# Natural ventilation due to wind action: practice knowledge against experimental airflow visualization

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ABSTRACT

The aim of this paper is to confront the designers practice knowledge on the behavior of natural ventilation due to wind action in housing buildings with complex internal partitions against experimental analogical airflow visualization. The methodology consisted of a survey with a group of architects, followed by experimental airflow visualization in physical scale models of a housing building, developed with a water table. The results from the survey showed that the architects were divided regarding the best and worst natural ventilation performance among the tested housing units. However, the experimental visualization showed that besides the orientation, other factors regarding the building geometry must also be taken into account. The main conclusion is that the architects practice knowledge is not enough for comprehensively describing the natural ventilation in this type of building, and that the equipment used was very effective and useful for doing it.

## 1. INTRODUCTION

The theory of wind pressure distribution on building surfaces (Etheridge and Sandeberg, 1996; Blessmann, 1990; Aynsley et al., 1977), associated to the knowledge of local wind pattern, is oftenly used by designers to preliminarily evaluate the performance of natural ventilation due to the wind action (Olgyay, 1998; Boutet, 1987).

The main problem is to apply that theory on buildings with complex geometry and/or internal distribution. In these buildings the distribution is not easily understood, once the assessment methods and the existent pressure coefficients fit best in buildings with simple geometry (Santamouris and Asimakopolos, 1997).

The aim of this paper is to confront the designers practice knowledge on the behavior of natural ventilation due to wind action in housing buildings with complex internal partitions against experimental analogical airflow visualization.

## 2. METHODOLOGY

The methodology consisted of two different research techniques: the first one was a qualitative survey with a group of 30 architects and lecturers of architecture design.

The second technique consisted of a series of experimental analogical airflow visualization in physical scale models of a four housing units per floor building, developed with a water table, employing the tracing method with a direct injection technique.

Four different buildings of equal typology were used, all of them built in Maceió-AL, Brazil. In the present paper the results of the building 2, which presented the best correlation with the qualitative survey, will be shown.

### *2.1 Qualitative survey*

The 30 architects and lecturers were divided in three groups of 10 members: (i) architecture practice (OFFICES); (ii) lecturers from the Architecture School of Federal University of Alagoas (UFAL), and (iii) lecturers from the Centre of High Studies of Maceió (CESMAC).

A survey of 32 questions, divided in two stages with 16 questions each was applied. Each question had a space for choice justification and images from building drawings.

The survey structure asked to put in order, from the best to worst, the expected performance of the natural ventilation due to wind action, for the four apartments of each building, in the first stage, and for the de four apartments with the same orientation of the four buildings, in the second stage.

*2.2 Experimental simulation*

The experiments were developed with reduced scale models; 1/200 for closed ones, and 1/100 and 1/50, for the ones with internal divisions.

The experimental apparatus used for running the simulations was a water table from the Ambient Comfort Laboratory, Architecture Dept., Federal University of Santa Catarina; which consists of an open channel with continuous flow (Pereira and Toledo, 2004; Toledo and Pereira, 2003).

The visualization method was the tracing one with a direct injection technique, using dishwasher detergent as the indicator (Toledo and Pereira, 2004).

Forty-eight simulations were developed for four different wind directions: Northeast, East, Southeast and South. The simulations were registered by video and photography with a Nikon Coolpix 4500 Digital Camera.

The outflow images were redrawn from the pictures, showing the air inlets, internal course, and outlets. The comprehensiveness of the internal outflows were calculated and the velocities were observed and registered by the video images.

The internal air outflow comprehensiveness and velocities were classified according the following scale: very large, large, regular, limited, and very limited, for comprehensiveness; and, very high, high, normal, slow, and very slow, for velocity.

*2.3 Building characteristics*

Four buildings from four apartments per floor typology were chosen. All of them have ten rooms, distributed in three distinct sectors: social – living/dinning room; private – two bedrooms, master suite, and bathroom; service – kitchen, laundry, bedroom and bathroom.

The building 2, described in this paper, has two symmetrical apartments in the front, with three external surfaces each. The apartment 1 faces North, East and the shaft (North opening), and the apartment 2, facing East, South and the shaft (South opening). The other two apartments facing backwards have four external surfaces: apartment 3 faces South, West and shafts B and C (with West opening), and apartment 4 faces West, North and shafts A and C, according to Figure 1.

*2.4 The Wind pattern in Maceió*

Maceió is the capital of the State of Alagoas and is located at Northeast of Brazil, at 9º40' latitude South and 35º42' longitude West.

The climate is tropical humid, with moderate temperatures (annual average of 24,8ºC); short thermal amplitude (average around 3ºC); regular rain season (2.167,7mm); annual relative humidity of 78,3%, (average variation between 82,6% and 74,7%).

The wind pattern in Maceió shows a prevailing direction from Southeast (36,04%) and East (31,73%) all around the year, followed by the wind from South (16,89%) and Northeast (9,98%), which present higher frequencies in the winter and summer seasons, respectively, according to Graphic 1.

## 3. ARCHITECTS EVALUATION

Only 21 people responded the survey, being 2 from the OFFICES, 9 from the UFAL and 10 from the CESMAC group. The survey results for the building 2 are shown in the Graphic 2.

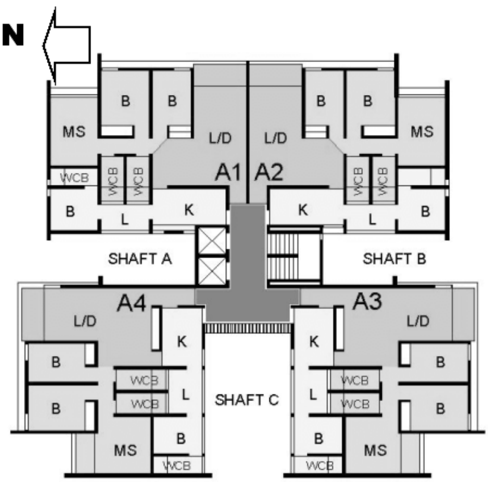
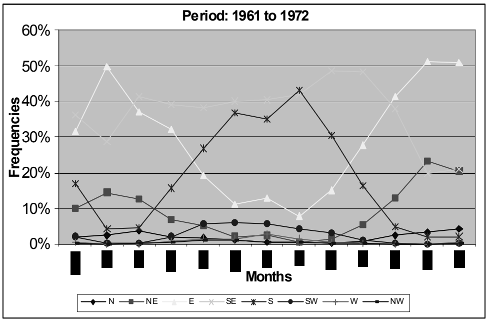
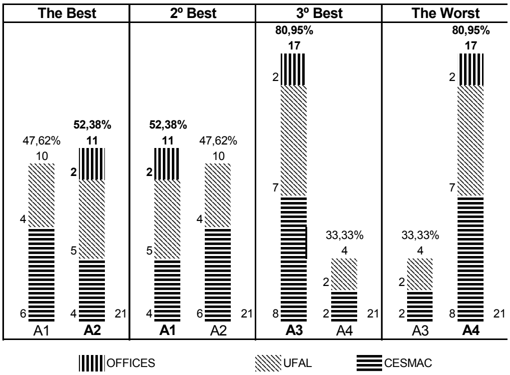



Figure 1: Apartments Plant of Building 2.




Graphic 1: Wind pattern in Maceió.




Graphic 2: Survey results for the Building 2.

The apartment chosen as the **best performance** was the **apartment 2** (52,4%), with the majority in the first two groups (OFFICES and UFAL); disputing the preference with apartment 1 (47,62%), with the majority in the third group (CESMAC). Justifications: exposition to all the four wind directions: E, SE, S e NE; living and bedrooms oriented towards East.

The **second best** was the **apartment 1** (52,38%), with the majority in the first two groups (OFFICES and UFAL); disputing the preference with apartment 2 (47,62%), with the majority in the third group (CESMAC). Justifications: exposition to wind from: E, SE e NE; living and bedrooms oriented towards East, no South wind exposition.

The **third best** was the **apartment 3** (80,95%), with the majority in all groups. Justifications: exposition to the winds from: SE e S; master suite does not receive wind from SE.

The apartment chosen to be the **worst performance** was the **apartment 4** (80,95%), with the majority in all groups. Justifications: exposition only to the NE wind, which is the most frequent in summer; the master suite it is not exposed to this wind.

It is perceptible a strong agreement regarding the choices of the worst and the third best performance (80,95%, both), and a weak agreement regarding the best and second best (52,38%, both) apartments of building 2.

## 4. EXPERIMENTAL EVALUATION

The analysis considered a preferred outflow pattern in a housing unit, which can be taken as: air inlets through the social and private areas; air outlets through the service areas; air passing by all rooms; good outflow comprehensiveness in all rooms; normal outflow velocities in the social and private areas, and normal to high in the service area.

### *4.1 Outflow with Northeast wind*

The inner outflow with Northeast wind direction is shown in Figure 2.

The **apartment 1** presents 4 inlets in the social (1), private (2) and service sectors (1); there is no outflow going through two bedrooms and the bathroom from the service area [unexpected!]; outflow comprehensiveness between limited and very large; outflow velocities between normal and slow; 2 outlets through the service sector.

The **apartment 2** presents 4 inlets through the social (1) and private (3) sectors; outflow in all rooms; comprehensiveness between very limited and large; velocities between slow and

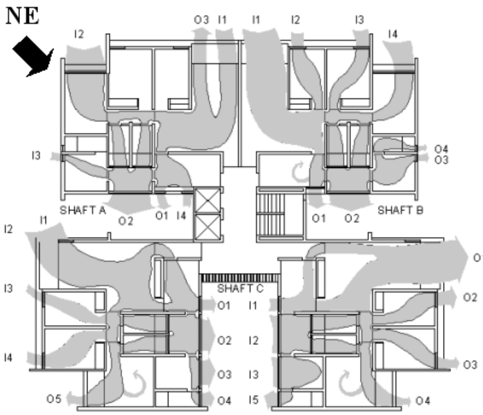



Figure 2: Outflow from Northeast wind direction.

high; 4 outlets through the service area.

The **apartment 3** presents 3 inlets through the service sector; outflow in all rooms; comprehensiveness between very limited and large; velocities between normal and high; 5 outlets through service (1), social (1), and private (3) sectors. However, the ventilation of this apartment is totally dependent on the outflow conditions of the apartment 4, situated at windward.

The **apartment 4** presents 4 inlets through the social (1) and private (3) areas; outflow in all rooms; comprehensiveness between very limited and large; velocities between slow and very high; 5 outlets through service (4) and private sectors (1).

The **apartment 2** is the one that presents the **bets performance** for the Northeast wind direction, followed by the **apartment 4**. The **apartment 1**, although is located at windward, it does not present a good inner outflow, showing three rooms with no outflow. The **apartment 3** is the one that presented the **worst performance**, due to be located at leeward and to be totally dependent on the outflow conditions of apartment 4.

*4.2 Outflow with East wind*

The inner outflow with East wind direction are shown in Figure 3.

The **apartments 1 and 2** presented very similar outflow, with 4 inlets through the social area (1) and private sector (3); going throughout all rooms, comprehensiveness between limited and very large; velocities between very slow and high; 4 outlets through the service sector. However, the apartment 1 presented one inlet more, returning from the shaft, in the kitchen, which enlarged the outflow comprehensiveness in that space.

The **apartments 3 and 4** presented identical outflows, with 4 inlets through the social (2) and private sectors (2); going throughout all rooms; comprehensiveness between very limited and very large; velocities between high and normal; 5 outlets through the service (4) and private (1) sectors.

The **apartments 1 and 2** presented the **best performance** in the **East** wind direction condition. The **apartments 3 and 4**, although being laterally located and at leeward, showed the **second best** inner outflow, with small comprehensiveness in the master bedroom, which also acts as an outlet, and a very limited comprehensiveness in the service bedroom and bathroom.

*4.3 Outflow with Southeast wind*

The inner outflows with Southeast wind direction are shown in Figure 4.

The **apartment 1** presented **5** inlets through the social (1), private (3) and service (1) sectors; outflow through all spaces, comprehensiveness between limited and very large; velocities between slow and high; 4 outlets through the service area.

The **apartment 2** presented 3 inlets through the social (1), private (1) and service (1) sectors; with no outflow through two bedrooms and the service bathroom; with comprehensiveness between very limited and large; velocities between slow and normal; 3 outlets at the service (2) and social (1) sectors.

The **apartment 3** presented 4 inlets through

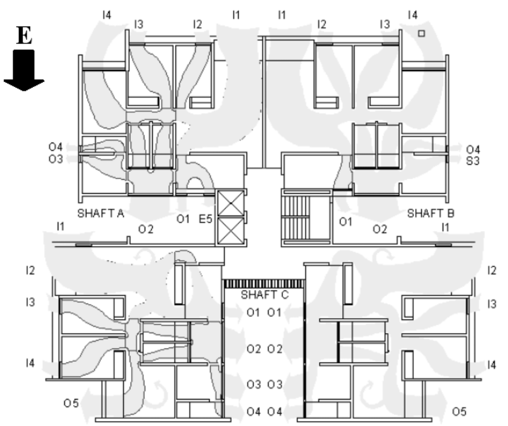



Figure 3: Outflow from East wind direction.

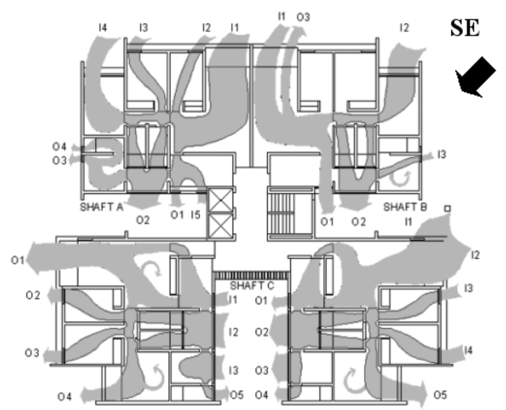



Figure 4: Outflow from Southeast wind direction.

the social (2) and private (2) sectors; outflow through all spaces; comprehensiveness between very limited and very large; velocities between high and very high; with 5 outlets through the service (4) and private (1) sectors.

The **apartment 4** presented 3 inlets through the service sector; outflow through all spaces; comprehensiveness between very limited and very large; velocities between normal and high; 5 outlets through the service (1), social (1) and private (3) sectors.

The **apartment 1** presented the **best performance** with the **Southeast** wind direction, followed by **apartment 3**. The **apartment 2**, although is situated at windward, had 3 spaces with no outflow. The **apartment 4** is the one that presented the **worst performance**, due to be located at leeward and to be totally dependent on the outflow of the apartment 3.

*4.4 Outflow with South wind*

The inner outflows with South wind direction are shown in Figure 5.

The **apartment 1** presented 3 inlets through the social (1) and private (2) sectors; with no outflow in the master bedroom bathroom, service bedroom and BATHROOM; comprehensiveness between very limited and large; velocities between slow and high; 3 outlets through the service (2) and private (1) sectors.

The **apartment 2** presented 4 inlets through the service sector; outflow in all spaces; comprehensiveness between very limited and large; velocities between normal and high; 4 outlets through the social (1) and private (3) sectors.

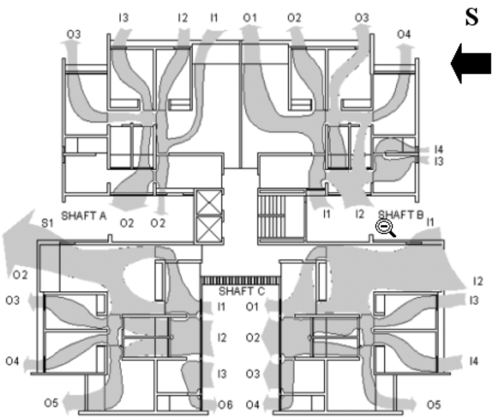



Figure 5: Outflow from South wind direction.

The **apartment 3** presented 4 inlets through the social (1) and private (3) sectors; outflow in all rooms; comprehensiveness between very limited and very large; velocities between very slow and high; 5 outlets through the service (4) and private (1) sectors.

The **apartment 4**, although it is situated at leeward, presented 3 inlets through the service sector; outflow in all spaces; comprehensiveness between very limited and very large; velocities between normal and high; 6 outlets through the service (1), social (2) and private (3) sectors. However, the outflow is totally dependent on the outflow conditions of apartment 3, located at windward.

The **apartment 3** presented the **best performance** with the **South** wind direction, followed by the **apartment 2**. The **apartment 1**, although it is situated at windward, presenting the **third best performance**. The **apartment 4** presented the **worst performance**, because is located at leeward and totally dependent on the apartment 3.

*4.5 Analysis summary*

Analyzing the four main wind directions in Maceió, the **best overall performance** was from the **apartment 1,** followed by the **apartment 2** (2º best)**.** The **worst performance** was from the **apartment 4**, with the **apartment 3** in the third place, as can be seen in Table 1.

The **apartment 1** presented the best performance with wind direction SE and E (larger occurrence probabilities) and the third best for the directions S and NE (least occurrence probabilities); the **apartment 2** presented the best performance with wind direction NE, the second best with directions E and S, being third with wind direction SE.

The **apartment 4** present the worst performance with the wind directions SE and S, although it was the second best with wind from NE and E; the **apartment 3** was the best with

Table 1: Apartments performance.

| WIND | APARTMENTS | | | |
|---|---|---|---|---|
| DIRECTION | A1 | A2 | A3 | A4 |
| Northeast | 3º | Best | Worst | 2º |
| East | Best | Best | 2º | 2º |
| Southeast | Best | 3º | 2º | Worst |
| South | 3º | 2º | Best | Worst |
| Overall | Best | 2º | 3º | Worst |

Table 2: Performance comparisons.

| | Best | 2º | 3º | Worst |
|---|---|---|---|---|
| SURVEY | A2 | A1 | A3 | A4 |
| EXPERIMENTS | A1 | A2 | A3 | A4 |

wind from S, the second for E and SE, and the worst for NE.

## 5. RESULTS COMPARISONS

The evaluation developed having the experimental simulations as a reference defer from the architects vote regarding the best and second best performances,; however, the choice for third best and the worst performance was matched, as shown in Table 2.

While this study has shown discordance between which apartments (1 or 2) had the best performance, the analysis developed through the visualization experiments showed that it was more difficult to choose between the apartments 2 and 3 for the second and third places.

## 6. CONCLUSIONS

In this paper the performance evaluation of natural ventilation in a block of apartments, developed with two different research techniques, a survey with architects and architecture design lecturers and experimental simulation with physical scaled models were confronted.

The answers obtained with the survey with architects and lecturers were not coincident regarding the two best performances, but very similar regarding the worst performances. The main reason was always the consideration of the best orientation in order to expose the social and private sectors to the prevailing winds.

By the other hand, the outflow experiments showed that, besides the orientation, other factors regarding the building geometry must also be taken into account, diverging from the architect's choice regarding the best performances.

The main conclusion is that the architects practical knowledge, usually based on the wind pressure distribution theory, it was not enough for an adequate evaluation of the natural ventilation performance due to the wind action in this type of building, and that the analysis based on the experimental outflow visualization shown itself to be more useful and effective.

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