Exhaust ventilation through a wind tower as response to high hermeticity in welfare housing

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In Mexico 76% of the population is concentrated in urban areas, the index is over 4.16 people per housing, where an appropriate indoor environment is impossible; however in warm sub-humid climate cross ventilation is one of the most efficient strategies to improve those conditions, but, the fast growth of social welfare housing (SWH), precludes their generation due to the high hermeticity of the architectural envelopes.

Wind-catchers are capable of improving Hygro-thermal comfort through a double action cycle. The optimized operation of these can be used to reduce the hot air layer in buildings of low height configuration. This correlational research use a simplified mathematical base through an experimental scaled-model to estimate the potential volume flow of exhaust ventilation due to Venturi effect applied on a four-sided wind tower.

The study was carried out during the month of April, an important warm season for Colima city, where ventilation rate is about 6.8 m/s, the average temperature oscillation is 20 °C. The model was tested using environmental chambers. Results showed that values near 1.85 m/s as a maximum wind speeds of passive extraction generated due to Venturi effect in the wind tower were capable of improve consistently the indoor air change rates
Keywords: Exhaust Ventilation, Venturi effect, Welfare housing

INTRODUCTION

Mexico has more than 55% of its urban population concentrated in just five metropolitan areas, which to date, have a potential demand estimated at 4.7 million houses. This demand will be reached through construction schemes at low cost; these limited conditions of habitability consider spatial and architectural configuration guide on economic criteria and structural safety.

This is due to the per capita income of the working class of the country and present seismic activity in the country. It is important to mention the 190 events of moderate to strong seismic activity, according to Richter seismic scale in the last five years.

Based on the foregoing, residential building codes are defined, whose standards ensure safe, but instead limit the possibilities of providing environmental control alternatives. As far as natural ventilation is concerned, the regulations of the major metropolitan areas of the country suggest a window opening between 5% and 17.5% of the area of the building, or are specified volume changes between 1-5 air changes according to the use of space. This shows the massivity suggested in building envelopes.

Other criteria of safety, such as fire prevention and acoustic, where buildings of less than 6 levels are classified as low risk and, any condition score less than 65 decibels, as measured at 0.50 outside is allowed; otherwise, only building insulation is recommended.

Morphological constraints like mentioned above inhibit natural cross ventilation, commonly used in hot and humid climates to improve Hygro-thermal comfort conditions. Because of this, the exhaust ventilation is an appropriate technical response to high massivity buildings, but it has been poorly studied in ventilation devices.

Antecedents

The idea of evaluating the performance of ventilation devices of convective nature -most important transfer mechanism in the ventilation- in historical prototypes that take advantage of areas with low air pressure inside layers (stack effect) has been described by many authors like K. Saranti (2006), who described temporary applications for vernacular devices such as bagders and wind-catchers built in Iran, Iraq, Saudi Arabia, North Africa and Greece.

According to some of the most renowned scholars of Islamic Azad University of Tabriz, wind tower has been used in the deserts Iranians since ancient times, is one of the architectural masterpieces of the Babylonian. Wind tower being a simple device that directs wind through the inside of the building to generate comfort for the most effective way may be, however, classified into two major types of functions according A´zami et al (2005):

1. Function according to the principle of opening drive against wind suction and rear openings upwind.
2. The function according to the temperature difference.

Other studies have used experimental wind tunnels, test smoke visualizations and CFD models at the University of Reading in UK, to investigate the effect of flow control mechanisms of air and heat inside the rooms with the performance of a wind tower. Pressure coefficients around the wind tower and the air flow within the room were stabilized.

The performance of the wind tower greatly depends on the wind speed and direction. Incorporating exhaust dampers and roof level reduces and controls the flow of air with a pressure loss coefficient of 0.01. (Elmualim, A. 2005)

In 2007, Li provided Additional documents that show a numerical study of the evaluation of the performance of a wind tower using CFD simulation by school of environmental science and engineering from Tianjin University in China, where a wind tower (500 sq. mm) connected to a room was modeled for different wind speeds in 4 directions of incidence. Numerical results show that the wind tower is influenced by both variables with respect to its quadrants. In all cases, the maximum rate of air entering the testing room through the wind tower is very close to the outside air velocity.

Other studies using CFD software flows and numerical analysis to 53 designs scale wind towers recently demonstrated the ability of these devices to reduce the ambient temperature of 40 ° C to temperatures of 32 ° C and increases in relative humidity up to 36.7% depending on the study models (Mahmoudi, 2009)

During the last decade a number of studies have been conducted by several environmental research centers and engineering schools around the world, Thailand has developed most of these investigations and the major role that simulation through computational fluid dynamics (CFD) research has taken is obvious. This was due to interest in increasing the level of trust that exists in the predictability of mathematical models that the theory had offered recently.

However, almost all of the existing literature has focused on studying the behaviour of traditional wind tower, without considering that it is possible not only induce the wind inside the buildings, but remove it from the living spaces to improve the indoor ventilation and consequently living conditions.

The present research aims to demonstrate the ability to ventilate low cost residential buildings whose architectural envelope inhibits cross ventilation and where it can be utilized passive ventilation through a wind tower.

METHOD

Placement

The experiment was developed by using experimental test modules located in Coquimatlan, Colima, inside the University of Colima; a metropolitan area of Colima city (103º48'W lat., 19º12'N Long, 365 meters above sea level).

Figure 1. Geographic location of Colima. Source: Authors

The climatic conditions in the region are described as warm sub-humid according Köppen-García´s climatic classification system, most important variables for this study are presented as follows:

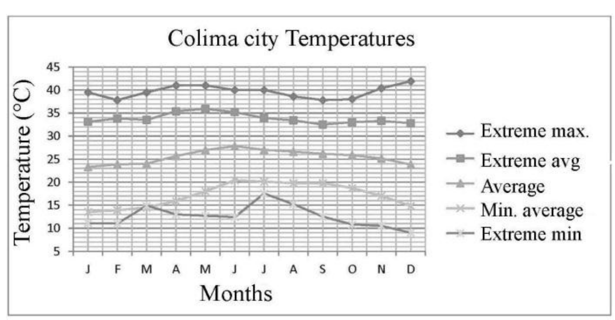

Figure 2. Annual temperature conditions in Colima City. Source: Authors based on Comision Nacional del Agua data

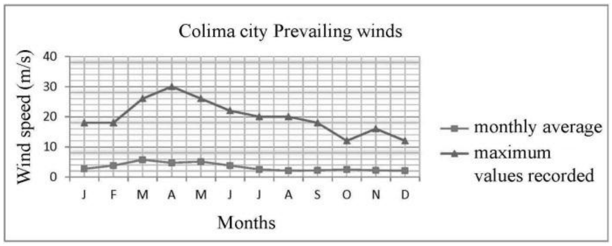

Figure 3. Annual wind conditions in Colima City. Source: Authors based on Comision Nacional del Agua data

Test Modules

The specific design features of the two test modules obey the 1:2 scale representation of a room with the minimum measures laid down in the first section, minimum acceptable dimensions of habitability requirements and operation of the building Regulations of Colima.

Modules have 2.46 m3 volume; 1.35mts long. x 1.35 mts wide x 1.35 mts high. They have a front opening in one side of 0.50m wide by 1.05m high to provide the necessary air inlet to simulate the ventilation of a room on a social housing when cross ventilation in spaces of this type is minimal and only occurs through an access door to the room open when the bedroom windows are closed or blocked significantly.

Materials employed are commonly used in Colima, clay brick walls and concrete slab on the roof, with 0.10m tall parapets, with walls painted on white color. Each of the modules is individually capable of offering almost identical weather conditions, for it was necessary to carry out a study of sunlight.

Figure 4. Experimental scenario, location: Coquimatlan, Colima. Source: Authors

To ensure the validity of the experiment, conditions of the two test modules used was compared. The wind conditions showed almost the same behaviour for both, as shown in figure

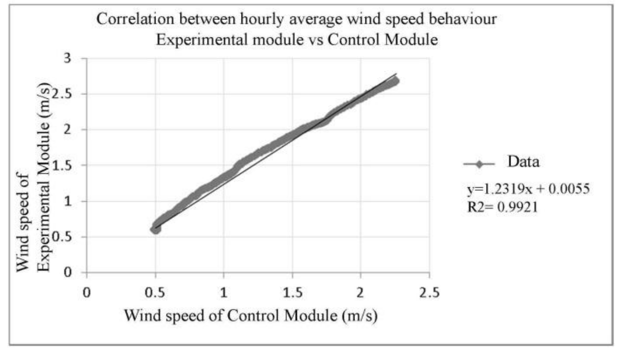

Figure 5. Correlation between experimental and control module wind conditions. Source: Authors

Data logging equipment

The basic instruments used to capture and record climate information detect wind and temperature variations with a high degree of sensitivity; these were located on geometric centre of test modules (for dry-bulb temperature) and under the roof (for wind speed) because of the magnitude scale generated by a passive extraction.

An unidirectional hot wire anemometer-thermometer HD2103.2 model from Delta Ohm company was used. It has a flexible telescopic probe AP471 S3 model with range sensors temperatures ranging from -30 °C to 110 ° C, wind of 0-40 m / s accuracy of ± 0.2%. Additionally was used the ONSET HOBO® data logger U12-012 model with temperature sensor range from -20 to 70 °C accuracy ± 0.35 °C, RH 5 to 95% accuracy ± 2.5% to measure the change of dry-bulb temperature due to passive ventilation.

Experiment

Once the experimental scenario was built, the scale of the wind tower was arranged considering the aspects of proportion. The design of the wind tower and the expected volume flow in it, was based on the consideration of the continuity principle and Bernoulli´s equation.

$$P_1 + \frac{1}{2}\rho * V_1{}^2 = P_2 + \frac{1}{2}\rho * V_2{}^2$$

Where:

P_1: Initial pressure
ρ : air density
V_1: Initial wind speed
P_2: Final pressure
V_2: Final wind speed

The mathematical expression shown above is the theoretical foundation to Venturi´s effect (see Fig. 6) applied in the model of 0.31 mts. length x 0.74 meters height fabricated from stainless steel metal frame and cement panels ½ "thick with 4 air inlets 0.25 mts. x 0.25 mts., reductions of 0.08 meters square section, each one consisting of 4 planes hubs; arranged with an inclination of 40 °, with a height difference between the input and output centroid ventilation 1.425mts. A channel of 2” Ø was isolated to measure the effectiveness of passive ventilation phenomenon on lower part of the wind tower.

Figure 6. Wind tower model installed on experimental module. Source: Authors

The relevant monitoring period was also determined to conduct performance of the ventilation device. The month of April in the semi-warm season was the relevant month for the purposes of this study, with average minimum temperatures of 15.9°C and an average maximum of 35.4 °C, an equivalent average temperature of 25.65 °C, and a significant wind presence.

The frequency of wind and temperature capture was established for each minute of the day, to form a daily profile based on 1440 records of each day of April 2011. April 5th was selected as representative day within the same sample that met the approximate temperatures than those reflected by the data provided by the typical weather for this month, taking into account for this average maximum and minimum temperatures average and typical day limits sought within records in question.

RESULTS

There is a major difference in the gusts of wind in the early hours of the day and the end of it, with magnitudes of greater value to the extraction tower wind with differences listed below 1 m/s, while the presence of major wind gusts are located within 11 and 18 hrs of the day what makes you think that the daily oscillation maintains a ventilation period favoring wider ranges ventilation.

Records obtained in the experimental module, from a sample of N= 1440, x_1 = 0.34 m /s, x_{1440} = 0.32m/s and $\bar{x}$ = 0.26 m/s show a trend line with an increasing behavior, this indicates that when increasing external ventilation conditions exist, also increase passive extraction conditions of the wind tower.

Records obtained show magnitudes near 1.85 m/s as maximum values during day time, while 0.97 m/s and similar values were recorded at night, average wind speed recorded was near 0.3 m/s.

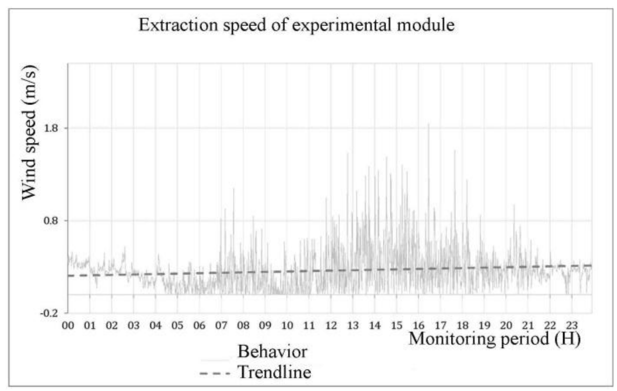

Figure 7. Wind tower ventilation on experimental module in a typical day conditions. Source: Authors

The interpretation of the results leads to the determination of performance showing the potential of this device (see Table. 1). However, it is necessary to determine in future studies the speed limit to achieve a pressure drop at the hub of the tower, as the above determines the extraction capacity of the tower.

Table 1. Wind tower performance based on results . Source: Authors

PERFORMANCE	
CONCEPT	WINDTOWER
Volume flow rate (day)	45.50 m3
Diurnal Volume Flow Rate	26.30 m3
Nocturnal Volume Flow Rate	19.20 m3
Air Volume Changes	18.49 avc
AVC Day	10.69 avc
AVC Night	7.80 avc
Ventilation rate (Day)	0.77 avc/h
Ventilation rate (diurnal behavior)	0.87 avc/h
Ventilation rate (nocturnal behavior)	0.67 avc/h

CONCLUSION

The above results demonstrate the potential in the passive ventilation through wind extraction in order to improve habitability parameters. In high hermeticity and low cost buildings is convenient to use passive technologies, however, the present study demonstrates that the minimum records are not perceived according to Beaufort´s scale, while the maximum ones, are classified as light breeze (1.6-3.3 m/s).

The operation of the wind tower is totally dependent on external ventilation conditions, due to this, it is essential to know therefore urban conditions for effective implementation of this device. However, the results obtained indicate air volume changes near those specified in building codes in metropolitan areas studied (1 air change per hour as minimum)

It is important to note that the temperature rise recorded in the experimental module with a value close to 1 °C demonstrates the ability of passive ventilation to heat the building envelopes. So it is important to clarify that natural ventilation in hot climates should be selective in order to provide convective cooling in the people, this happens when the outside temperature does not exceed 37 ° C.

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