268: Ventilation Performance in a Funneling Window

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Abstract

Colima, (latitude 19º15'; longitude 103º44', altitude 450m) is a small city in the mid-western coast of Mexico with a warm sub-humid climate. Under these weather conditions, one of the main strategies of bioclimatic adaptation is natural ventilation.

However, in some seasons the wind speed is not enough to generate relative thermal comfort, primarily during the summer months. Summers in Colima are seasons of high temperatures, and low wind speeds, for that reason it is required to not only think of having appropriate orientations and dimensions for openings to capture wind, but to also think of the need of incorporating mechanisms that increase the wind speed. Due to this, improving the local comfort conditions through a passive system, located in the window itself, will increase external wind velocity.

The potential use of a reception and concentration system of the wind was determined. The resulted method was that the window design itself could modify the velocity and direction of the wind. It was determined that by using flat surfaces it was possible to manipulate the mechanics of the wind to improve the ventilation conditions of the inhabited space and in that way to increase the realm of comfort temperatures.

This work analyzed the performance of the windows of a house installed with a mechanism to increase the wind speed. The mechanism was a reduction of the interior dimensions of a flat-surfaced window to a 30º angle. The external dimensions of the window were 2.17 x 1.72 meters. The interior plane was 1.73 x 1.34 meters. The dept was 0.9 meters. With these dimensions, the interior area represented about 40% of the external surface. During a season of low natural ventilation, a systematic log of the wind speed in the external plane and interior of the funneling window with unidirectional anemometers of filament was recorded. The results showed increments that went from 20% to 300% of the air velocity, and an average increment of 140%.

The obtained velocity data represented an intermediate correlated grade of 0.47, and the following equation: External velocity = 0.514 Internal Velocity + 0.182m.

Keywords: Window, Wind Mechanics, Venturi effect.

1. Introduction

Wind is a result of the uneven heating of the earth. This uneven heat is due to differences in Earth's topography and differences between landmasses and sea areas.

In Colima, there are seasons of high and low air movement. For this reason, it is essential to increase indoor ventilation during the low air movement season.

In Colima's warm sub-humid climate, it is favorable to induce air movement indoors since it will improve thermal comfort of occupants by reducing humidity and cooling indoor areas.

Indoor ventilation could be increased with the adequate design of a mechanism, based on the Venturi effect, in windows; as well as changing air direction to fulfill the requirements of each building.

The window is an opening for environmental control with multiple functions related to the indoor-outdoor space. Every house has windows even though they may not always possess a bioclimatic purpose. However, these openings have specific traits in each house and important differences in relation to the occupants.

There are a number of investigations about ventilation to study natural ventilation operations when air is induced indoors. From these investigations, there are results about induction angles, changing of air movement paths, size of incoming and outgoing apertures and indoor obstacles.

Givoni (1962) demonstrated that by having openings only in one wall, ventilation was inferior since the pressure gradient was minimal. However it was possible to improve those conditions with an adequate positioning of two air concentrating windows on a single wall.

Olgyay (1963) pointed out that it was better to introduce wind at 90^o. Since speed (V=Q/r x A) depends on the relationship between inward and outward areas (r), and size of the inward opening (A); as far as the flow (Q) and the angle of incidence are constant.

The speed increase of wind through the mechanism will be accomplished right after it passes the inward opening and it will then decrease once indoors. As it took place with the ventilation experiments conducted by Sobin (1966). Sobin considered that the optimal ventilation is reached when the angle of wind incidence is 45 degrees in horizontal openings.

While at 90-degree angle of incidence, squared or vertical openings are preferred.
Rivero (1988) considered important to have the dimensions of outside walls accounted since these can have either a positive or a negative influence in capturing air during the times of high and low air movement.
Gomez-Amador, et al (2006) demonstrated that a window registers different air movement speeds at different heights, since warmer air will move toward the top of the opening.
Recently, occupants have been considered an active part of the indoor environmental control process, especially in houses. There are researches dealing with the importance of this role. The home improvement made by occupants and the impact of this on ventilation has been analyzed in Colima (Rowe, 2005), along with the influence of door and window operation on the house's thermal performance (Moreno Peña, 2007).
This paper will analyze the funneling effect on windows by means of the differences of wind velocity, even though wind behavior depends on multiple important variables, such as wind direction, angle of incidence in relation to the window, cross ventilation and one-way ventilation, size of inward and outward opening, wind flow, wind distribution, and indoor wind velocity. There are also window devices such as ... that affects the wind behavior.

2. Method

The analysis was made on a window from a house in Colima City. The window was facing northeast (37^{o} N). The window was 2.17 m height by 1.72 width on the external plane; 1.73 m height by 1.34 m width on the internal plane.
These measurements are a result of using two concentrating planes, a vertical one of 30^{o} on relation to the window, and a vertical one of 45^{o} in relation to the window's own plane. (figures 1, 2 and 3)

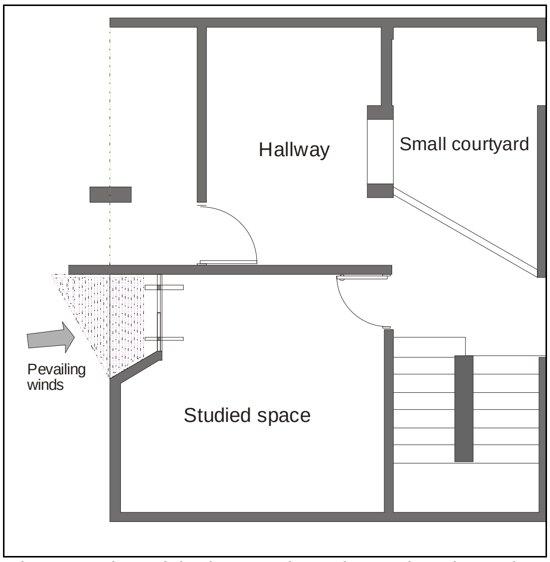

Figure 1: View of the house where the analyzed area is located. Outside of this area there is an open hall next to a small deep patio.

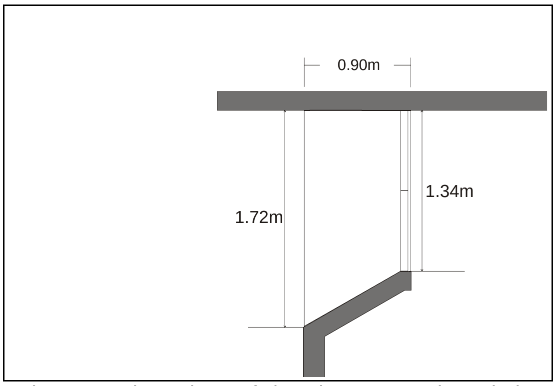

Figure 2: Dimensions of the air-concentrating window from its horizontal plane.

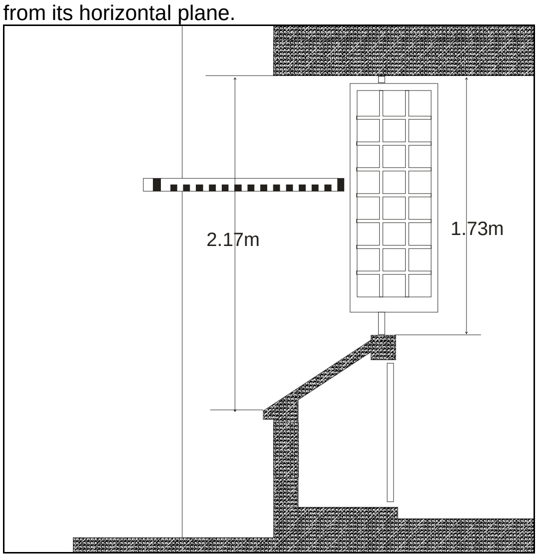

Figure 3: Dimension of the air-concentrating window from its vertical plane.

In Colima City prevailing winds come from the West. The speed recording log was done during daytime in October, when prevailing winds come from the North northwest, which results on an angle of incidence of 50^{o} in relation to the window's plane.

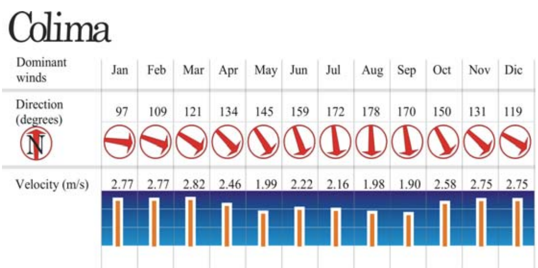

Figure 4: speed and prevailing winds in Colima City.

To record the wind velocity some unidirectional sonic anemometers (Airflow Anemosonic UA30) were placed on the window. The start velocity of the anemometer is 0.008 meters per second and the resolution is 0.001 M/s (Figure 5)

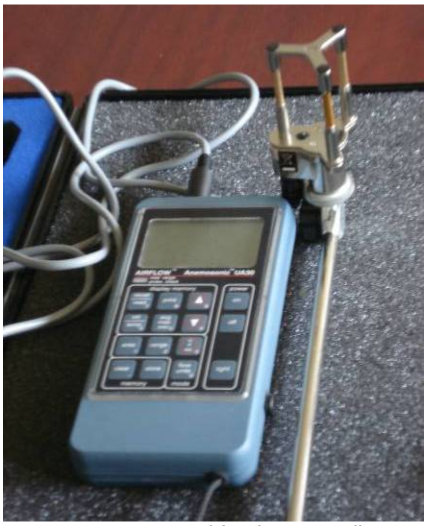

Figure 5: Anemometer used for data recording.

The anemometers were placed at the center of the opening, one on the windowpane and the other on the external surface. This was done to avoid each other's obstruction. (Figure 6)

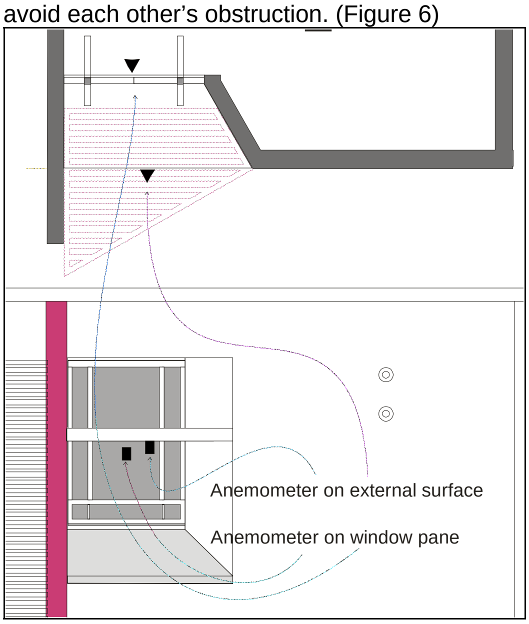

Figure 6: Top location view of anemometers on the window (top). Frontal location view of anemometers (bottom).

Due to the wind velocity variation, the data was recorded simultaneously on both anemometers. Therefore, the log did not concur with the wind velocity altered by the air concentrating planes, but to an approximation. 202 pairs of logs were recorded at irregular two-hour intervals for a total of four hours.

There was a door directly across from the window within the same room. All the recording was done with this door wide open. (Figure 1)

Since the anemometers did not have a memory to make the recording automatically, the anemometers' displays were placed together to take a picture of both at once every time a log was made.

3. Results

The chart below shows the recorded logs of wind velocity on both planes of the window.

Wind velocity comparison between the internal and external planes.

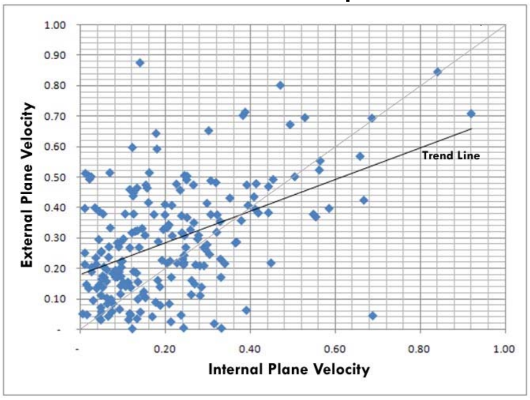

Figure 7: Recorded data correlation chart.

The chart shows a lack of unity in the records. The difference between the internal plane in relation to the external plane goes from 40% up to 4000%. The average wind velocity in the external plane is 0.208, and the average wind velocity for the internal plane is 0.289. The average increment of wind velocity indoors is 140%.

The found data shows a tendency to increase the wind velocity indoors in relation to the outdoor velocity. This represents an average correlation of 0.47. The relation between the indoor and the outdoor velocity is:

$$OV = 0.514\ IV + 0.182 \quad (1)$$

Where:

OV: Outdoor Velocity

IV: Indoor Velocity

Nonetheless, this system does not work under every condition. To meet the increment on wind velocity as mentioned above, it is required to have the door wide open. An analysis made with the door closed shows a high data dispersion.

When comparing the tendency line of the recorded data and the normal behavior line of the chart above, it is possible to appreciate the system's efficiency when the wind velocity is above 0.38 m/s.

Comparing data from average values and data calculated with the equation V=Q/r x A, the expected wind velocity increment would be 1.57 m/s for incoming wind, in opposition to 1.39 m/s as registered through the study. The equation assumes a perpendicular incidence of wind as a premise.

5. Conclusion

To delineate the behavior of an air-concentrating window is more complex than direct recording of wind velocity. Any measurement system applied to a building will show limitations when trying to mold the behavior of the window, since wind direction and wind velocity are rather random. The analysis under controlled wind direction and velocity conditions or in a wind tunnel would allow a better systematization. However, it is important to merge analysis from models, simulators, and full-scale objects within a study.

It is indispensable to continue analyzing the phenomenon with better equipment in order to obtain recording of wind velocity and wind direction simultaneously to discern the direction effect over the window device.

There are other aspects to have in account. Particularly, null wind velocity was recorded outdoors, while at the same time airflow was recorded indoors. This is explained by the simultaneous readings and the suction effect, the latter is a consequence of a high-walled small patio that created a wind-tower effect.

Considering the variation of the angle of wind incidence during the velocity recording process and having in account the assessment of velocity records with the calculated ones, the window behavior is favorable for a sensitive increment on indoor wind velocity.

Independent of current results, additional strategies are required to improve indoor performance, and reach thermal and humidity comfort for occupants.

6. Acknowledgements

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