BUILDING REGULATION AND THERMAL COMFORT: THE OPENING TYPOLOGY INFLUENCE ON NATURAL COOLING INSIDE OFFICE BUILDINGS IN MACEIÓ

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ABSTRACT

The opening typology influences the ventilation of the rooms offering more or less resistance to the airflow. The Building Regulation of Maceio of 1985 determines the minimum openings area based on the floor's area, as 1/6 for light and 1/12 for ventilation. These items have a straight influence on the air flow pattern inside the rooms, as well as on the users' thermal comfort. The aim of this study is to investigate three different openings typology in office buildings in Maceio city (sash, top hung and vertical pivot window) with open area based on the Building Regulation. Computational simulations where realized with PHOENICS 3.6 software on a typical office building.

INTRODUCTION

According to Gratia and Herde (2004), in office buildings, the long permanence of people stimulates the care with the surroundings' quality. People who stays in these places have been required for a more healthy and exciting place, so that it is provided, generally, by a mechanical cooling device. However, natural cooling, if properly applied, can be effective during the occupation time. In these places people prefer to control cooling and lighting, what require a distinct cooling design or a natural cooling design.

The flexibility the users prefer, many times, do not match the cooling devices used, because they do not consider the people adaptation to the place. These devices determine lighting and temperature conditions based on numeric data set from the cooling and light systems, generating, sometimes, a uncomfortable surrounding to occupants. However, people who use these places seem to be adapted to the temperature variation during the working time (NICOL, 2004; GRATIA; HERDE, 2003), accepting almost 3ºC above the temperature listed as comfortable (AYNSLEY, 1999).

A large percentage of Brazil is classified as having a warm, humid climate. In those regions, natural ventilation combined with solar protection, is the most efficient building design strategy to reach thermal comfort by passive means. Maceio is a city located on the Northwest of Brazil (S 9° 31' latitude). This weather is classified as hot and humid with two seasons witch are divided on a summer dry and a winter wet. The main temperature is 26°C and the annual thermal amplitude is 3,4°C approximately.

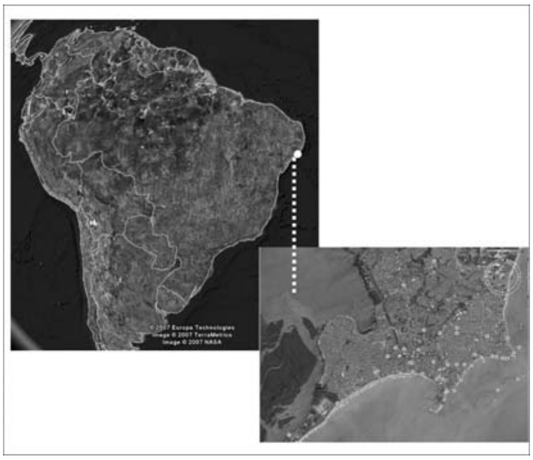


Figure 1 –The location of Maceió. Source: Google Earth (on line available. Access date: 11/03/2007)

Regarding natural cooling, an important strategy for hot humid climates, the size, the shape and the position of the openings are major factors which determine the airflow configuration inside buildings (KUKREJA, 1978; OLGYAY, 1998). These items are influenced directly by the Building Regulation. That normalization is of great importance when specifying the minimal standards of the main architectural variables affecting human comfort, such as room's area, opening's area designed for lighting and ventilation, the best ventilation strategy to be used, etc. If natural cooling is to be achieved is notable that the codes and the rules need to be reviewed in order to deal with the energy efficiency aspects (PEDRINI; LAMBERTS, 2003).

The increase of natural ventilation inside the rooms depends on the architectural typology adopted and the specifications regarding the building openings. These openings may allow or make difficult to achieve a proper air flow inside rooms, being also responsible for rain protection, noise and solar radiation control. Thus, the opening's design must be carefully considered, otherwise it will endanger comfort conditions inside an ascertain place. The opening typology influences natural ventilation inside buildings offering more or less resistance to the airflow.

The Building Regulation of Maceio determines the minimum openings area based on the floor's area, being 1/6 (opening to floor area ratio) for daylighting and 1/12 for natural ventilation. These items have a straight influence on the airflow determination inside the rooms, as well the users' thermal comfort.

On Maceio's office buildings the most common window typologies are the sash windows and top hung windows, made of glass and aluminum. The sash window does not allow the right conduction of the air flow, nor being partially opened on rainy days, Figure 2a e b. The top hung window allows a partial control of the aperture porosity but does not promote the airflow conduction. Nevertheless, its kind of opening, projected outside, allows some rain protection, figure 2b.


(a)

(b)

Figure 2 – Sash (a) and top-hung (b) windows. Source: The authors, 2005.

The vertical or horizontal pivot windows seem to be an interesting typology because they promote the wind blow plus the airflow conduction, besides integrating inside and outside surroundings while offering protection against rain and solar radiation. However, windows with a poor control of airflow and conduction system and made of glass, as sash windows, seem to be the less appropriated; even being the most used opening typology, especially on office buildings.

It is notable that the window type, on the most cases, does not take advantage of natural ventilation potential, even presenting the minimal area required to ventilation specified by the Building Regulation. The aspects related to the natural ventilation behavior, resultant from the effective area designed to catch ventilation (on the distribution pattern and wind speed) must be evaluated. This evaluation aims to contribute to future changes on the Building Regulation specifications.

The paper investigates the impact of using three different windows typologies (sash, top hung and vertical pivot window), on the airflow distribution and on the wind speed inside office rooms, having the minimal area for ventilation as specified on the Maceio's Building Regulation.

METHOD

The method developed on this paper is a comparative analysis among the performance of three different kinds of windows (sash, top hung and vertical pivot window) on office buildings. The parametric analysis was carried out using a computational tool known as PHOENICS 3.6. This software is based on the Computer Fluid Dynamics (CFD), which came as an interesting alternative tool to the traditional Wind Tunnel on the studies of building natural ventilation. The results may be viewed as vectors, speed fields or isolines, where the wind speed variation is shown in a color score.

The building typical model has rooms through a corridor, with eight floors, figure 1a. The model rooms have 18m² of area (3,00 x 6,00), 2,60 m of height and a centered window on the wall, measuring 1,10 x 3,00, with a 1,00 m of windowsill and a window shaft of 0,50 x 3,00 m. The window open area were considered as being 1/12 of the floor's area as an effective area to ventilation (1,50 m²), according to the Building Regulation of Maceio.

There were studied rooms of the 1st, 5th and 8th floors; representing the lowest floor, a middle-height position floor and the highest floor. Thus, is expected a wide evaluation of the ventilation behavior inside the rooms because of the wind speed variation, elapsed by the wind gradient, on the several floors, figure 2b. The open door of the room is the outlet opening.

There were studied three kinds of squares: sash, top hung window and vertical pivot window, figure 2c. The first two are the most used typologies on the office buildings that were visited on the city. The third kind studied, vertical pivot, although isn't used in a large way on most of the office buildings; has less resistance to the air movement and has the possibility of guiding the airflow. Nevertheless, its potential has not being properly explored.

The three squares were compared by its quantitative and qualitative fulfillment, regarding natural ventilation purposes. That information may be important to better understanding of the square modification impact to the air distribution and speed inside the office building rooms, to the same opening used area.

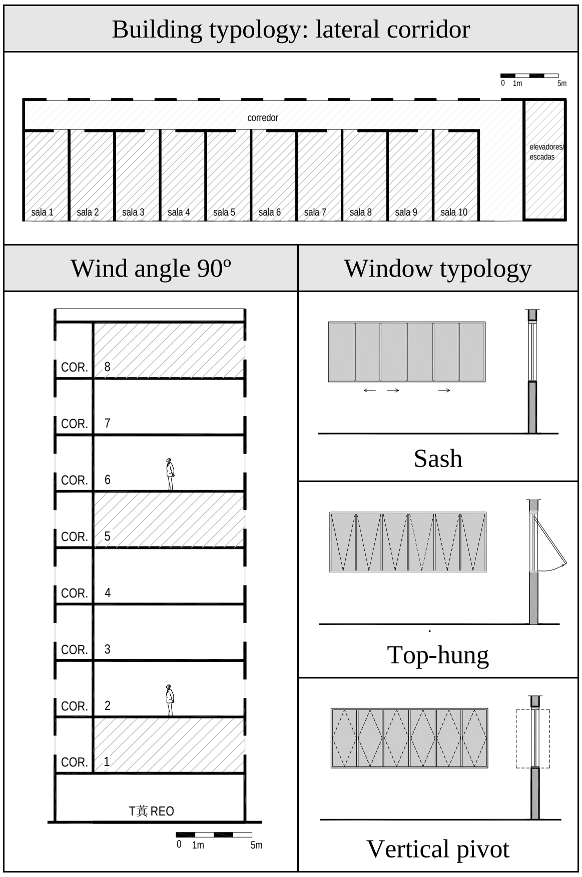


Figure 3 – Architectural variables resume.

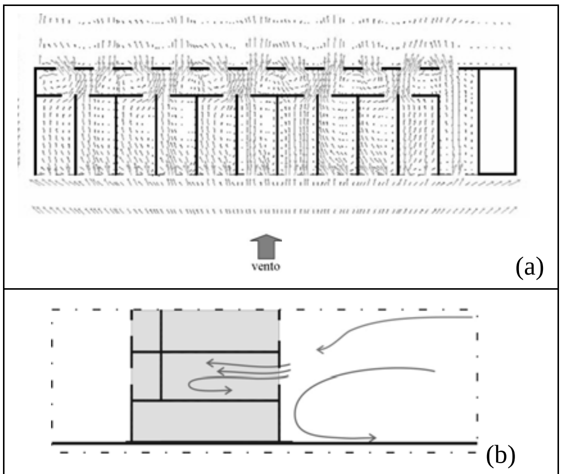
The wind's incidence angle adopted was 90º, which is the normal incidence to the façade. The wind speed was estimated using the rough coefficient of the ground to buildings placed in down town, the wind' speed data (measured at the meteorological station) and the openings height (JACKMAN, 1986 *apud* BITTENCOURT; CÂNDIDO, 2005). The wind mean speed measured at the meteorological station (V_m) was 3,00 m/s according to data of the station placed in Maceio airport, with 10m height far from the ground. The correction coefficients used were k = 0,21 e a = 0,33. The resultant gradient has a wind speed variation on each 1m, till it gets up to 30m. The wind' speed on the first floor was 1,60 m/s, 2,41 m/s on the fifth and 2,77 m/s on the eighth.

The findings were analyzed on a nine-point-grid plan with 1,5m height from the floor. This plan height is placed on the half room's height; analyzing the wind speed on each room's point and to estimate the mean speed inside it.

RESULTS

1. SASH WINDOW

On the first floor, the mean speed in the room was 0,86 m/s. The maximum speed was 1,47 m/s, obtained on the 1, 2 and 3 points, nearby the squares openings and the room's door, figure 4a. The minimal speed was 0,36 m/s on the 6 and 9 points (except on the 10 room, where the velocity of the point 9 was 0,73 m/s).In the other points of the room, the wind' speed varied between 0,73 m/s and 1,10 m/s, totalizing 78% of the room's points.

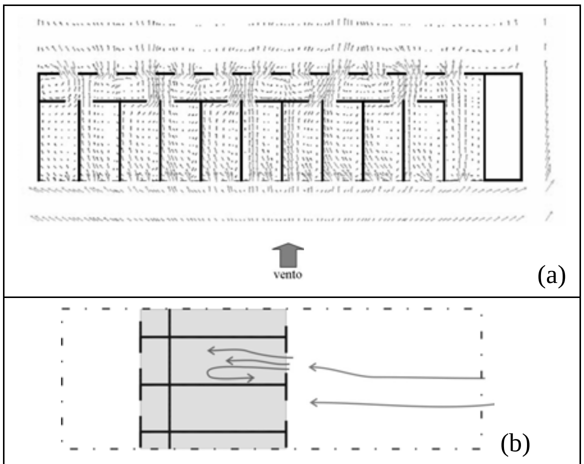


$V_{average}$ (m/s)	$V_{mín}$ (m/s)	$V_{máx}$ (m/s)
0,86	0,36	1,47

Figure 4 – Plant model(a) and section (b) – sash window (1st floor).

The sash squares, promotes a concentrated flush where the windows are opened. In 60% of the room the wind speed did not exceeded 0,36 m/s, corresponding to closed side of the sash window, figure 4b. It is noted the influence of the square's typology on the airflow distribution inside the room, favoring the air flow concentration on the open side of the window. Considering the outside wind speed as 1,60 m/s, the mean speed values were 43% and 62% of the outside speed available. The airflow is guided to the user's height, but with a low speed and a not uniform distribution, figure 4b.

On the fifth floor, the mean speed values were larger than the ones of the first floor. On the rooms 1 and 2 the mean speed was 0,85 m/s, decreasing to 0,78 m/s on the room 3. On the room 4 the speed raised to 1,06 m/s, and 1,10 m/s to the rooms 5 and 6, 1,13 m/s to the room 7. On the room 8 the mean speed was 0,98 m/s and decreased to 0,73 m/s at rooms 9 and 10, picture 4a.



$V_{average}$ (m/s)	$V_{mín}$ (m/s)	$V_{máx}$ (m/s)
0,92	1,47	0,36

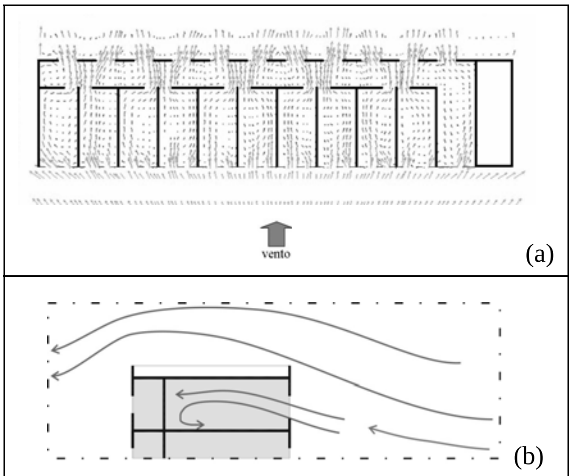
Figure 5 – Plant model(a) and section (b) – sash window (5th floor).

Regarding the airflow distribution, it is noted that the wind flow inside the room is not uniform. The formation of vortex zones on most of the rooms indicates that the effective aperture area to ventilation may not be enough to promote a uniform air flow distribution.

The airflow guidance where the squares are opened, occurs without helping the airflow distribution inside the room, it can endanger the users thermal comfort that keep themselves inside the not benefited spaces by the air movement.

On the eighth floor, room 1, the mean speed was 0,77 m/s, increasing to 0,81 m/s inside the rooms 2 and 3, and 0,85 m/s inside the rooms 4 and 5. On the room 6 increase to 1,06 m/s, decreasing to 0,94 m/s on room 7. On the rooms 8 and 9 the values were 1,06 m/s and 1,02 m/s, respectively and on the room 10 the speed was 0,81 m/s. The raising of these values were influenced by the speed registered on the near window zone, so that the outside wind speed on this floor was 2,77 m/s. However, this acceleration did not produced a uniform air flow distribution inside the room, figure 6a.

The area with wind speed of 0,36 m/s and 0,73 m/s is comparatively larger than the other floors, figure 4a, 5a and 6a. The air' flow distribution is irregular, with vortex zones with low air speed, figure 6. The air flow is guided up to the ceiling, forced by the external air movement that moves itself in an ascendant way to pass over the obstacle created by the building, figure 6a. The adopted square is the sash, so that it does not promote the air' flow guidance on the user level, figure 6b.



$V_{average}$ (m/s)	$V_{mín}$ (m/s)	$V_{máx}$ (m/s)
0,90	1,84	0,36

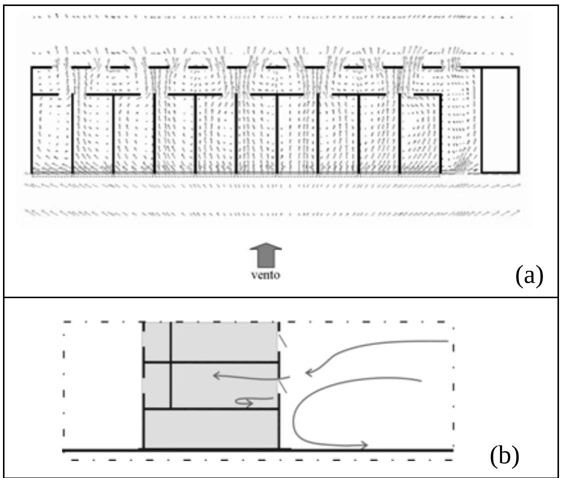
Figure 6 – Plant model(a) and section (b) – sash window (8th floor).

2. TOP HUNG WINDOW

On the room 1, the wind' speed was 0,60 m/s, 0,70 m/s on the room 2 and 0,67 m/s on the room

3. On the room 4 the speed was 0,83 m/s, 0,77 m/s on the room 5 and 0,80 m/s on the room 6. On the rooms 7, 8, 9 and 10 the speeds were 0,83 m/s, 0,87 m/s, 0,90 m/s and 0,80 m/s, respectively, figure 8. On this floor, the outside wind speed on the openings height was 1,60 m/s. Comparing with the inside air speed we can find the wind outside available percentage inside the room. The inside mean speed value varies from 40% to 60 % of the outside wind, figure 6a.

The mean air speed inside the rooms with top hung windows were smaller. However, the values distribution on the rooms was uniform when using top hung windows, especially on the 4, 5, 6, 7 and 8 rooms. Just in 30% of the ambient the speed value was 0,30 m/s, representing a flow which is a not noticeable by the users.

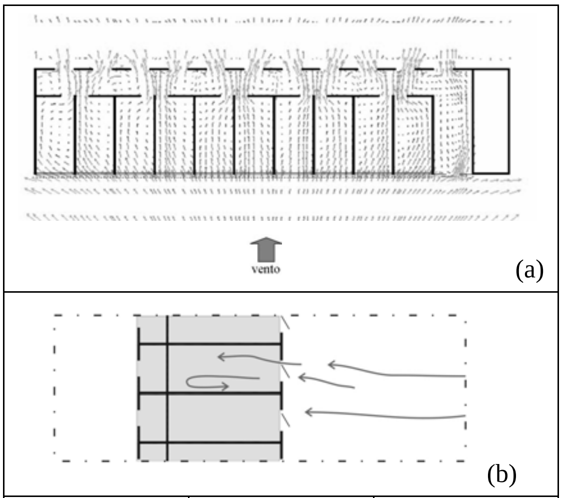


$V_{average}$ (m/s)	$V_{mín}$ (m/s)	$V_{máx}$ (m/s)
0,78	1,20	0,30

Figure 7 – Plant model(a) and section (b) - top hung window (1st floor).

On the fifth floor, the mean values of wind speed rises in relation of the first floor. On the room 1 the mean speed was 0,73 m/s, increasing to 0,87 m/s on the room 2 and 0,93 m/s on the rooms 3, 4 and 5. 0,97 m/s on room 6, decreasing to 0,93 m/s on room 7 and 8.

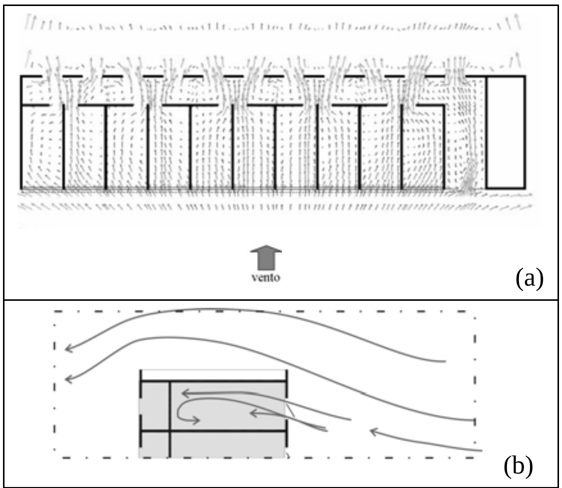
On the rooms 9 and 10 the value was 0,90 m/s, picture 7a. The available percentage of wind speed that were of 2,41 m/s on the fifth floor, vary between 31 and 40 %. It is noted that the typology of square adopted reduces the blowing wind to the ambient.



$V_{average}$ (m/s)	$V_{mín}$ (m/s)	$V_{máx}$ (m/s)
0,91	1,20	0,30

Figure 8 – Plant model(a) and section (b) - top hung window (5th floor).

On the eighth floor, the values were 0,80 m/s on the rooms 1 and 2, 0,87 m/s on the rooms 3 and 4. This values raises to 0,97 m/s on room 5 and 1,03 m/s on room 6. On the rooms 7 and 8 is 0,87 m/s and 0,80 m/s on the room 10.



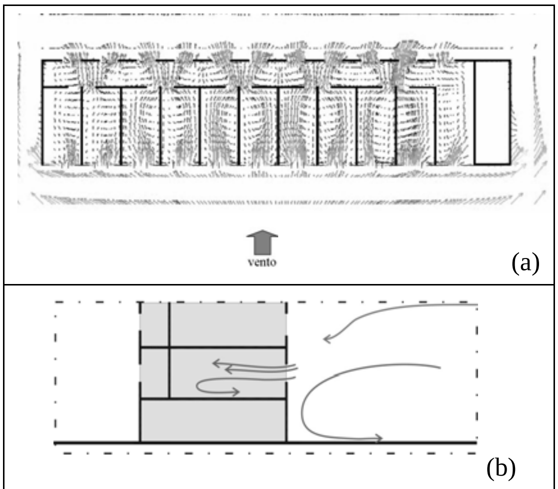
$V_{average}$ (m/s)	$V_{mín}$ (m/s)	$V_{máx}$ (m/s)
0,90	1,20	0,30

Figure 9 – Plant model(a) and section (b) - top hung window (8th floor).

In relation of the air' flow distribution, it is noted that most part of the room display air movement, figure 9. The wind' speed values were higher than the other floors. Benefited by the ascending external component, the air' flow is induced to enter by the top hung window, figure 9b.

3. VERTICAL PIVOT WINDOW

Because of the permeability promoted by the square, the wind reached most of the room area in relation to the other kinds of squares adopted, figure 5a, 8a and 10a. The mean speed on the rooms 1, 2 and 3 was 0,71 m/s. 0,86 on the room 4, raising to 1,01 m/s on the room 5. On the room 6 was 0,82 m/s. The external available wind percentage varied between 47 % and 67 %, considering the approximated speed of 1,60 m/s on the analysis plan height. It is noted that the vertical pivot typology promoted a better use of the external wind speed with the same opening area of the sash and top hung windows.

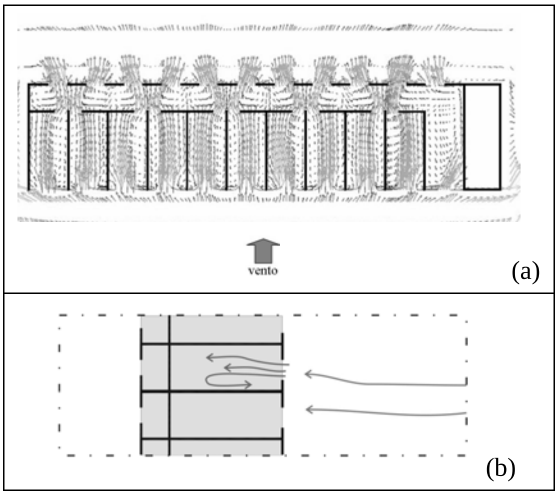


$V_{average}$ (m/s)	$V_{mín}$ (m/s)	$V_{máx}$ (m/s)
0,83	1,69	0,67

Figure 10 – Plant model(a) and section (b) - vertical pivot window (1st floor).

On the fifth floor, the mean speed values were 42 and 70% of the external value (2,40 m/s). On this typology, the squares resist less to the air movement, so that it promotes a better ventilation pattern inside the examined rooms. It presents an uniform air flow distribution and a reduced vortex zones, figure 11a.

The mean speed of the room 1 was 1,01 m/s, 1,24 m/s on the room 2 and 1,27 m/s on the room 3. On the room 4 it raises to 1,64 m/s, decreasing to 1,54 m/s on the room 5 e 1,35 on room 6. On the room 7 the mean speed values was 1,68 m/s, decreasing to 1,38 m/s and 1,35 m/s on the 9 and 10 rooms, figure 11a.

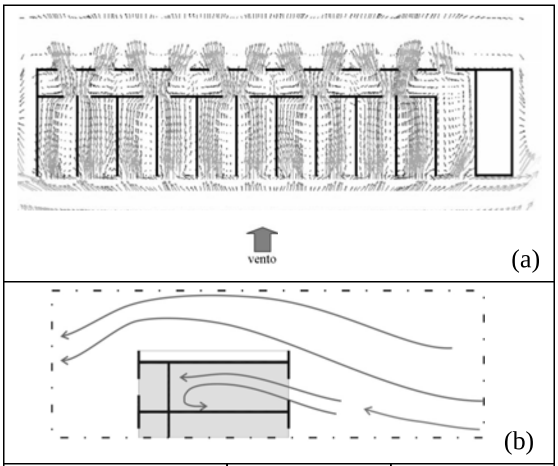


$V_{average}$ (m/s)	$V_{mín}$ (m/s)	$V_{máx}$ (m/s)
1,38	2,02	0,67

Figure 11 – Plant model(a) and section (b) - vertical pivot window (5th floor).

On the eighth floor, in relation of the air' low distribution, there were differences among the values, so that they are not absolute values. However, analyzing the air flow inside the room, there are few vortex areas. The air speed is increased to not less than 0,67 m/s, figure 11a.

The mean values of the wind' speed were higher, being over 1,0 m/s inside every room. On the room 1 it was 1,08 m/s, raising to 1,38 m/s on rooms 2 and 3 and 1,57 m/s on the room 4. On the room 5 the average was 1,72 m/s, decreasing to 1,16 m/s on the room 6. On the room 7 that value raises to 1,57 m/s and keep 1,61 m/s on the rooms 8, 9 and 10.



$V_{average}$ (m/s)	$V_{mín}$ (m/s)	$V_{máx}$ (m/s)
1,47	2,02	0,67

Figure 12 – Plant model(a) and section (b) - vertical pivot window (8th floor).

CONCLUSION

This paper discusses the impact of using three different windows typologies (sash, top hung and vertical pivot window), on the airflow distribution and the wind speed inside office buildings, having the minimal area for ventilation as specified on the Maceio's Building Regulation. Results indicate the square typology influences on the ventilation values inside the rooms. The air flow distribution was directly affected by this item, especially on the vortex zone formation. Although the square's opening kind is an important item to ventilation, it is not properly considered in the Building Regulation specifications.

It is suggested that future investigation should establish correction factors to consider the openings typology effectiveness, informing the impact of adopting different square typologies on the wind speed inside the room.

The square fulfillment has demonstrated being influenced by its position on the building (floor), as verified by the ascendant flow behavior analysis through the studied floors. Depending on the floor's height the air' flow direction inside the room comes from up or down direction.

That direction is still influenced by the typology and openings position of inlet and outlet. The outlet openings demonstrate an influence on the horizontal distribution standard of the air flow inside the studied rooms, so that it would be better used on buildings design. It is suggested, however, more studies about typology and position of the outlet openings needs to be carried out.

The vertical pivot square demonstrated a better fulfillment regarding the air flow distribution and wind speed inside the rooms. The sash square typology promotes a blowing wind concentrated near the openings' area and because of the fixed part the vortex zone formation occurs inside the rooms. The top hung window, does not promote a uniform air flow inside the rooms; it works like a obstacle to the entering wind due to its shape, especially on the first and fifth floors.

The necessity of varying the openings typology on different floors, although it is not the Building Regulation focus, could be used by designers. Regarding the outlet opening importance, that would be the most studied items by the designers, in order to promote better thermal comfort conditions inside the rooms. These items could be useful on the rules creation and more suitable codes, thus it would improve the comfort and energetic efficiency of the built ambient. However, it is important to designers to dominate the ventilation principles to use it on the buildings design process. Associated to the restricted position of the standard, the professional must comprehend the rules to built adequately using natural ventilation as a cooling strategy for the built environment.

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