	1.46
	blade alone	1.30	−0.94	1.60

4. REFERENCES

J. Meseguer, A. Sanz, J.M. Perales, S. Pindado, *Aerodinámica civil. Cargas aerodinámicas en las edificaciones*. McGraw-Hill Interamericana de España, S.A.U., Madrid, 2001.

I.E. Idel'chik, *Handbook of hydraulic resistance*. Begel House, Inc., New York, 1996.

Annex 1

V R I J E   U N I V E R S I T E I T   B R U S S E L
VAKGROEP TOEGEPASTE MECHANICA

The wind tunnel used in the present study is an open circuit wind tunnel. The air is moved thanks to a centrifugal fan located before the contraction. After the fan there is a stabilisation chamber, and then the contraction. The flow is driven to the testing chamber (2 x 1 square metres cross-section) through a long constant section square duct. After the testing chamber the wind tunnel has a small diffuser and a bend, as the air is finally thrown out the wind tunnel in the direction of the VUB lab's ceiling (see pictures in figure A1.1).

Figure A1.1. Some pictures of the VUB's wind tunnel, where the testing campaign was carried out.

The wind tunnel is equipped with a BnC-Lambrecht 630a pitot tube located at the ceiling of the testing chamber, upstream to the point where the models are allocated. This pitot tube is connected to a SETRA Model 239 differential pressure sensor, which measures the dynamic pressure. This sensor is connected to a National Instruments PCI-6221 board installed in a computer which controls the whole measurement process. The wind tunnel is also equipped with a balance made by TEM Engineering Limited, connected to a National Systems PCI-6220 board which is installed in the computer as well. At the computer the process can be monitored thanks to a graphic interface programmed using LabVIEW.

Annex 2

V R I J E   U N I V E R S I T E I T   B R U S S E L
VAKGROEP TOEGEPASTE MECHANICA

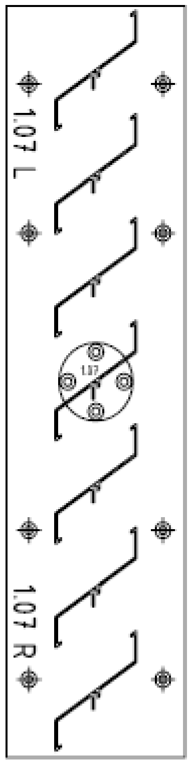

Figure A2.1 (continuation). Sketches of the Linius® blades model configurations tested.
Blades codes are indicated on each sketch.

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Conclusion

For blade type L.066.01 following force coefficients can be used for continuous louvres systems with blades on pitch 66:

- c_x = 1,27
- c_y = 0,71

Usually, in calculation notes for a vertically positioned Linius system of Renson (with horizontally positioned blades), those values are respectively referred to as:

- c_{fy} = 1,27 (horizontal wind load coefficient)
- c_{fz} = 0,71 (vertical wind load coefficient).