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Impact of orientation, aspect ratio, WWR on natural ventilation of non-high-rise residential building in a warm humid climate.

Impacto de la orientación, relación de aspecto, WWR en la ventilación natural de edificios residenciales no altos en un clima cálido y húmedo.

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ABSTRACT

Due to urbanization and population growth, cities are developing their infrastructure to accommodate everyone moving to metropolitan areas. As a result, the local government's planning and development regulations for buildings are increasingly emphasizing built-up areas, which raise building density. These building development rules have yet to consider the natural ventilation potential. External obstruction, especially surrounding buildings, will have a more significant impact on natural ventilation. This study investigates the effect of the factors such as orientation, canyon aspect ratio, and WWR of the building on the natural ventilation potential inside the building. The residential complex, constructed based on the Tamil Nadu Combined Development and Building Rules, 2019 (TNCDBR), is selected to study natural ventilation. Parameters like air temperature, relative humidity, and wind speed are measured on-site and analyzed. The aim is to evaluate the natural ventilation in the residential cluster compared with the comfort ventilation standards of NBC. Results indicated the impact of the building's orientation, WWR, and aspect ratio. The findings of this study intended to increase the understanding of natural ventilation potential in residential buildings and thus provide information for urban planning and building design.

Keyword: Aspect ratio, Natural ventilation, Building orientation, warm-humid climate, comfort ventilation.

RESUMEN

Debido a la urbanización y el crecimiento demográfico, las ciudades están desarrollando su infraestructura para dar cabida a todos los que se trasladan a áreas metropolitanas. Como resultado, las regulaciones de planificación y desarrollo de edificios del gobierno local hacen cada vez más hincapié en las áreas urbanizadas, lo que aumenta la densidad de edificación. Estas normas de desarrollo de edificios aún deben considerar el potencial de ventilación natural. La obstrucción externa, especialmente los edificios circundantes, tendrá un impacto más significativo en la ventilación natural. Este estudio investiga el efecto de factores como la orientación, la relación de aspecto del cañón y el WWR del edificio sobre el potencial de ventilación natural dentro del edificio. El complejo residencial, construido según las Reglas de construcción y desarrollo combinados de Tamil Nadu de 2019 (TNCDBR), se selecciona para estudiar la ventilación natural. Parámetros como la temperatura del aire, la humedad relativa y la velocidad del viento se miden y analizan in situ. El objetivo es evaluar la ventilación natural en el grupo residencial en comparación con los estándares de ventilación confortable de NBC. Los resultados indicaron el impacto de la orientación del edificio, WWR y relación de aspecto. Los hallazgos de este estudio pretendían aumentar la comprensión del potencial de ventilación natural en edificios residenciales y así proporcionar información para la planificación urbana y el diseño de edificios.

Palabra clave: Relación de aspecto, Ventilación natural, Orientación del edificio, clima cálido-húmedo, ventilación de confort.

INTRODUCTION

Rapid urbanization has resulted in unplanned, densely populated metropolitan areas that block the impact of the wind on the city (Gülten and Öztop 2020). Urban environments tend to have adequate natural ventilation compared to rural ones, particularly in street canyons. Significant obstacles to its use in urban environments include reduced wind speed, urban heat islands, noise, and pollution (Ghiaus et al. 2006). The arrangement of urban buildings and the roadway networks in an urban area is strongly related to ventilation performance, which determines the thermal comfort of indoor and outdoor constructed areas (Merlier et al. 2018). Increasing natural ventilation potential helps in achieving thermal comfort and better indoor air quality, which in turn reduces the energy demand. A good understanding of urban climate and the associated IEQ status in naturally ventilated urban buildings is fundamental for improving their IEQ. Low wind speeds in street canyons result in fewer pressure differences around buildings to drive indoor natural ventilation. In India, local governments review the planning norms regularly, focusing on ensuring affordable urban living spaces and increasing built density. The urban form in developing cities, including Chennai, is guided by a revised set of TNCDBR building rules in 2019 for selected locations. These have been drafted to ensure urban land affordability. Therefore, the impact of factors affecting natural ventilation concerning urban development regulations on natural ventilation performance should be considered.

Natural ventilation is the primary factor that has various benefits, including occupants' comfort and health, reduced building heat, etc. achieving maximum natural ventilation leads to energy-efficient and sustainable buildings. In the Urban environment, natural ventilation performance in the buildings is affected mainly by the surrounding buildings, which can significantly reduce the WS. Hence, studying this impact to attain the maximum natural ventilation into the building.

A. Influence of surrounding building

(De and Mukherjee 2018) studied different orientations and different canyon aspect ratios are simulated and compared to find the most suitable design alternative for the study area. Results indicate that canyon aspect ratio of 2.5 with taller buildings and greater spacing in between them is optimal in terms of human thermal comfort at the pedestrian level.

B. Accessing natural ventilation.

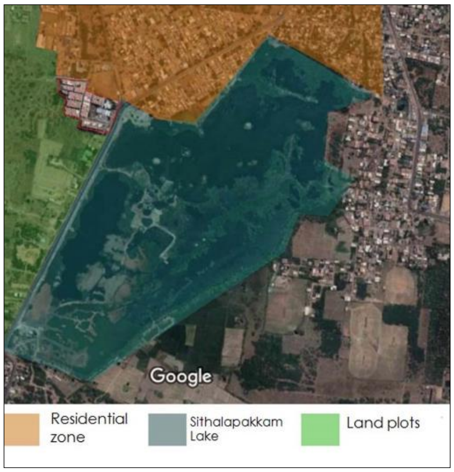
Analysis of the natural ventilation performance of residential areas done by Aya Gültena, and Hakan F. Öztopb in 2020. This study aimed to utilize the natural wind to create optimal natural ventilation to achieve thermal comfort of the indoor environment through the best layout and placement of residential blocks, creating proper distance between blocks and orienting blocks properly inside a residential complex site in a summery humid climate. Optimal natural ventilation in residential complexes investigated by NastaranZarrinGhalam, Mohammad Farrokhzad, Hassan Nazif (2021) derived at appropriate distance between the buildings, orientation of the layout, design of interior spaces. (Ai and Mak 2018) investigated the natural ventilation performance of buildings in an urban context from both street configuration and envelop design perspectives. The study shows that the ventilation performance of buildings is decreased with the increase of aspect ratio of a street canyon.

C. Impact of building regulation

Ebin Harrison Salal Rajan and Lilly Rose Amritha (2020) studied the Impact of built geometry guided by building development control rules of Chennai. Their study found that the rules to govern urban planning and development have a significant role in ensuring a comfortable outdoor environment. The simulation results indicate that Tamil Nadu’s Combined Development and Building Rules (2019) can considerably improve thermal comfort. Hosen, Md. Kamal Islam, and Kazi Saiful (2019) found that the distributions of the wind velocity are significantly affected by building configurations based on increasing MGC, FAR and setback.

METHODOLOGY

Natural ventilations and impact of surrounding buildings is studied through previous literature study. Site selection was done based on warm-humid climatic conditions and available wind potential. Field study conducted in a residential complex for 3 consecutive days, where parameters such as air temperature, relative humidity, and wind speed were measured and documented. Results were analyzed and discussed



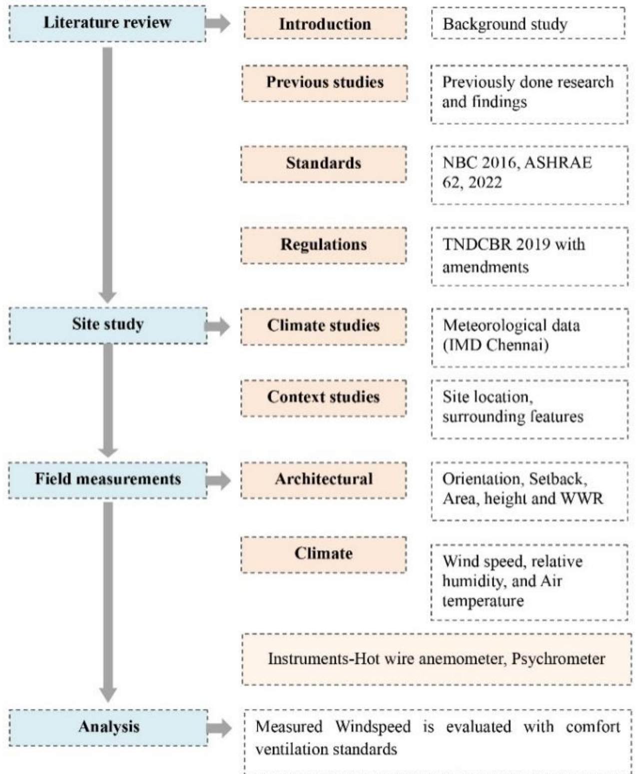


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Fig. 1 Methodology

FIELD STUDY

A. Site selection

The significance of natural ventilation in a Warm-humid climate is necessary to achieve thermal comfort. Warm-humid environments have extreme temperatures and humid levels. Chennai, the metropolitan city, which is the capital of Tamilnadu, is located at 13.0827° N, 80.2707° E in South India. Chennai City extends to an area of 176 km2 and has a population of 4,646,732 (District Census Handbook, 2011). The site has a long coastline of 19 km along the Bay of Bengal (Salal Rajan and Amirtham 2021) Developments were increasing rapidly due to urbanization; Hence the new TNDCBR-2019 regulations aimed at affordable living resulted in growth in building density.

Fig. 2 Site context

B. Climate study

Chennai has warm-humid climate. Summer, monsoon, and winter are the three major seasons in the region. April to May are the hottest months, with a maximum temperature can reach up to 31.7 °C and a minimum temperature of 24.1 °C. The winter in Chennai is from November to February, with maximum and minimum temperatures of 33.5 °C and 18.5 °C, respectively (fig 2) June and July receive maximum windspeed (IMD 2020). The prevailing wind in Chennai is from the South-west between the end of May to the end of September and the northeast during the rest of the year.

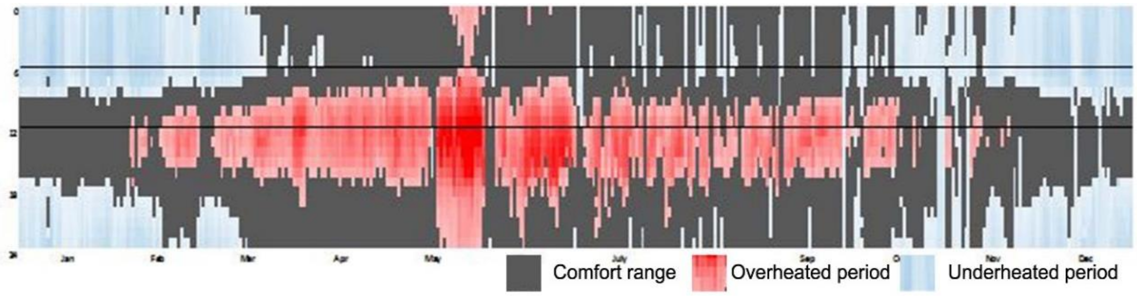

Fig. 3 Dry Bulb temperature

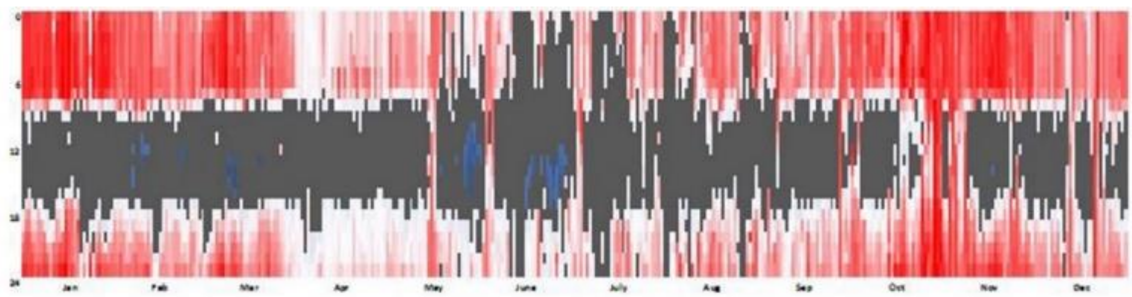

Fig. 4 Relative Humidity

The comfort range based on IMAC for Chennai is 26°C-30°C. Overheated period, i.e., more than 30°C experienced in 2741 hours from EPW file. Humidity is critical, as Chennai is in a coastal region. Relative humidity values range from 60% to 80% (fig 3). This observatory is in the Regional Meteorological Centre campus, Nungambakkam, Chennai, in Tamil Nadu, where the wind instruments are installed at 13 m above ground level.

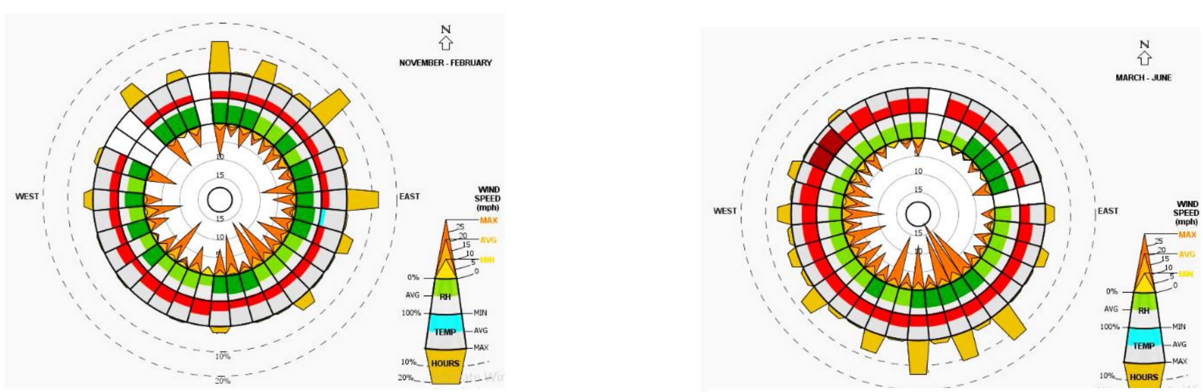

Fig. 3 Windrose

C. Building description

Residencial complex located in Chennai constructed based on TNCDBR-2019(Appendix A). The study area is an apartment complex consist of 9 residential blocks including 1 club house. The site is located next to the sithalapakkam lake, sale plots, and residential zone. Site is around 8.5km from Bay of Bengal. It consists of 2BHK,3BHK residential units, area varies from 557.00 sq. ft. - 1118.00 sq. Ft.

- Site Area: 4.8 Acres
- Height: Stilt+4 (15m)
- Plot coverage: 50%
- F.S. I - 2
- Total units: 437 units
- Setback: 3.5m-7m4.2

D. field measurement

The Measurement days are December (21,22,23) 2022.The readings were taken 1.5m above finished floor level. Outdoor windspeed measured around and between the building complexes. Windspeed was measured in corridor spaces next to the windows of all floors in all direction. Indoor windspeed measured inside residential spaces Floor 4 (block 3, west facing flat), (block 5, East facing flat), (block 5, south facing flat), (block 5, East facing flat), (block 4, between the building). Measurements are used to calibrate the software.

Instruments: Equinox hot wire anemometer with resolution of 0.01 is used to measure wind speed, Beetech BTH-600 Temperature and Humidity Meter (Psychrometer) used to measure humidity.


Fig. 5 Hot wire anemometer and psychrometer

Outdoor windspeed was measured in total 16 points from all four directions and between the buildings. Average wind speed from all direction and between the buildings is considered for analysis. Measurement was taken at the center point between compound wall (6ft height) and residential blocks or midpoint of the distance between 2 blocks.

Fig. 6 Outdoor measuring points

Corridor spaces have window sizes of 1.2m x 1.2 m. width of all the corridor spaces is 1.5 m. It has an openable upvc glass window. Measures were taken in corridor for all floors and all direction. Corridor measurements were taken to understand the windspeed variation due to height difference.

Indoor windspeed measured at 4 points in the room and average is considered for the study. Indoor and outdoor windspeed near the windows were measured during the measurement the windows are open without any mechanical ventilation. Residencial spaces consist of openable upvc glass windows.

Fig. 7 Indoor measuring point

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RESULT AND DISCUSSION

Analysis was carried out to understand the effect of orientation, height of the building and distance between them. The effect of opening on natural ventilation efficiency is studied Field measurements were cross compared with NBC standards of comfort ventilation and analyzed.

A. windspeed – direction

Measurements done in the blocks with different orientations like block5 and block4. Points in the north receiving more windspeed due to prevailing wind direction. Measured points in the west receive less windspeed, to meet comfort ventilation. The graph clearly shows that the windspeed between the buildings is less than the other direction irrespective of the prevailing wind speed.

According to comfort ventilation standards measured points in west with air temperature more than 30°C and humidity nearly 75% have insufficient windspeed for thermal comfort. This may be the result of prevailing wind direction and obstruction of the surrounding building. Measured point N in the east direction receives more windspeed due to absence of compound wall and there is no obstruction in the north direction.

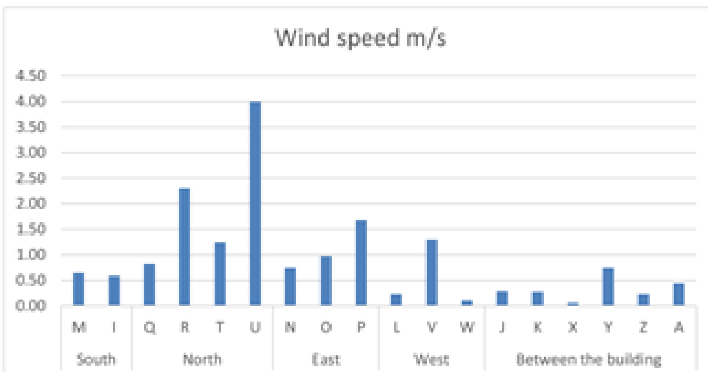

Fig. 8 Windspeed variation at different points

B. windspeed – between the buildings

Table 1 windspeed between the buildings

	Measure points	Distance	Day 2	Day 1	Day 3
Between the building	J	3.60	0.20	0.29	0.18
	K	6.00	0.10	0.28	0.09
	X	7.50	0.15	0.06	0.16
	Y	6.60	0.85	0.75	0.75
	Z	4.40	0.43	0.23	0.55
	A	7.00	0.43	0.44	0.55

Windspeed with no obstruction on four sides are comparatively higher than windspeed between the building. Table 1 values are recorded more in points Y and Z since there is no building obstructing the prevailing winds from northwest direction. Point k has less windspeed away from north winds with series of buildings. Point J has more windspeed compared with point k in contrast with distance between the buildings. Windspeed is reducing relatively based on the distance going deeper into the layout. Since point J and K have more temperature and insufficient windspeed, these points will not meet comfort standards.

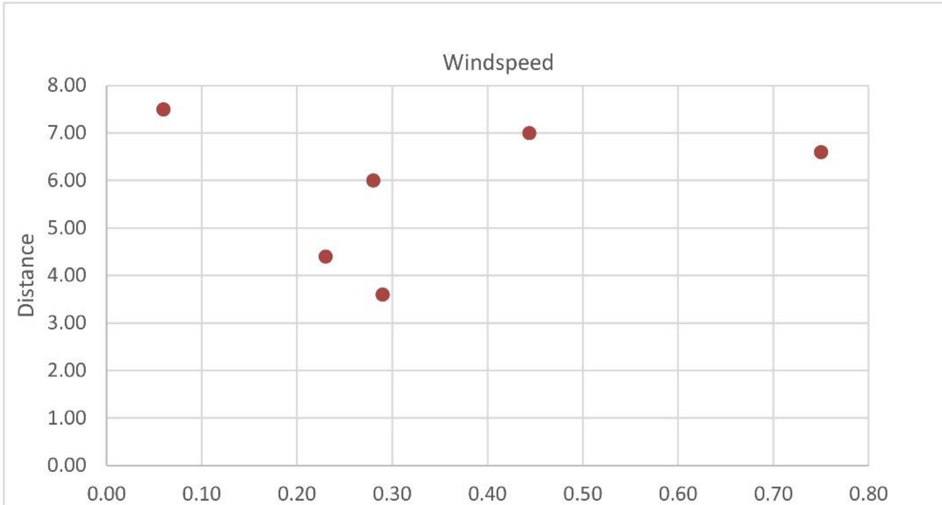

Fig. 9 windspeed and the distance between the building

C. wind speed-height

The corridor space near to the north facing window receives maximum wind speed of 7 m/s. southern side had minimum wind speed. Windspeed gradually increasing with increase in floor height. Average values of indoor and outdoor wind speed indicate the significant variation of 37%. F4 receives more wind speed may be the result of thermal or pressure difference of the wind.

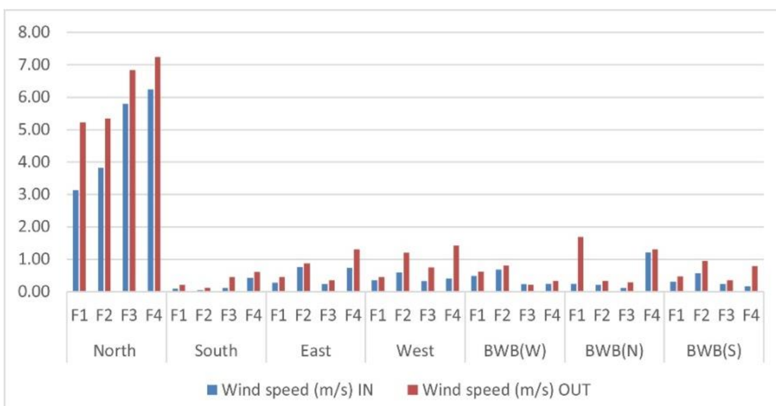

Fig. 10 Windspeed based on heights.

D. wind speed-indoor

Flat which have north faced windows receiving more windspeed. Rooms next to the balcony have more wind speed, shows the impact of WWR. North facing flat of Block 5, Kitchen and Bedroom 1 receive maximum, windspeed more than the comfort, level due to north facing windows, Toilets other bedrooms comparatively less but still meeting the standards of comfort ventilation Flat of Block 4, Located between the building have 0 wind speed South facing flat of block 5. Windspeed in bedrooms are meeting comfort ventilation standards while kitchen and living room are not.

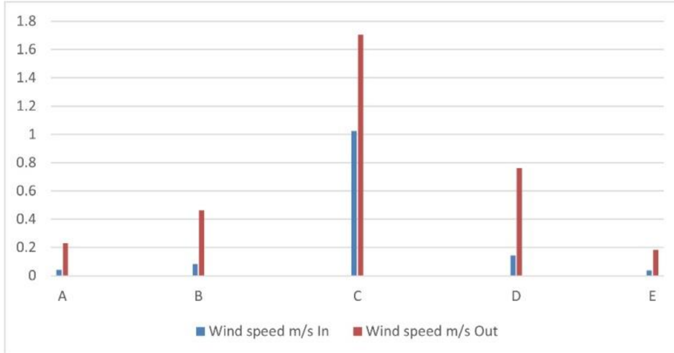

Fig. 11 indoor windspeed

CONCLUSION

In this paper the impact of the parameters like orientation, aspect ratio, WWR are studied in the non-high rise residential building in Chennai. The results indicate that the

- Orientation with respect to prevailing Wind directions has significant impact on both the outdoor and indoor wind speed.
- Minimum of 0.1 m/s recorded between the buildings shows that the Presence of surrounding building and distance between them reducing the wind speed.
- Windspeed increases with increase in height irrespective of prevailing wind directions and external obstruction.
- Size and orientation of the openings are reducing indoor wind speed of the building 50%-70%.

The values compared with the comfort ventilation standards indicate that most of the points meet the standards. However, the study depends on the measurement days of winter month. A study proved that ventilation performance was reduced by urban developments. We are planning to do the detailed studies CFD simulation soon.

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