

Wind Tunnel Raffaele Balli

WAP - Flagpole test



University of Perugia, Department of Engineering

Aerodynamic test - Results report

Customer: WAP - We Are Portugal Lda

Device under test:
Vertical Flagpole overall height 2.3m

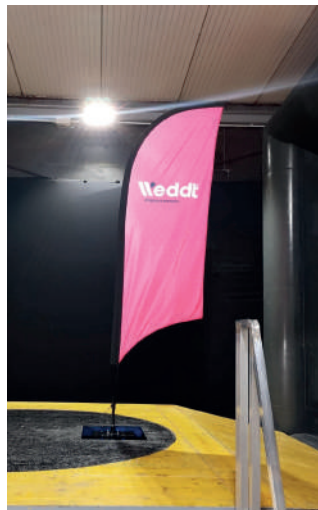


Figure 1: Test Layout

Scientific Supervisor: Prof. Francesco Castellani

Francesco Castellani

Contents

1	Introduction	3
2	Measurement Layout	4
3	Results from drag measurements	6
4	Flagpole deflection	7
5	Conclusions	10

1 Introduction

The present report summarizes the results from tests of the flagpole provided by WAP - We Are Portugal Lda.

The aim of the test session was to assess the flagpole's stiffness and its attitude in surviving to high wind speed gusts (up to the wind tunnel's limit of 160 km/h) .

In order to perform the measurements (in terms of drag force and flagpole deflection) several tests with steady-state wind regime were performed.

During each test the maximum wind speed was maintained stable for 120 seconds; the overall summary of the measurements is in table text.

id test	Wind speed (km/h)	Wind speed (m/s)
1	80	22
2	100	28
3	120	33
4	140	39
5	160	44
6	160	44
7	20	6
8	10	3
9	160	44
10	160	44

Table 1: Summary of the tests performed on the flagpole on May 23rd 2019.

2 Measurement Layout

The flagpole with an overall height of about 23 m was placed at the end of the open test-chamber in order to have all the device inside the main streamtube spreading from the upstream section with an overall area of $(2.2 \times 2.2) \text{ m}^2$ (see figures 1 and 2).

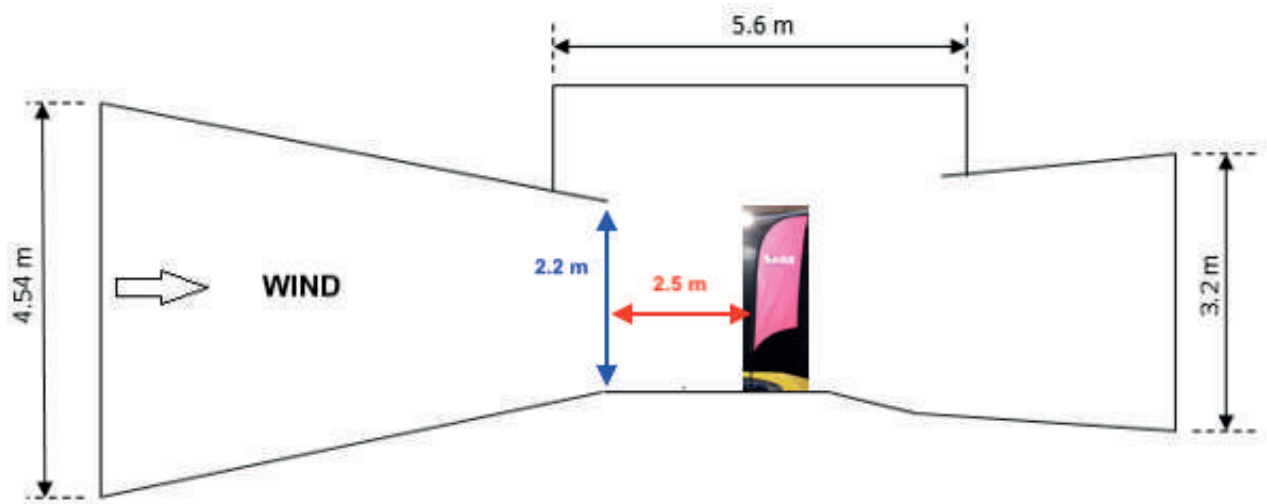


Figure 2: Vertical section of the test layout

The flagpole base flange was clamped on the wind tunnel load cell few centimetres under the floor as shown in figure 6. In this way the base of the structure is not interested by the wind as it happens in the field installations according to the wind shear.

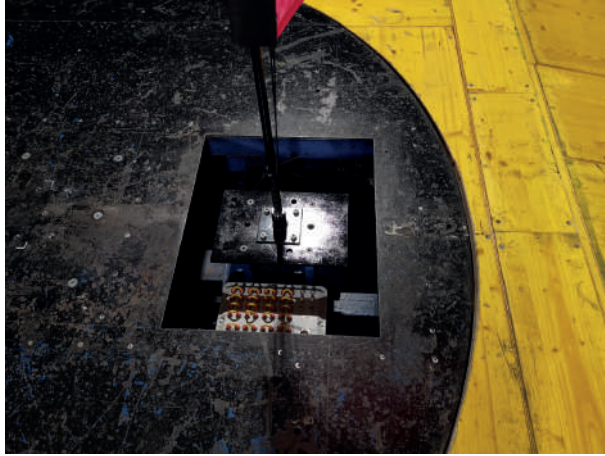


Figure 3: Flagpole base flange arrangement

3 Results from drag measurements

In figure 4 the trend of the measured drag forces versus the wind speed intensity is represented.

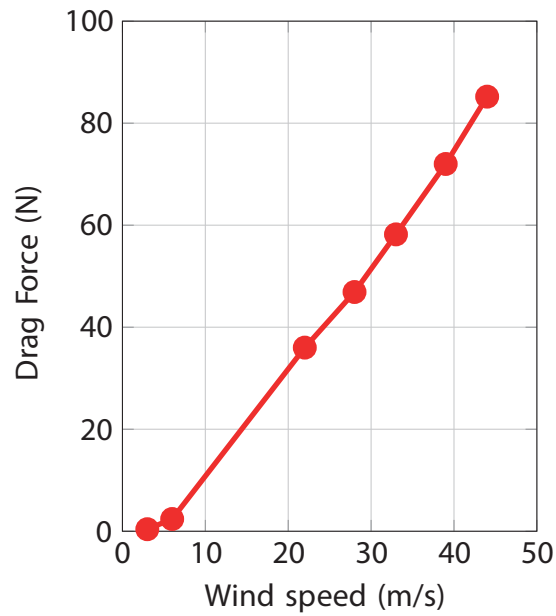


Figure 4: Plot of the drag force versus the wind speed.

The trend seems to be approximately linear: this is consistent with the fact that flagpole's deflection induces an important reduction in the cross-sectional area.

4 Flagpole deflection

Beside the load measurements also the flagpole's deflection has been estimated using image processing of the frames acquired through a high-speed camera.



A.) Flag position at the beginning of the test.

B.) Flag position at the target wind speed.

Figure 5: Flag behaviour for a test with a target wind speed of 33 m/s (120 km/h).

A marker was placed on the tip of the flag (see figure 5) in order to correctly estimate the deflection during the oscillations observed at the target wind speed.

The deflection was also estimated at the maximum wind speed as the flagpole was able to survive

without any relevant damage.

The high speed camera was placed laterally as close as possible to the device; the height of the characters painted on the flag was used as reference in order to scale the deflection from pixel to centimetres.

The deflection was finally estimated using the overlap of two frames: the first one with the flag at the beginning of the test with no wind and the second with the flag in its position suffering the target wind speed intensity.

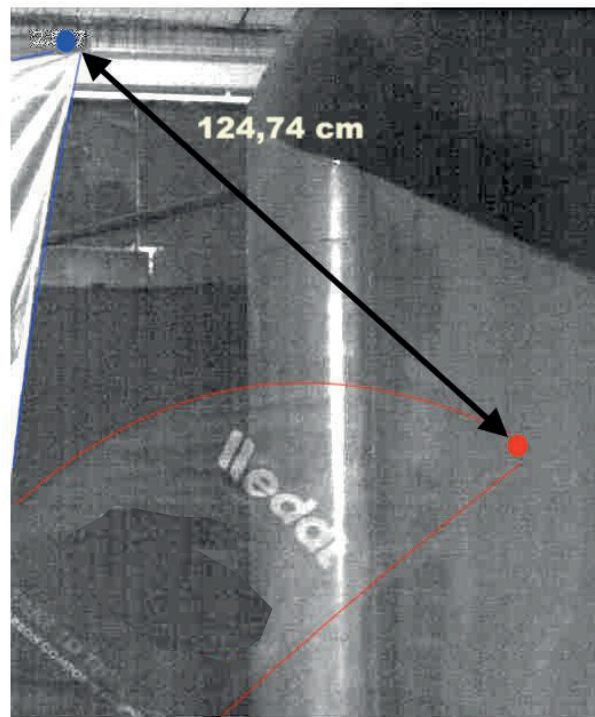


Figure 6: Deflection estimation through image post-processing (test 3 with a wind speed of 120 km/h).

As the flagpole is strongly oscillating when the wind is blowing the estimated deflection has to be considered as an average estimation affected by statistical uncertainty.

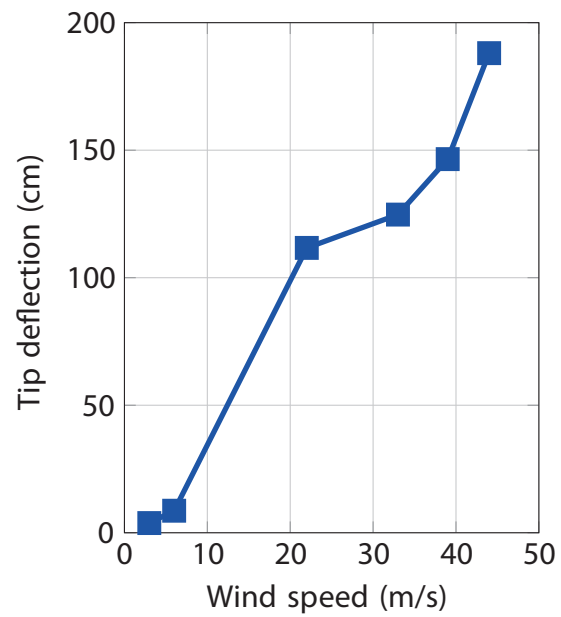


Figure 7: Plot of the deflection versus the wind speed.

5 Conclusions

From the results of the test session it is possible to conclude that:

- the most valuable result of the test is that the flagpole was able to survive to the maximum wind speed (160 km/h) without any remarkable damage;
- the drag force was discovered to be approximately linear versus the wind speed, the maximum measured force was 85 N with a wind speed of 160 km/h;
- the deflection of the structure was discovered to be quite important and the maximum bending of the tip was estimated to be 188 cm at 160 km/h.