# THERMAL COMFORT AND WIND ANALYSIS

***PR_01_GURUGRAM***

## Quality Control

| Date | Version | Revision Description | Prepared by | Approved by |
|---|---|---|---|---|
| **Dec 02, 2023** | 0 | First Draft | Aritro | Aritro & Kaushikee |
| **Dec 16, 2023** | 1 | Revised as per comments | Aritro | Aritro |

CONTENTS

## List of Figures

# 1 Introduction

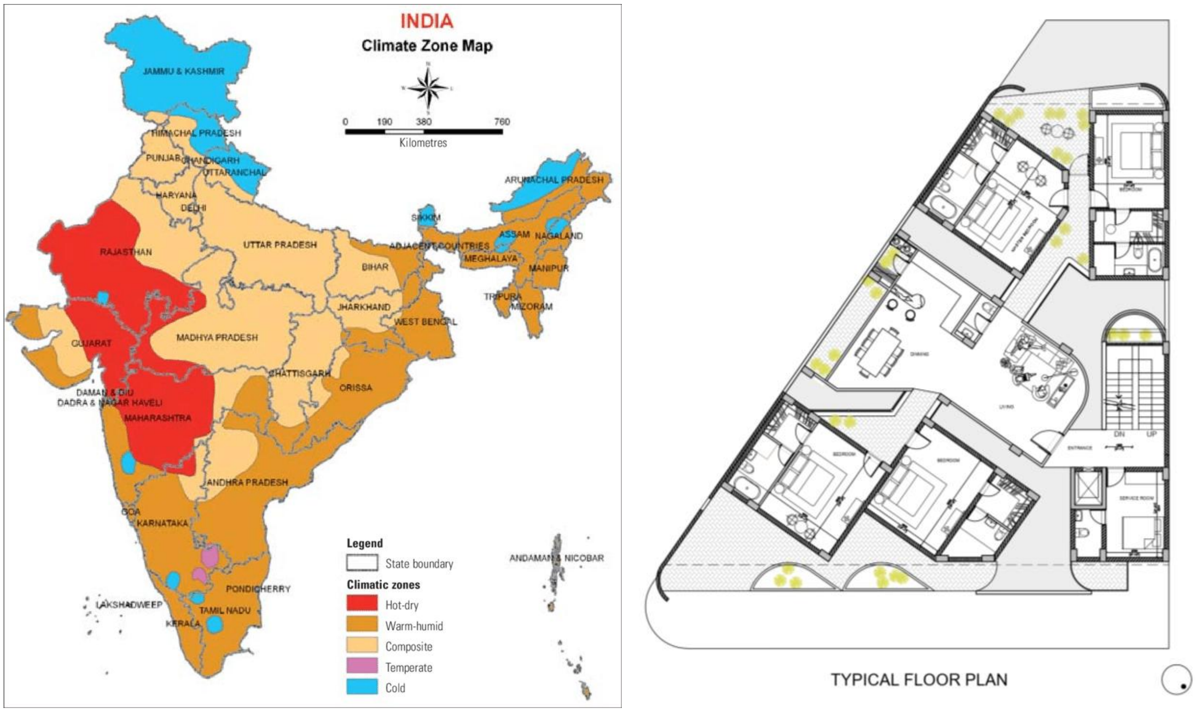



*Figure 1: (a) Climate zone of India; (b) Typical floor plan*

Gurgaon, located in the state of Haryana in India, experiences a composite climate due to its geographical location and surrounding environmental factors. Gurgaon witnesses hot and dry summers, typically lasting from March to June. During this period, temperatures can soar, with daytime temperatures often reaching or exceeding 40°C. Winters in Gurgaon are mild to severe , lasting from November to February. During this season, temperatures drop to a comfortable range, with daytime temperatures ranging from 10°C to 25°C. The transitional seasons of spring (March to April) and autumn (October to November) in Gurgaon exhibit mild temperatures. These seasons experience pleasant weather, with temperatures ranging from 20°C to 30°C.

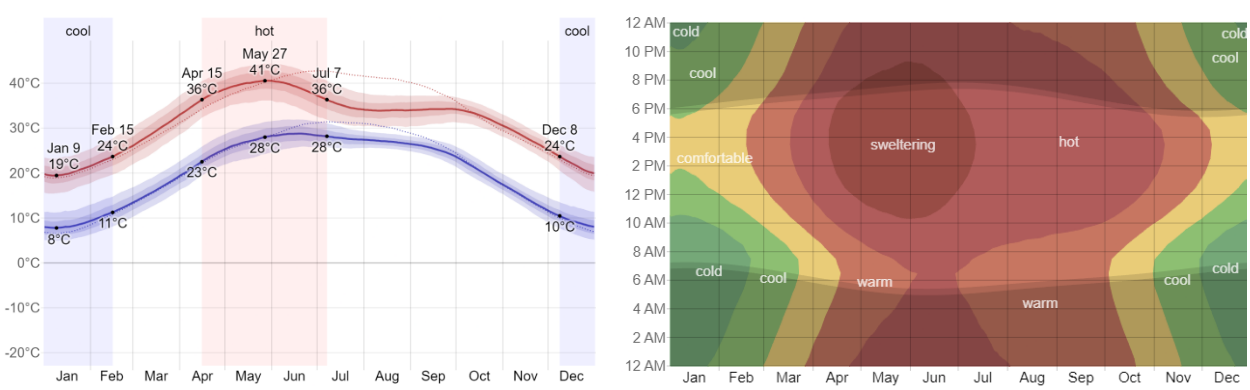



*Figure 2: (a) Temperature graph of Gurugram; (b) heat map for comfort situations*

## 1.1 Humidity

Unlike temperature, which typically varies significantly between night and day, dew point tends to change more slowly, so while the temperature may drop at night, a muggy day is typically followed by a muggy night. Gurgaon experiences extreme seasonal variation in the perceived humidity.

The muggier period of the year lasts for 4.5 months, from May 31 to October 16, during which time the comfort level is muggy, oppressive, or miserable at least 25% of the time. The month with the most muggy days in Gurgaon is August, with 30.1 days that are muggy or worse. The month with the fewest muggy days in Gurgaon is February, with 0.1 days that are muggy or worse.

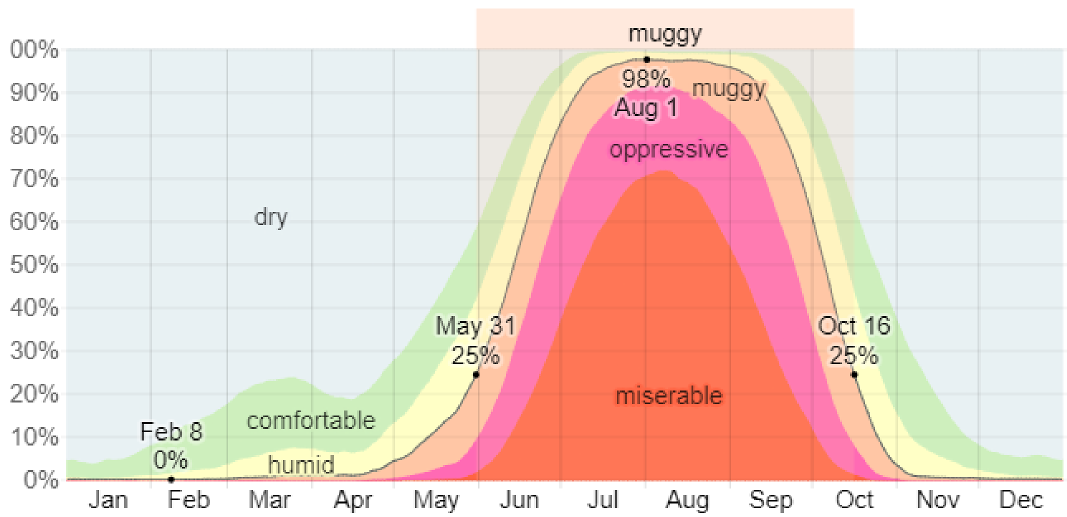



*Figure 3: Relative humidity and comfort ranges*

## 1.2 Wind Direction

The predominant average hourly wind direction in Gurgaon varies throughout the year. The wind is most often from the west for 6.0 months, from January 18 to July 18; for 1.1 months, from August 24 to September 28; and for 1.6 weeks, from November 29 to December 10, with a peak percentage of 65% on May 25. The wind is most often from the east for 1.2 months, from July 18 to August 24, with a peak percentage of 40% on July 31. The wind is most often from the north for 2.0 months, from September 28 to November 29 and for 1.3 months, from December 10 to January 18, with a peak percentage of 41% on November 4.

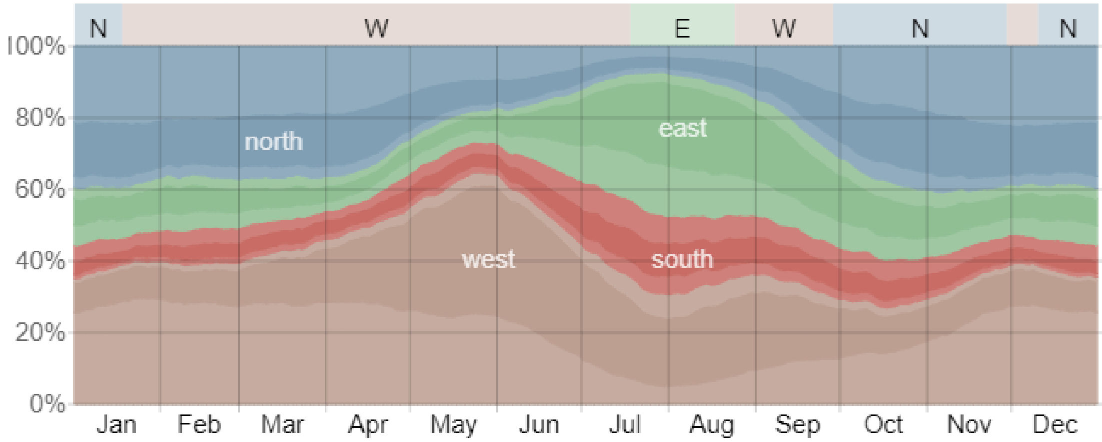



*Figure 4: Wind-flow and direction*

## 1.3 Psychometric Chart for Preliminary Comfort Analysis

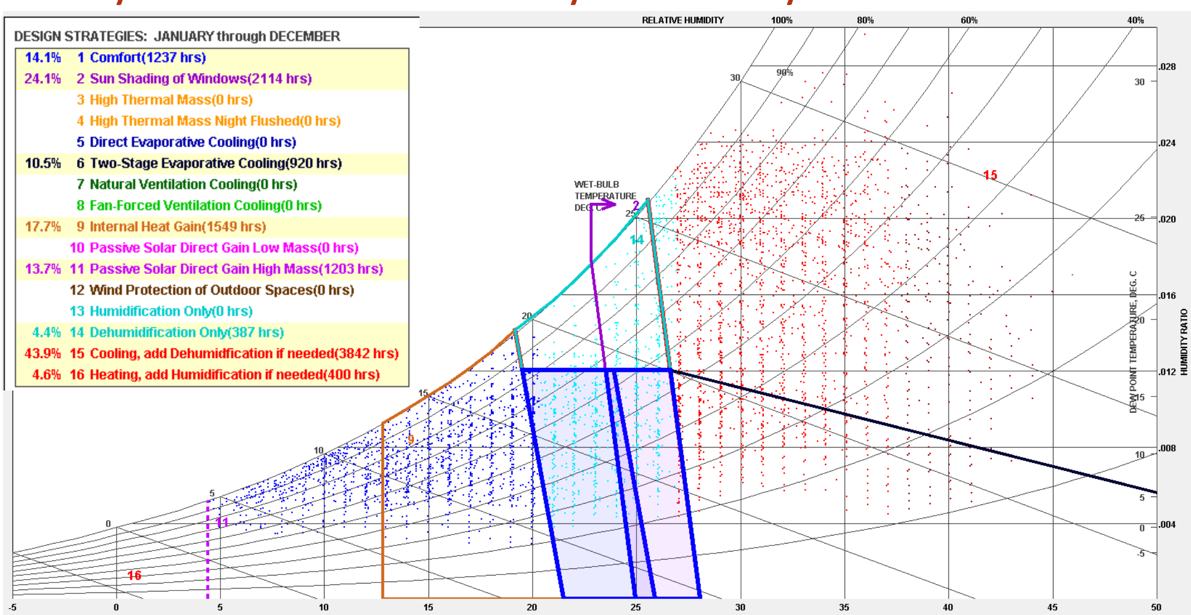
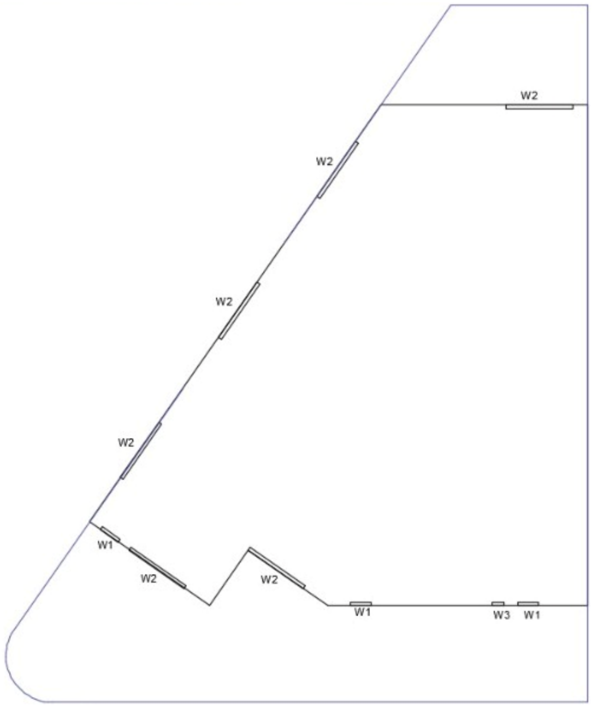



*Figure 5: Psychometric chart for preliminary comfort analysis*

# 2 Cases

## 2.1 Base case

This is the base case. Here, the block is taken as a single-zone entire mass built structure with no sunshades and balconies. It has large windows on all sides of the walls and is oriented north-up.




| WINDOW TYPE | HEIGHT | WIDTH | SILL | REMARKS |
|---|---|---|---|---|
| W1 | 1200 | 900 | 900 | |
| W2 | 3000 | 3000 | 300 | |
| W3 | 1200 | 600 | 900 | bathroom window |
| W4 | 3000 | 900 | 300 | curved window |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

*Figure 6: Base case plan with window schedule*

## 2.2 Shaft cut-outs and balconies

In this case the building is oriented as per optimum orientation and balconies as sun-shading devices are introduced. The shafts for air movement are also introduced in this case.

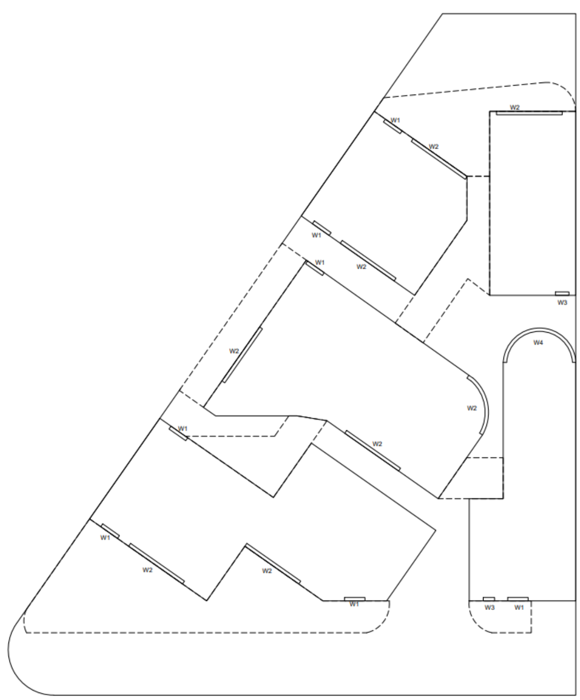


*Figure 7: Case 2 - Shaft cut-outs and balconies*

## 2.3 Skewed courtyards

This case has been modified via tapering the shafts with a narrow opening for enhanced air movement.

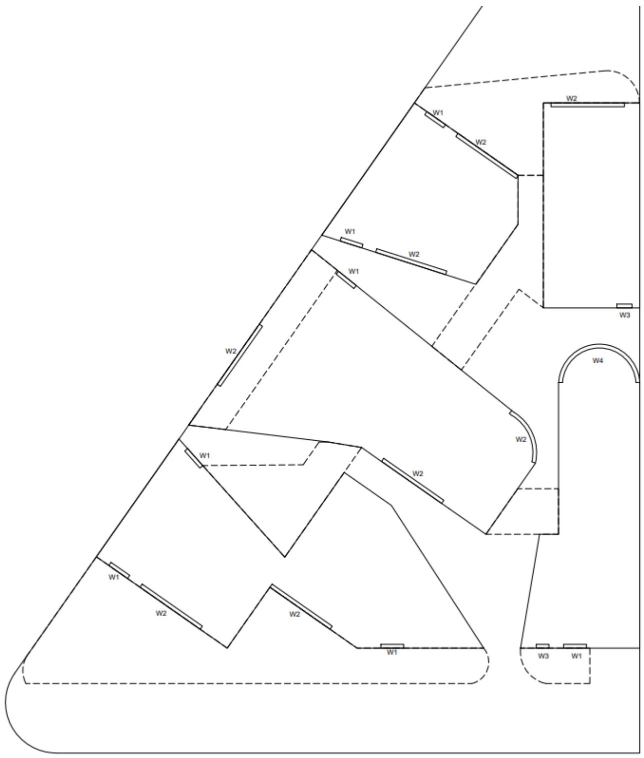



*Figure 8: Case 3 - Skewed courtyards*

## 2.4 Tapered floors

This case has been modified and analysed by tapering the floors.

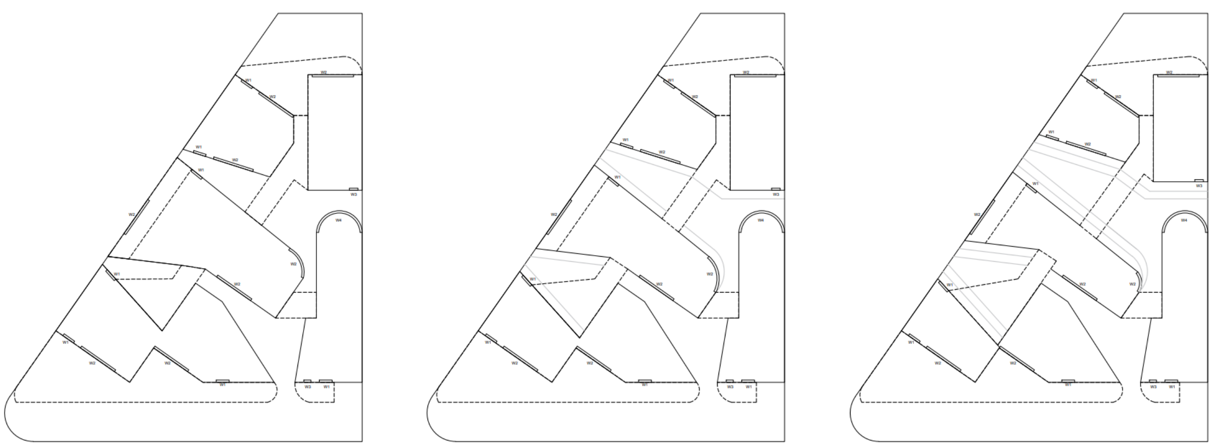


*Figure 9: Case 4 - Tapered floors*

# 3 Thermal Comfort Analysis

A thermal comfort analysis was done on these 4 cases including to analyse the occupant thermal comfort in terms of Total comfortable hours and the Degree Discomfort Hours.

## 3.1 Determining thermal comfort performance

This part outlines the procedure for calculating the DDH and Comfortable Hours.

The equation (1) uses the 30-day running mean outdoor temperature ($T_{out\text{-}30DRM}$) to calculate the neutral temperature ($T_{neut}$). The absolute difference between the calculated neutral temperature and the observed indoor operative temperature within the space at hour '*i*' is the degree of discomfort for that hour. Summation of DDH across 8760 hours yields the annual DDH. Equation (2) presents the computation of DDH.

$$T_{neut} = 0.42\ (T_{out\text{-}30DRM}) + 17.60 \tag{1}$$

$$DDH = \sum_{i=1}^{8760} |T_{neut}^{i} - T_{op}^{i}| \tag{2}$$

## 3.2 Determining comfort hours

'Comfortable hours' is defined as the number of hours the indoor operative temperature falls within the 80% acceptability range. 80% acceptability range is defined as deviation of 3.6°C around the neutral temperature ($T_{neut}$).

$$f\ (x) = |T_{nuet}^{i} - T_{op}^{i}| \tag{3}$$

$$DDH = \sum_{i=1}^{8760} C_{hours},\ where\ f(x) \leq 3.6 \tag{4}$$

## 3.3 Base case

Computing the above formula for total comfortable hours it was found out that the base case has a total of **3780 comfortable hours** of the total 8760 hours in a year.

## 3.4 Shaft cut-outs and balconies

In this case 3 rooms from the top floor was considered for thermal comfort simulation, I.e., 1 bedroom facing the north and the other facing south respectively and the common living-dining area. Here, it was observed that the 2 bedrooms had a total of **4240 and 3970 hours** comfortable, whereas the living room had **3900 hours comfortable**. The average comfortable hours for the floor comes out to be **4037 hours.**

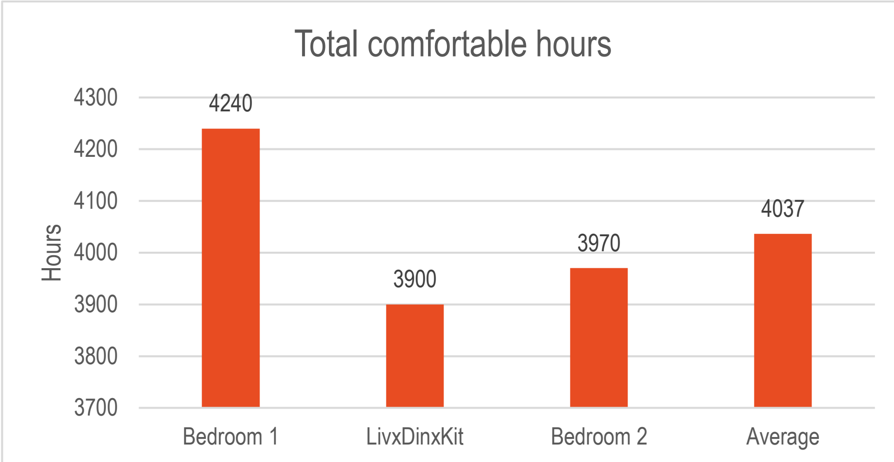



*Figure 10: Shaft cut-outs and balconies comfortable hours*

## 3.5 Skewed shafts

In this case the comfort hours for the 3 rooms were found to be **3830, 3850, and 3800 hours** respectively with an **average of 3838 hours**. There is a reduction of comfortable hours in this case due to the **presence of air-drafts**.

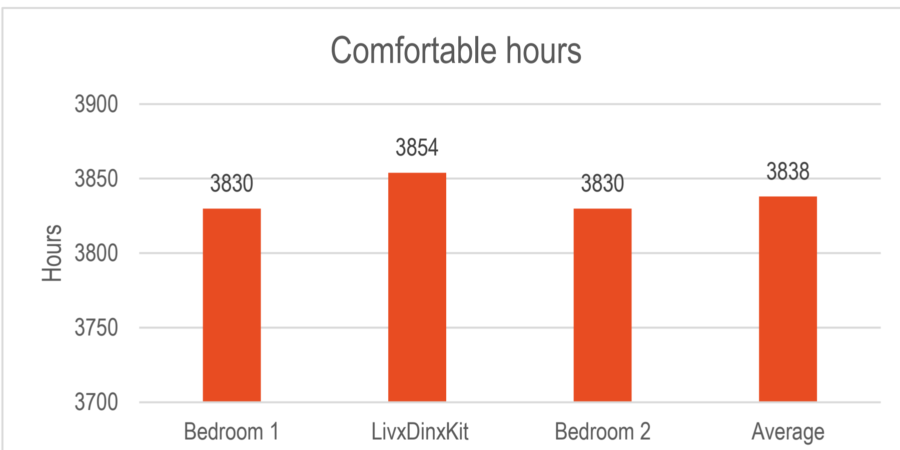



*Figure 11: Skewed shafts comfortable hours*

## 3.6 Tapered floors

In this case the comfort hours for the 3 rooms were found to be **3805, 3795, and 3822 hours** respectively with an **average of 3807 hours**. There is a reduction of comfortable hours in this case due to the **presence of air-drafts and tapering of the blocks**.

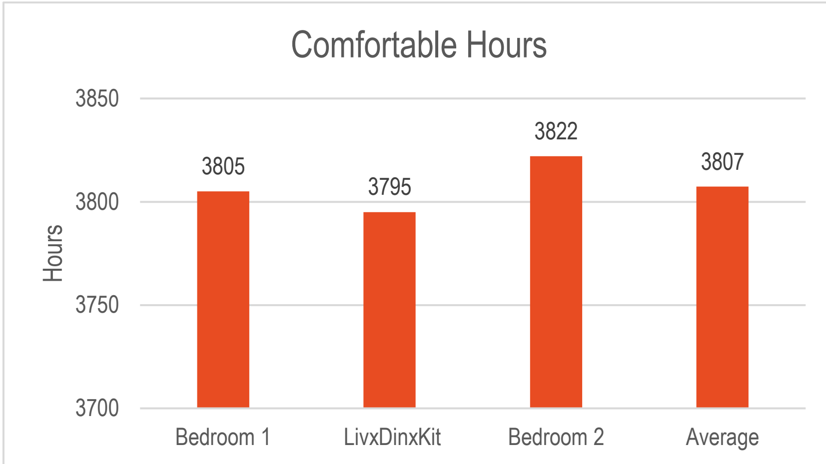



*Figure 12: Tapered floors comfortable hours*

# 4 Wind and CFD

Wind and external CFD analysis was performed to watch on the performance of the jaalis and the pockets created for wind flow.

## 4.1 Base Case

In this case the building is not aligned as per optimal orientation. The wind direction considered here is west. It is observed that the wind velocity inside the **pockets 0.5 m/s to 2.6 m/s** from bottom-top. Due to orientation, the air inside the building open areas does not reach an optimum. Here, the air velocity at stationery level is **very low and is at a range of 0.1 m/s to 0.8 m/s**.

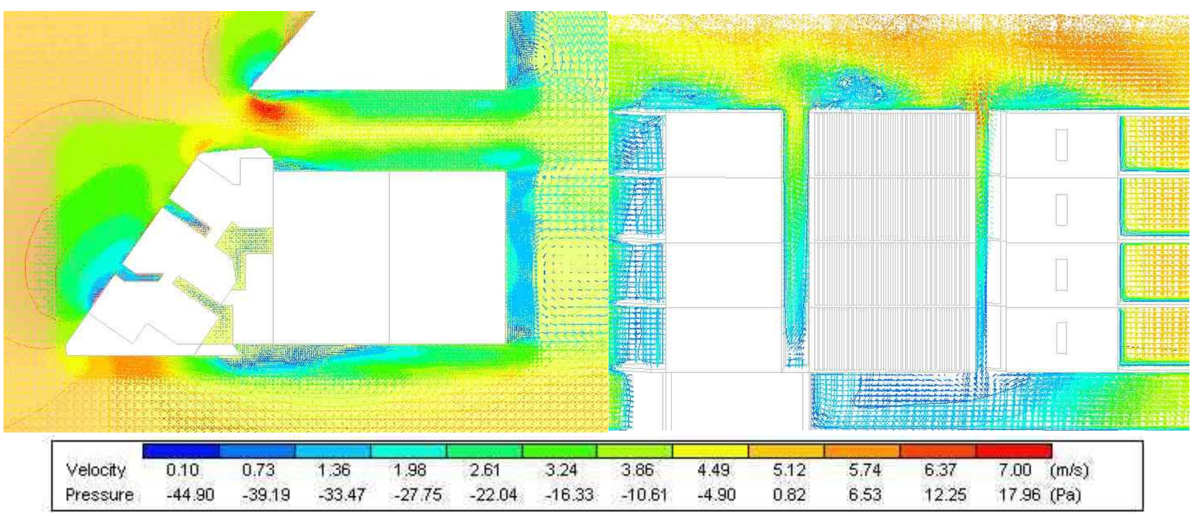



*Figure 13: Wind-flow inside the site for the base case*

## 4.2 Shaft cut-outs and balconies

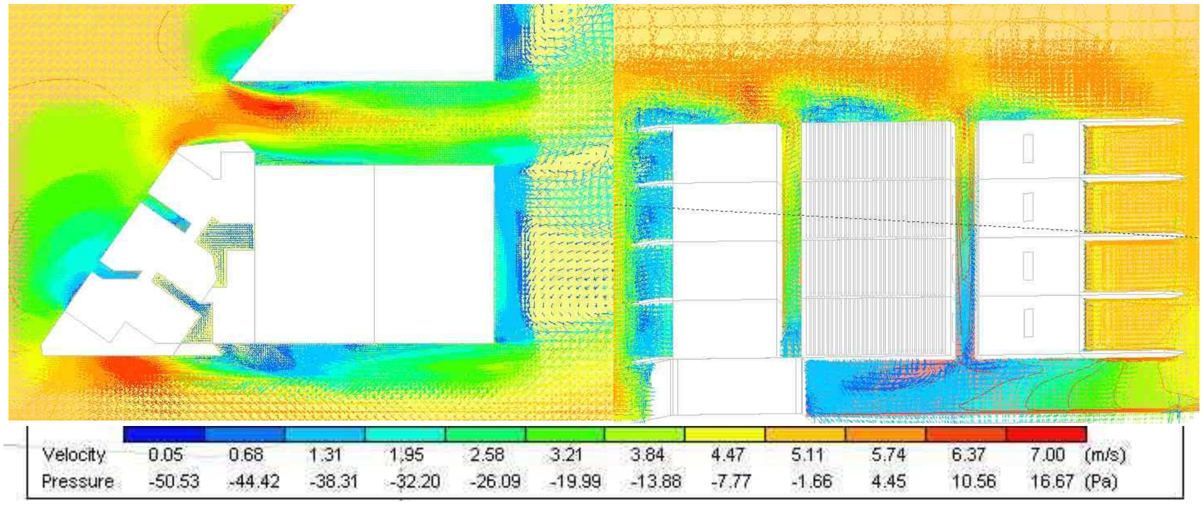



*Figure 14: Wind-flow in the site for Shaft cut-outs and balconies*

In the designed case where the orientation is kept north-south and as per the prevailing wind, it is observed that the **air in the pockets starts flowing creating a air speed range of 0.7 m/s to 3.2 m/s which is significant in providing comfort**. However, at a stationery level the air velocity is **low and ranges between 0.2 m/s to 1.5 m/s**. Below is an infographic for air flow pattern and the pressure created at points.

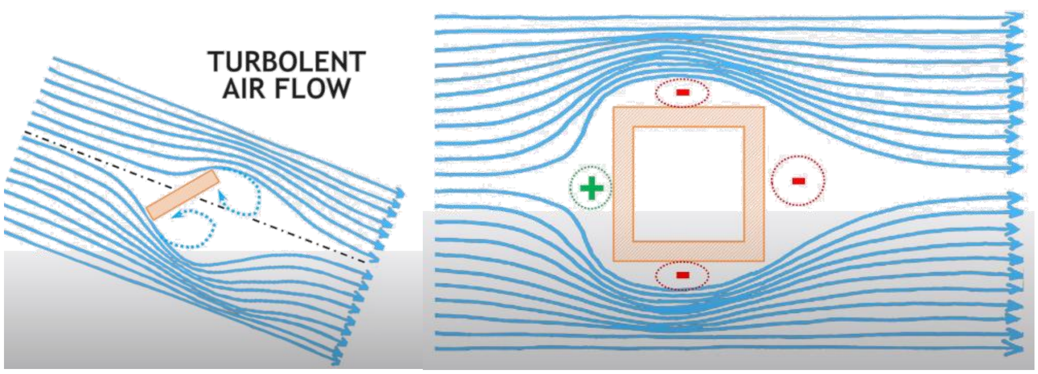



*Figure 15: Air-flow pattern and pressure at different points*

## 4.3 Skewed shafts

In this case, due to the skewing of the courtyards to create smaller apertures for air to enter and then eventually opening up inside the site improves the air flow as air velocity increases inside the site. Here, it is observed that at the stationery level the air velocity ranges between **0.3 m/s to 2.3 m/s, which is a significant rise from the previous case.** It is also found that the **movement of air inside the site has also improved due to skewing of the shafts**.

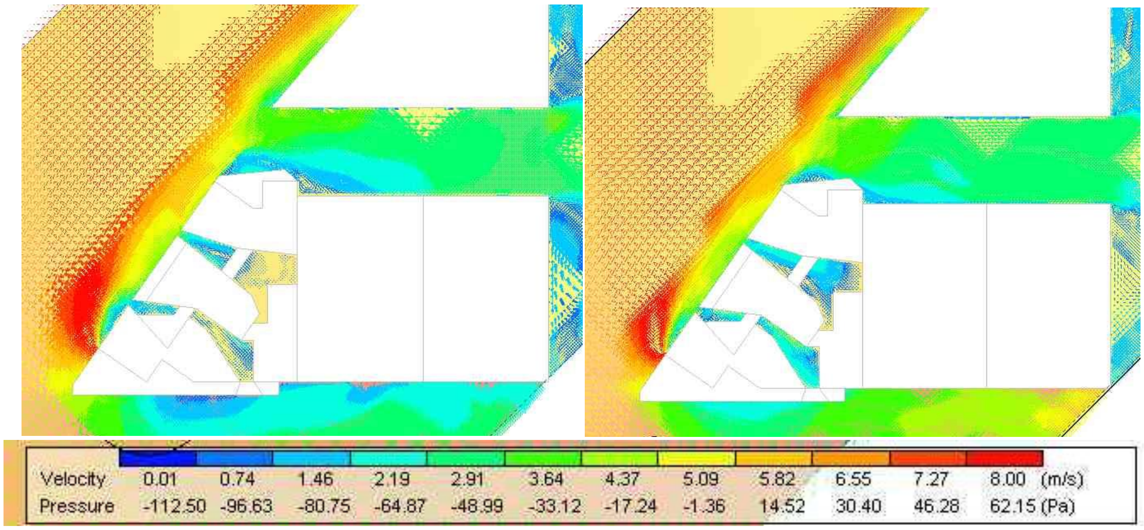



*Figure 16: Skewed shafts - (a) air velocity @6.5m level; (b) air velocity @9.5m level*

## 4.4 Tapered floors

In this case, along with skewing of the courtyards to create smaller apertures for air to enter, the upper floors were tapered back to provide more open area for air to move. Here, it is observed that at the stationery level at 9 meters the air velocity ranges between **0.8 m/s to 4.4 m/s, which is a significant rise from the previous case** as the air gets more volume to move through. It is also found that the **movement of air inside the site has also improved due to tapering of the floors**.

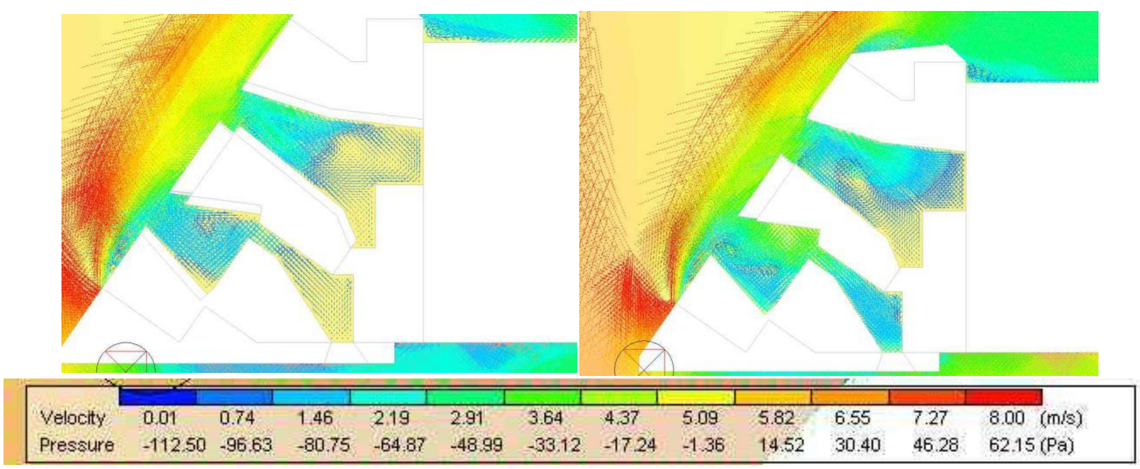



*Figure 17: Tapered floor - (a) air velocity @6.5m level; (b) air velocity @9.5m level*

# 5 Conclusion and recommendations

From all the above analysis it is observed that although the skewing and tapering helps in enhancing the air velocity in the site significantly, the air drafts created via this has slightly hampered the thermal comfort performance of the building by ~150 hours. Hence, it is suggested that case 1 with smaller shafts and balconies be utilised with reduction of window sizes to further improve thermal comfort.