# Architecture and Aerodynamics, Passive downdraught evaporative cooling (PDEC) in non-domestic buildings Wind Tunnel Tests for the Experimental Building design.

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**ABSTRACT** MCA is a partner in a research group which is beingfunded by the European Commissions JOULE program to explore the application of passive downdraught evaporative cooling (PDEC) in non-domestic buildings (1). As part of MCA's task to design a full scale experimental building, special components were designed to catch the wind and distribute through the building spaces. To determine the most efficient form for thesecomponents, a series of wind tunnel tests was undertaken at the University of Ancona, Italy. The following abstract describes the objectives methods and results of these tests.

## 1. Introduction

The efficient functioning of passive cooling systems in buildings depends largely on our ability to control internal air flows. The direction, speed and turbulence of the wind changes constantly thus creating unwanted fluctuations in the air-flow. It is possible to overcome this difficulty by careful design of the building components.

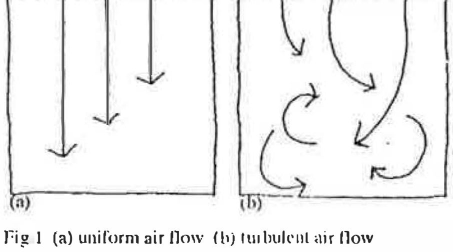


Fig 1 (a) uniform air flow (b) turbulent air flow

A full scale experimental building, designed by MCA, has been constructed in Catania in Sicily. The building consists of a tower and two test cells in which we can observe the functioning of the PDEC system and the induced air movement. A uniform stream of air of low turbulence is best for the evaporative cooling system. For this reason components were designed, a wind catcher and a wind straightener, to optimise the control of the air flow in the tower.

Quanlitative tests on scale models of the Experimental Building were carried out to assess the performance of the different components both individually and in combination. These visualisation studies seeked to inform the design of a system that can be adapted to different situations, climates and building typologies. An important consideration in doing these experiments was to explore practical instruments and methods for designers to inform their designs at an early stage of the project within acceptable costs and with valid results.

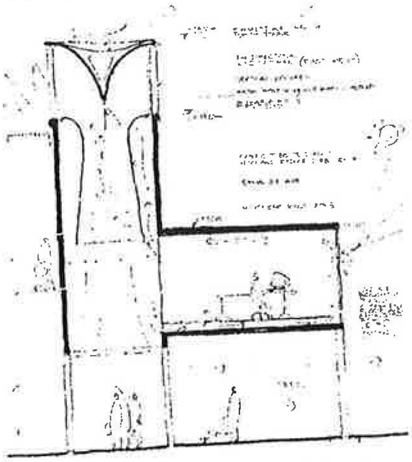

Fig.2 The Experimental Building Sketch design

## 2. The Wind Tunnel

The wind tunnel that was used is located in the laboratory of the Faculty of Mechanical Engineering in the University of Ancona in Italy. It was created to test aeroplane wing sections and spoilers, but its dimensions and capacity allow us to use it with architectural scale models. In the wind tunnel we can measure local wind speed and direction (mean velocity), turbulence intensity and do visualisation studies.

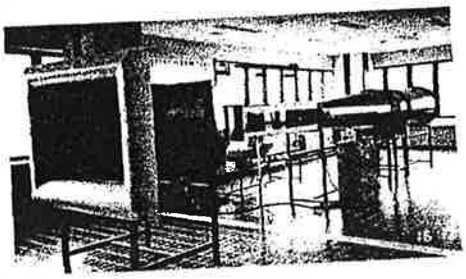

Fig.3 The wind tunnel in Ancona University

The different measuring tools are:
*mean velocity:* an axial flow vane anemometer, a Pitot tube
*turbulence intensity-:* a rapid sampling anemometer
*visualisations:* smoke: helium bubbles, parafin and talcum powder

The visualisation studies undertaken at Ancona involved letting wisps of vapourised oil into the tunnel which shows clearly the air flow patterns. This gives information about the capacity of the prototype to reduce turbulences and to optimise the air flow

## 3. Models for testing

To retain similarity of flow patterns at a reduced scale it is neccessary to increase the velocity. The key parameter is the Reynolds number:

$$\frac{Lxv}{V} \qquad \frac{\text{length x velocity}}{\text{Kinetic viscosity}}$$

Ideally this should be the same at model scale as at full scale i.e. if the scale is reduced the wind speed is increased. The models used in the wind tunnel must therefore be solid enough to resist very high wind speeds. We prepared 1:20 scale plexiglass prototype models of the experimental building. The models consisted of one tower onto which different components could be fixed. This gave us the flexibility to easily test different configurations. As the plexiglass models we built are at scale 1: 20, using the Reynold's number, we could simulate an air speed of 4/ 5 m/sec running the machine at a real speed up to 200 Km/h.

## 4. Building Components

The components to be tested were wind catchers, air straighteners and louvres.

### 4.1 Wind Catchers

The function of the wind catcher is, as its name suggests, to bring as much air as neccessary into the building. An ideal wind catcher should function well even when there is very little wind. The choice of which type of wind catcher to use in the building depends on:

- Efficiency
- Suitability for the site (i.e if there is a strong prevailing wind)
- Cost and materials

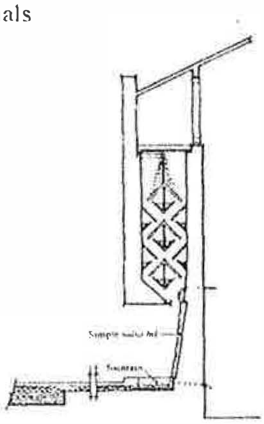

Fig.4 Malqaf (dowdraught cooling tower) designed by Hassan Fathy (Source H. Fathy)

We examined three different shapes for the wind catcher to test in the wind tunnel:

- Mono directional

These can catch wind only from one direction but give quite a uniform flow.

- Two directional

The wind is caught from two directions but causes an uneven flow.

- Multi directional

The wind is caught from all directions but the flow is much less uniform.

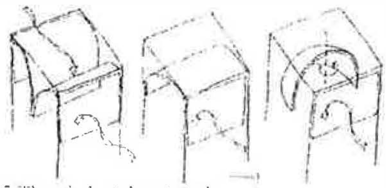

Fig.5 The wind catchers tested

The disadvantage of the mono directional catchers is that it catches the wind from one direction only. It would be costly and involve additional machines to develop a rotating wind catcher. The advantage of the multi-directional catcher is that it has a large opening area and is tolerant of all wind directions but it causes an uneven airflow within the tower. It is therefore our objective to make the multi directional catchers work. To do this we need a straightening device

### 4.2 Straighteners

The simplest devices for straightening the air flow are a grid or honeycomb. These are quite effective for reducing turbulence but are not effective for making the flow even. They would work well with the mono directional catchers but would be less successful with the multi directional catchers. Another way of straightening the air is to have a constriction followed by gentle dilation. This is a classical technique for producing a uniform low turbulence flow which gives the shape to the wind tunnel. We felt that this was the right technique to smooth the flow from the multi directional wind catchers.

The parameters for this device are:

1. the constriction ratio, which is the ratio of the throat area to the area of the tower plan. (a/b-see fig.6)
2. The dilation angle. This angle should be as shallow as possible (around 10° would be best).
3. A smoothly shaped inlet.

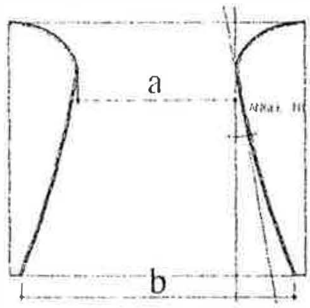


Fig.6 The air straightener

## 5. Experimental Protocol

Before commencing the wind tunnel tests we established an experimental protocol. It was decided to evaluate the efficiency of each component individually and then in combinations of catchers and straighteners.

## 6. Wind Tunnel Test Visualisations June 1996

Different wind catchers were tested first:

**Wind catcher N° 1:** asymmetrical mono directional.
**Wind catcher N° 2:** symmetrical which catches the wind from two directions.
**Wind catcher N° 3:** a quarter sphere which simulates a rotating device.

The second series of tests involved testing the different wind catchers in conjunction with the different straighteners. Two types of straightener were tested:

**Straightener N° 1:** Narrow constriction
**Straightener N° 2:** Wide constriction

## 7. Results of the visualisation tests

The results of the tests involving the different wind catchers and wind straighteners are outlined here.

### 7.1 Wind catcher n° 1- asymmetrical mono directional

This is an asymmetrical catcher that has been designed for prevailing wind conditions. The test indicates a small area of turbulence below the windward opening. This turbulence gradually disappears and the air flow seems to be slightly asymetrical at the bottom of the tower. (See fig.8)

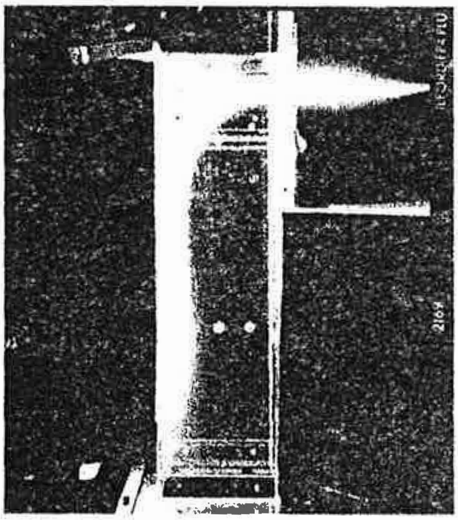

Fig.8 Visualisation of wind catcher n°1

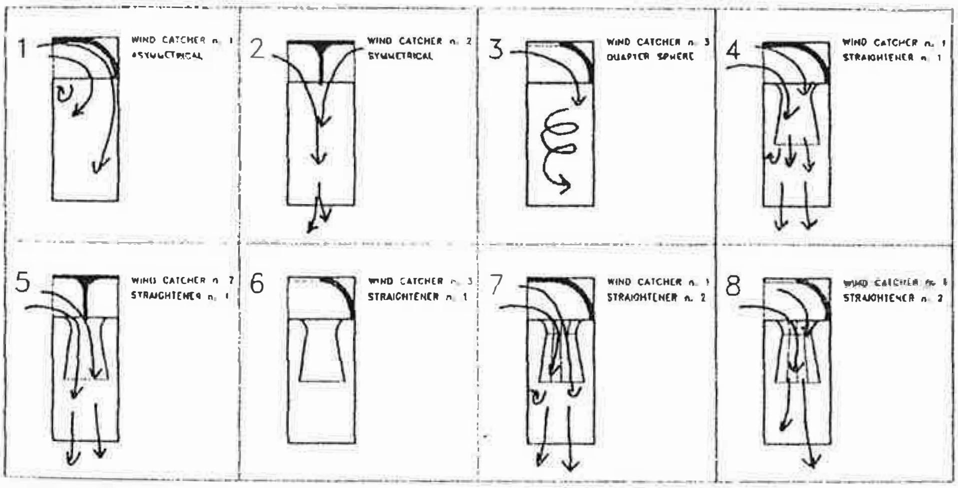


Fig 7 Experimental Protocol

**7.2 Wind catcher n° 2 - symmetrical bi-directional**
This catcher is bi-symmetrical and allows the wind in from two opposite directions. An even air flow is concentrated towards the middle of the tower's section.

**7.3 Wind catcher n° 3 - quarter sphere**
This catcher aims to simulate a revolving system that can follow the wind coming from any direction. The model simplifies this system by using a fixed quarter of a sphere on one side of the tower. The visualisation shows how this particular geometry tends to create a rotation of the flow around the vertical axis, with a spiral-like shape. A major area of turbulence appears under the windward opening and a minor one on the opposite face. The outlet flow is less uniform than in case 1. (See fig.9)

**7.4 Wind catcher n° 1 with Straightener n° 1**
The straightener is a Venturi tube whith a constriction ratio of 50%.
Its effect is quite evident, especially if compared with the efficiency of the head alone. The flow is very diffused and uniform inside the tower.
A small zone of turbulence appears immediately after the straightener, on the windward face. The outlet flow is uniform.

**7.5 Wind catcher n° 2 with Straightener n° 1**
This configuration seemed to be the most successful. The flow is quite central and uniform.

**7.6 Wind catcher n° 3 + Straightener n° 1**
The effect of the straightener seems to be very similar to the case n° 4.
Any difference in the outlet flow has not been visualised.

**7.7 Wind catcher n° 1 + Straightener n° 2**
The straightener is a Venturi tube with a constriction ratio of 80%.
The straightening effect is similar to that of case 4, giving quite a uniform flow.

**7.8 Wind catcher n° 3 + Straightener n° 2**
Here again the air flow is more uniform using the straightener which has an 80% constriction

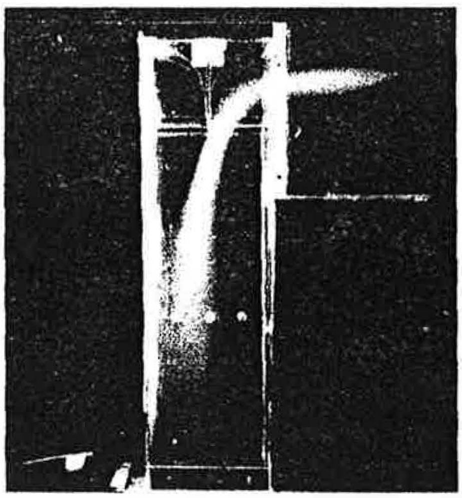

Fig.9 Visualisation of wind catcher n°2 with straightener n°1

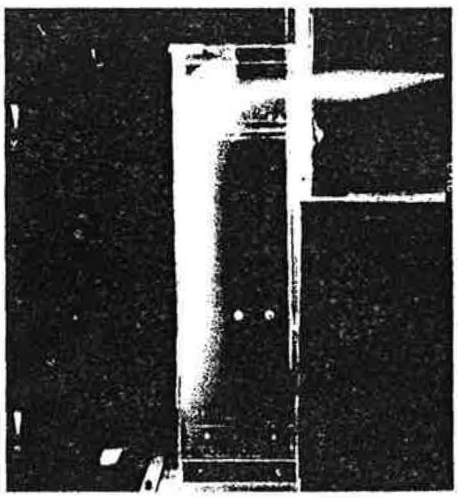

Fig.10 Visualisation of wind catcher n°3

## 8. Conclusions

The visualisation tests showed quite clearly the effectiveness of each component. The heads alone, although efficient at catching the wind, give quite a turbulent air flow. The air straighteners have proved to work well at reducing this turbulence.

For the Experimental Building in Catania, given that the prevailing wind is east-west, it appears that the most efficient combination is the symmetrical head as with a straightener with a narrow constriction. The components have been constructed and installed in the Experimental building and their performance will be tested and moonitored this summer. The design of this type will be developed in more detail as part of a full scale building design project.

The next step is to revise the experimental protocol and measure pressure differences in a second series of tests.

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The wind tunnel tests were carried out with Professor Gianni Cesini of the Dipartimento di Energetica, University of Ancona, Via Brecce Bianche, 1-60100 Italy

The aerodynamics consultant was Peter Heppel Engineer.

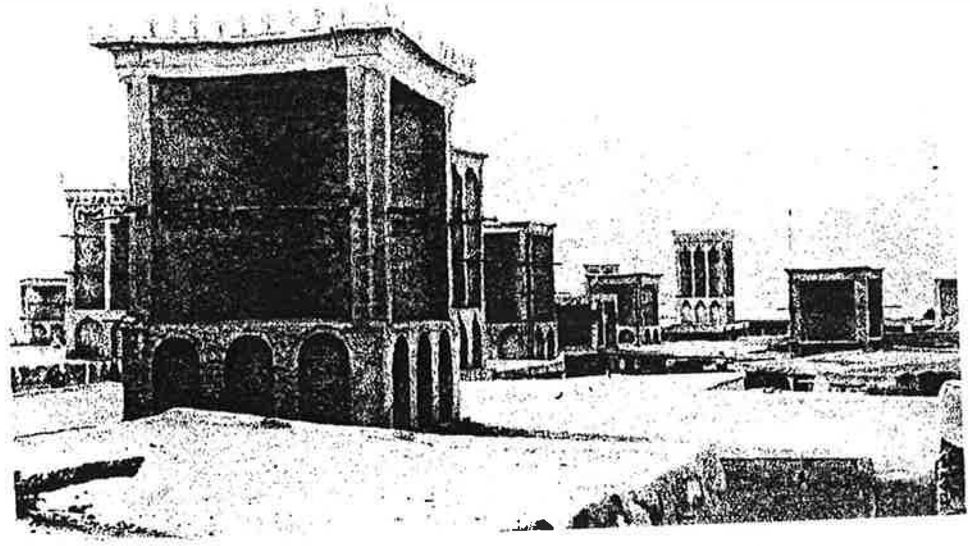

Fig. 11 Traditional persian wind turret in LAft (Source: Khansari, Yavari- 1984. *Espace Persan* - P. Mardaga Editeur, Liège)