WARSAW UNIVERSITY OF TECHNOLOGY
The Faculty of Power and Aeronautical Engineering
Institute of Aeronautics and Applied Mechanics

Report

„Test to determine the coefficient Cx (SCx) at 150 km / h for the URBANO LED family and the URBINO LED family by the LUG manufacturer”

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Warsaw, March 2018

1. Aim of the project.

The aim of this study was to determine the drag coefficient Cx and observe the effects of wind pressure for the luminaires URBANO LED and URBINO LED.

Image No. 1 and 2. View of the luminaires

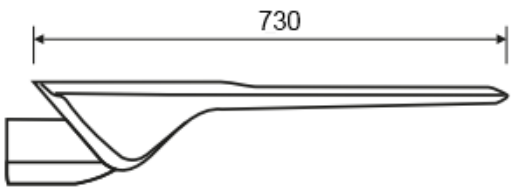
URBANO LED

URBINO LED

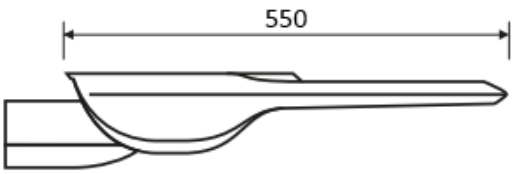
Source: LUG materials

Figure No. 1. A side projection of the luminaires

URBANO LED



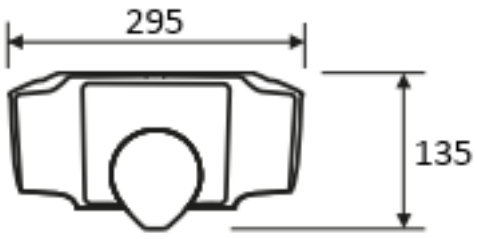
URBINO LED



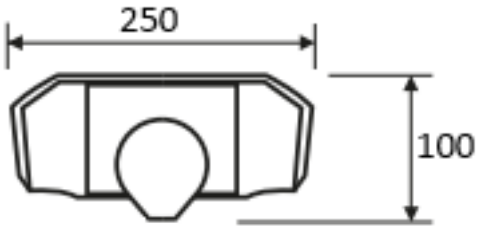
Source: LUG materials

Figure No. 2. A back projection of the luminaires

URBANO LED



URBINO LED



1. *Source: LUG materials*

2. Measurement

2.1. Coefficient Cx measurement

Between 09 – 27 February 2018, the measurement were conducted in order to determine the air resistance coefficient *Cx* for inflow directed from the front, side and back of the luminaire series URBANO LED and URBINO LED, manufactured by LUG Light Factory.

The measurements were taken in Tunnel No. 1 of the Warsaw University of Technology Institute of Aerodynamics. The tunnel with a diameter measuring 1.16 m wos equipped with the Witoszyński weight, where the resistance force Px was measured. Received measurements of the Px power were used to calculate the air resistance coefficient Cx.

Figures 3, 4 and 5 present schematic circuit measurement and images from 3 to 14 illustrate the suspension of the luminaire for each setting.

The first setting was designed to determine the Cx coefficient for the luminaire flown around from the front (Figure No 3 and Image from 3 to 6), which corresponds to the smallest cross-sectional area. The second setting shows change of the suspension and flow around from the side of the frame (Figure No 4 and Image from 7 to 10) – setting with the largest cross-sectional area.

The measuring system is shown in Figures No 3, 4 and 5 and consisted of the following elements in sequence:

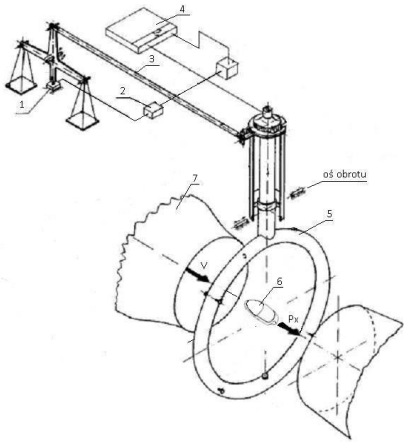
1. train gauge force transducer,
2. amplifier,
3. lever system,
4. computer
5. frame weight,
6. luminaire model,
7. wind tunnel.

Luminaire tested in a wind tunnel was attached with wires to the frame which covers the measuring space. Method of attachment is shown in Images from 3 to 14, and schematically in Figures No 3, 4 and 5. Wires binding luminaire to the frame transfer all the forces occurring in the model to the frame, including the tested force Px.

The Px resistance force acting on the model due the frame weight and lever system is transferred to the strain gauge force transducer. From the transducer the resistance force Px value is transmitted through the amplifier to the computer, due to which it can be read.

Flow from the front

Figure No 3



Source: own materials

URBANO luminaire

Image No 3 with horizontal mounting

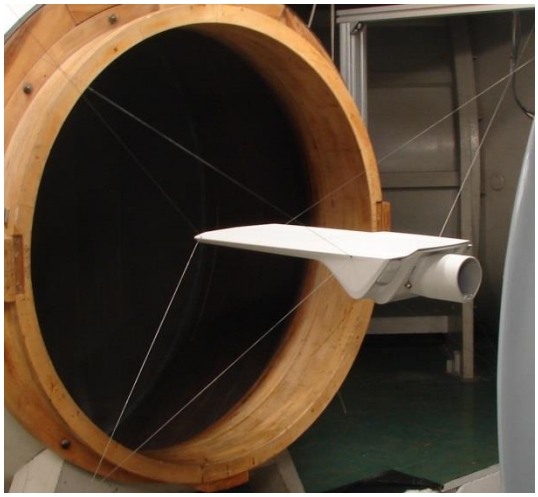
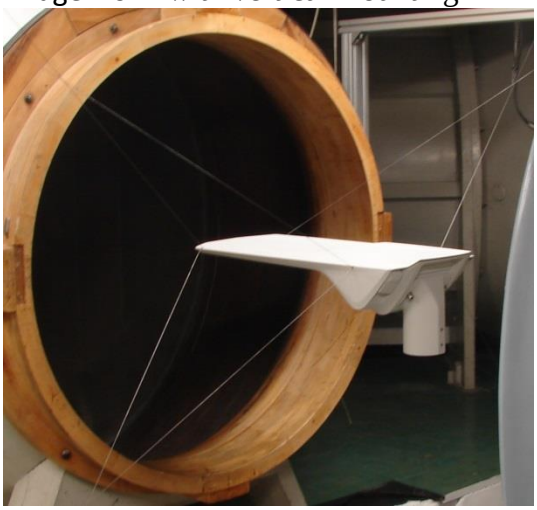


Image No 4 with vertical mounting



URBINO luminaire

Image No 5 with horizontal mounting

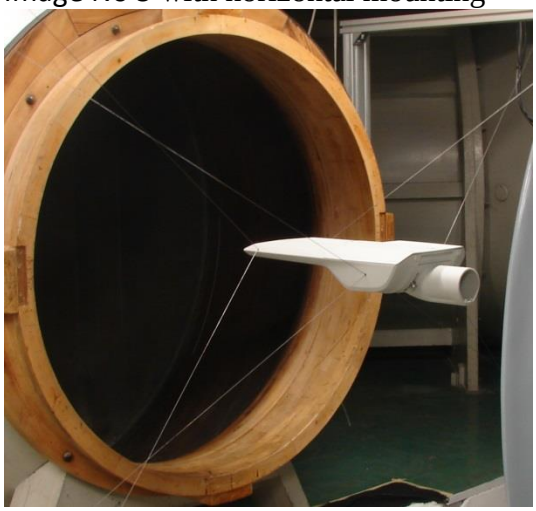


Image No 6 with vertical mounting

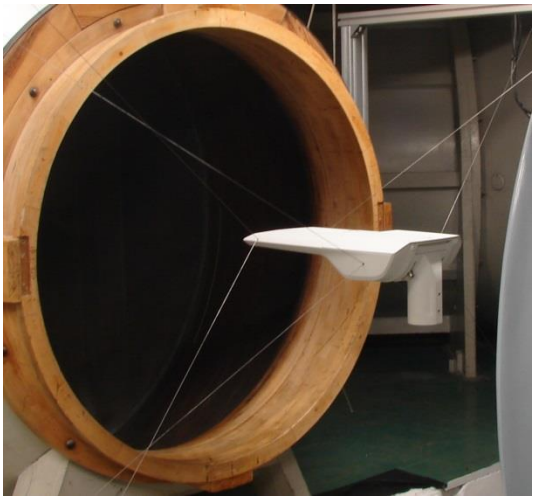
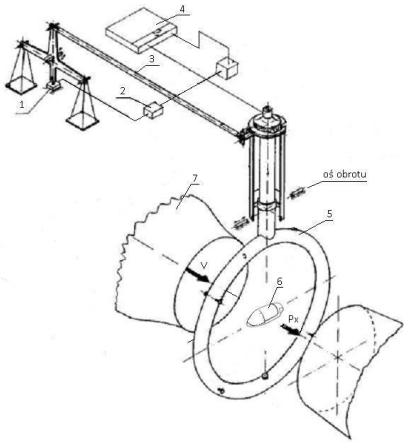


Photo: Stanisław Gradolewski

Flow from the side

Figure No 4



Source: own materials

URBANO luminaire

Image No 7 with horizontal mounting

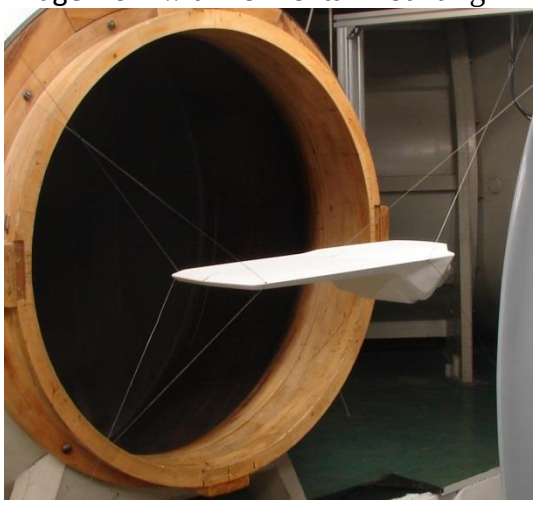
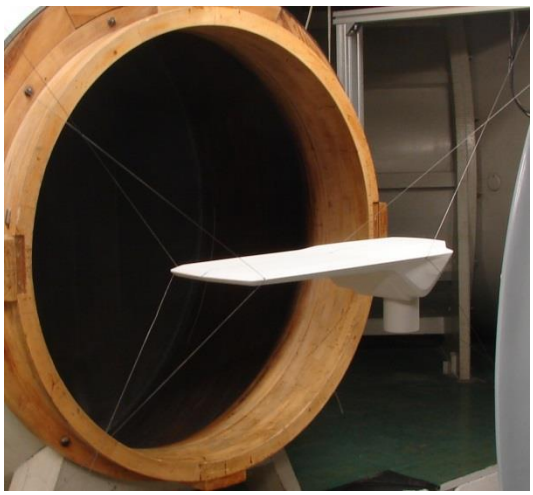


Image No 8 with vertical mounting



URBINO luminaire

Image No 9 with horizontal mounting

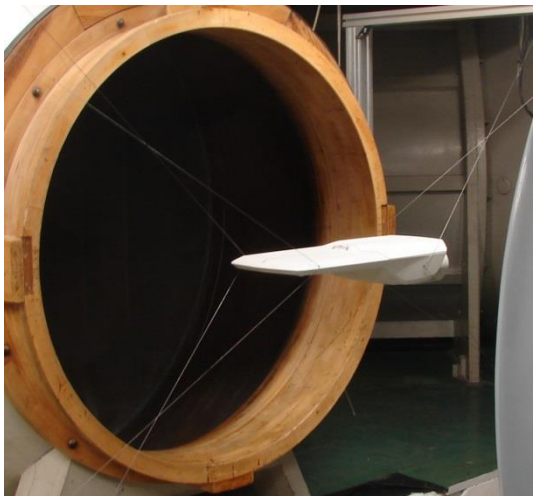


Image No 10 with vertical mounting

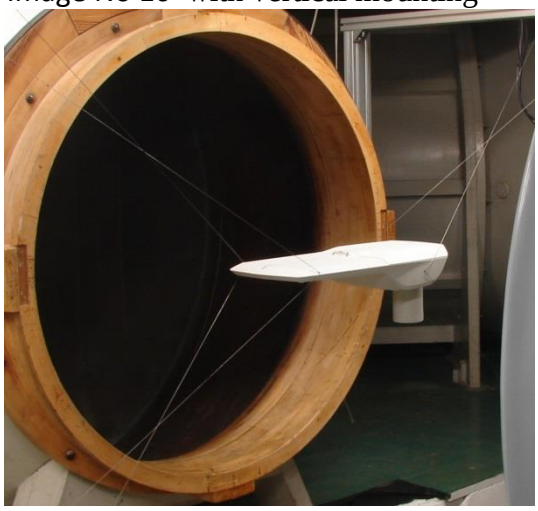
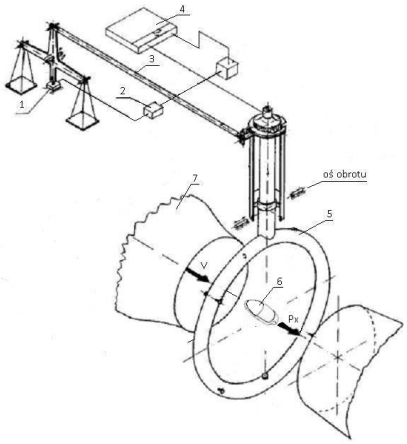


Photo: Stanisław Gradolewski

Flow from the behind

Figure No 5



Source: own materials

URBANO luminaire

Image No 11 with horizontal mounting

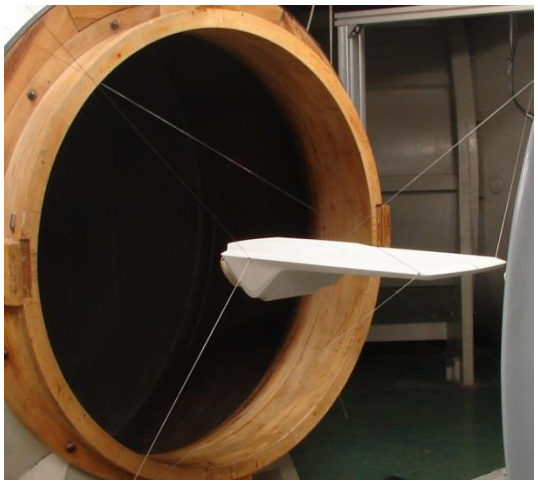
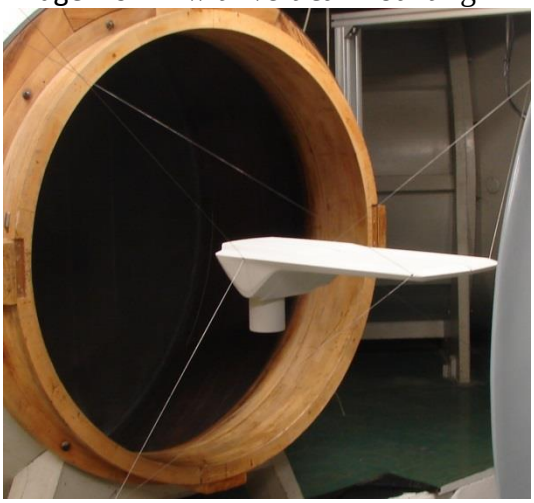


Image No 12 with vertical mounting



URBINO luminaire

Image No 13 with horizontal mounting

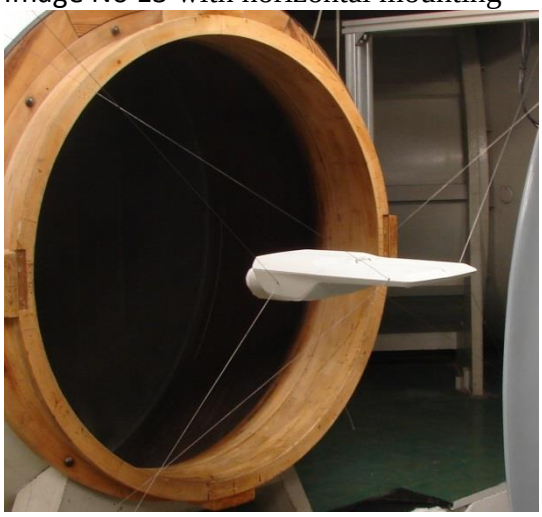


Image No 14 with vertical mounting

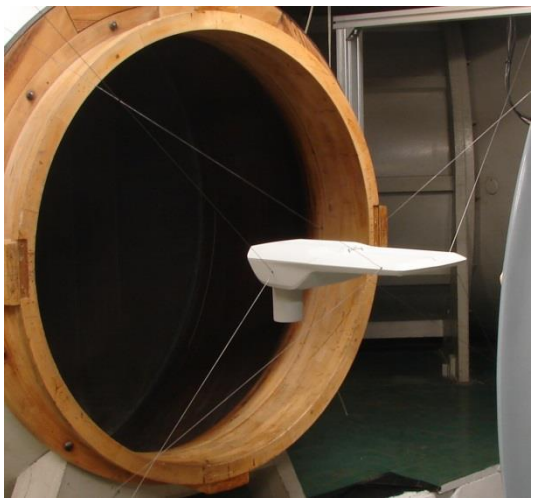


Photo: Stanisław Gradolewski

3. The results of measurements

3.1. Determination of coefficient Cx

The results of measurements and calculations are shown in Table No 1.

The measured Px force is gross volume. Cx calculations take into account the correction for the tare weight and the forces acting on the wires securing the luminaire.

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Table No 1. The results of measurements and calculations for three settings

			The luminaire URBANO									
Day parameters			from the side					fron the side (fastening down)				
	P_{atm}	hPa	1006.5									
	t_{atm}	°C	21									
	T_{atm}	K	293.15									
	R	$m^2/(s^2K)$	287									
	r	kg/m^3	1.192238									
Measurements	V	mmH_2O	39	55	76	100	110	39	55	76	100	110
		m/s	25.33	30.08	35.37	40.57	42.55	25.33	30.08	35.37	40.57	42.55
	S	m^2	0.049					0.039				
	P_x	N	13.8	20.5	29.1	38	42.6	14	21	29	38.5	42.7
	arm + wires	N	2.5	3.2	4.75	6.9	7.9	2.5	3.2	4.75	6.9	7.9
Results	C_x*S	m^2	0.030	0.032	0.033	0.032	**0.032**	0.030	0.033	0.033	0.032	**0.032**
	Cx		0.603	0.654	0.667	0.647	**0.654**	0.613	0.673	0.664	0.657	**0.658**

			The luminaire URBANO																			
Day parameters			from the front					from the front (fastening down)					from behind					from behind (fastening down)				
	P_{atm}	hPa	1004										1006.5									
	t_{atm}	°C	21.5										21									
	T_{atm}	K	294.65										294.15									
	R	$m^2/(s^2K)$	287										287									
	r	kg/m^3	1.187259										**1.1922**									
Measurements	V	mmH_2O	39	55	76	100	110	39	55	76	100	110	39	55	76	100	110	39	55	76	100	110
		m/s	25.4	30.1	35.4	40.7	42.6	25.4	30.1	35.4	40.7	42.6	25.33	30.08	35.37	40.57	42.55	25.33	30.08	35.37	40.57	42.55
	S	m^2	0.039					0.047					0.039					0.047				
	P_x	N	8.4	11.5	16.1	21.8	24.3	11.8	17.3	24.3	32	35	10.5	13.2	21.5	29.1	32.5	12.4	17.8	24.5	33.5	37
	arm + wires	N	2.5	3.2	4.75	6.9	7.9	2.5	3.2	4.75	6.9	7.9	2.5	3.2	4.75	6.9	7.9	2.5	3.2	4.75	6.9	7.9
Results	C_x*S	m^2	0.015	0.015	0.015	0.015	**0.015**	0.024	0.026	0.026	0.025	**0.025**	0.014	0.019	0.022	0.023	**0.023**	0.026	0.027	0.026	0.027	**0.027**
	Cx		0.392	0.391	0.387	0.386	**0.386**	0.618	0.664	0.666	0.650	**0.638**	0.367	0.473	0.573	0.577	**0.582**	0.547	0.572	0.560	0.573	**0.570**

			The luminaire URBINO									
Day parameters			from the side					fron the side (fastening down)				
	P_{atm}	hPa	996									
	t_{atm}	°C	20									
	T_{atm}	K	293.15									
	R	$m^2/(s^2K)$	287									
	r	kg/m^3	1.183825098									
Measurements	V	mmH_2O	39	55	76	100	110	39	55	76	100	110
		m/s	25.4	30.2	35.5	40.7	42.7	25.4	30.2	35.5	40.7	42.7
	S	m^2	0.039					0.039				
	P_x	N	11.3	15.6	21.9	29.5	32.8	12.2	17.1	24	32.4	36
	arm + wires	N	2.5	3.2	4.75	6.9	8	2.5	3.2	4.75	6.9	7.9
Results	C_x*S	m^2	0.023	0.023	0.023	0.023	0.023	0.025	0.026	0.026	0.026	0.026
	Cx		0.590	0.589	0.590	0.591	0.589	0.650	0.661	0.662	0.667	0.668

			The luminaire URBINO																			
Day parameters			from the front					from the front (fastening down)					from behind					from behind (fastening down)				
	P_{atm}	hPa	996																			
	t_{atm}	°C	20																			
	T_{atm}	K	293.15																			
	R	$m^2/(s^2K)$	287																			
	r	kg/m^3	1.183825098																			
Measurements	V	mmH_2O	39	55	76	100	110	39	55	76	100	110	39	55	76	100	110	39	55	76	100	110
		m/s	25.4	30.2	35.5	40.7	42.7	25.4	30.2	35.5	40.7	42.7	25.4	30.2	35.5	40.7	42.7	25.4	30.2	35.5	40.7	42.7
	S	m^2	0.0175					0.0246					0.0175					0.0246				
	P_x	N	5	6.4	9.1	13	14.2	9.1	12.4	17.9	24.1	27	7.1	9.5	13.5	18.5	20.5	8.85	12.2	17.2	23.2	25.8
	arm + wires	N	2.5	3.2	4.75	6.9	7.9	2.5	3.2	4.75	6.9	7.9	2.5	3.2	4.75	6.9	7.9	2.5	3.2	4.75	6.9	7.9
Results	C_x*S	m^2	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.017	0.017	0.017	0.017	0.017
	Cx		0.37	0.34	0.33	0.36	0.33	0.7	0.69	0.72	0.71	0.72	0.69	0.67	0.67	0.68	0.67	0.67	0.68	0.68	0.68	0.67

Abbreviations and formulas:

P_{atm} – atmospheric pressure. (in hPa)

t_{atm} – ambient temperature. (in °c)

T_{atm} – ambient temperature = t_{atm} + 273.15. (in K)

R – gas constant (287 $m^2/(s^2K)$)

ρ – air density = P_{atm} /(R* T_{atm}). (in kg/m^3)

Δp – dynamic pressure in the tunnel. (in mmH_2O)

V – speed of flow in the tunnel = $\sqrt{2\Delta p / \rho}$. (in m/s)

S – reference surface (in m^2)

Px – resistance force. (in N)

Cx – resistance coefficient $\frac{Px}{\frac{\rho V^2}{2} S}$.

Table No 1 presents measurement results for three settings: air stream from the front, side and back of the tested luminaires and pre-recorded parameters of the day. In the formula for Cx as the reference surface S appropriate rectangular cross-sections were used.

With the transformed formulas, based on the obtained measurements and parameters, resistance coefficients were calculated.

The determined resistance coefficients for flow (V=150 km/h) from the front, side and back are respectively:

The front	The front (fastening down)
URBANO: 0.39	0.64
URBINO: 0.33	0.72
The side	The side (fastening down)
URBANO: 0.65	0.66
URBINO: 0.59	0.67
The back	The back (fastening down)
URBANO: 0.58	0.57
URBINO: 0.67	0.67