Impact Of Building Height Variation on Outdoor Thermal Comfort: A Comparison of The Existing and Proposed Development in The Case of BDD Chawls, Mumbai

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Abstract- *The study compares the existing and proposed development at the BDD Chawls at Worli, Mumbai to analyze the variation in the thermal comfort level caused by these two scenarios.Envi-met was used to simulate the existing and proposed development. The thermal comfort indexes Tmrt and PET were used to understand the variation in the thermal comfort level. The effect of climatic and non-climatic parameters was observed to achieve the necessary conclusions. The variation in comfort indexes occurred due to the variation in heights and orientation of the building facades. These physical parameters define the hours of solar access, shading of the open spaces, and wind pattern, which eventually contributes to the variation in the comfort indexes. It can be said that the planning in terms of morphology can help improve the thermal comfort level in the warm and humid climate of Mumbai.*

Keywords- Warm and humid climates, thermal comfort, redevelopment, solar access, PET.

I. INTRODUCTION

Mumbai is one of the most densely populated metro cities in India with an estimated population of 12.5 million [1].This city has developed various types of formal and informal housing styles. Dwellings such as chawls are an outcome of the exponential city population [2]. Chawl is composed of a number of houses arranged in such a manner that there is a column passage in the front, having common activities such toilet and staircase. Houses are often small having a bathroom and Kitchen or kitchenette. The chawls are often multi-storied. In the case of BDD chawls, Worli, the chawls are ground and three storied high. On the contrary, the recent development saw building heights of around 300 meters in the neighborhood.

The variation in the built morphology can have varying impacts on the thermal parameters. Since, it can alter several parameters significantly such as hours of solar access, shadow pattern wind movement surface-air interactions etc. The Microclimate of a neighborhood is a complex phenomenon that needs an in-depth understanding of each element.

There are various parameters that need attention in order to understand the variation of thermal comfort caused by them. [3]studied existing built geometry at colder climates, [4]studied the effect of surface temperature whereas, [5]studies the effect of material performance. There are studies that are done at warm and humid climates in the Indian context. These studies are focused on Chennai[6]–[8] and the West Bengal region[9]. The western part of the country having a warm and humid climate is not yet explored for outdoor thermal comfort studies. Mumbai, which is one of the densely populated cities, needs to be studied. The density of built masses is the key parameter that needs to be seen since it may havea positive or negative effecton outdoor thermal comfort.

This paper compares the existing and proposed development at the BDD Chawls at Worli, Mumbai to analyze the variation in the thermal comfort level caused by these two scenarios. This is an ideal project in a way it represents the older development and modern development in the city. The existing site is a representation of the city which was seen decades ago. Whereas the proposed development is an exact representation of the current development since it corresponds to current density, building heights open spaces etc. The study is limited to the physical parameters of the site and material characteristics are not taken for the comparison.

II. MATERIALS AND METHODS

Existing site:The site selected is the existing BDD (Bombay development department) Chawls at Worli, Mumbai. 207 ground plus three-storied buildings were constructed in around

1920 spreading over 93 acres. Figure 1 shows the location of the site with an existing site and the proposed site.

Proposed development:The Maharashtra government has announced the redevelopment project. MHADA (Maharashtra Housing and Area Development Authority) [10] is the nodal agency for the redevelopment project. A total of 42 buildings will be built in two phases. In order to cut the maintenance, cost the architect has proposed a maximum height of 70 meters.

Figure 1 Site selected for the study (a) Location in Mumbai (b) Existing site (c) Proposal

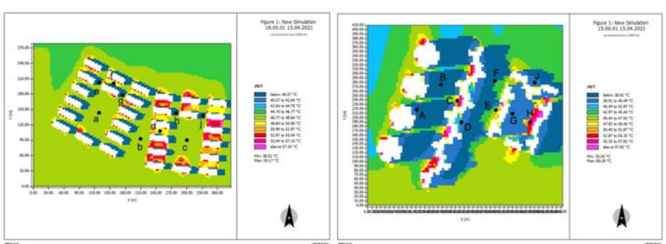

Figure 2Spatial variation at (a) Existing site (b) Proposed site

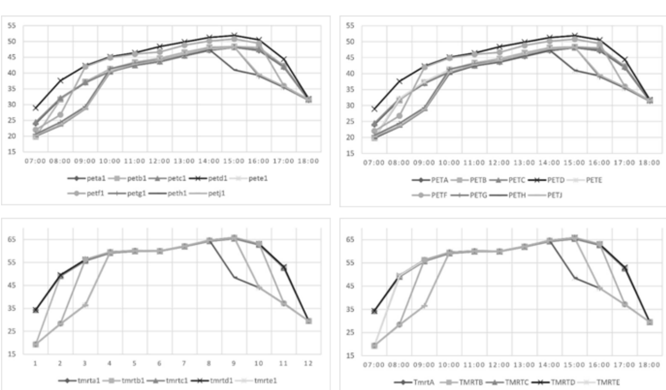

Figure 3Temporal variation (a) PET at existing site (b) PET at proposed site (c) Tmrt at existing site (d) Tmrt at proposed site

Climate of the site: Mumbai is located at Warm and humid climatic zone as per climatic zones of India [11], [12]. The city is moderately hot with a high level of humidity. The mean maximum temperature is about 32°C in summer and 30°C in winter while the average minimum is about 26°C in summer and 18°C in winter. The city also experiencing the impacts of climate change. In 2021 the state government initiated the Mumbai Climate Action Plan to tackle the increasing challenges of climate change [13].

Simulation tool: Since the microclimate at the proposed site cannot be measured manually, simulation is the useful tool for the analysis in this paper. Both the scenarios (existing site and proposed site) were simulated using the commonly used simulation software Envi-met. In this paper Envi-met 4.6.6 is used. It can simulate the non-steady state surface-plant-air interaction. It can give the output of various climatic and non-climatic parameters.

Both the scenarios were modeled with typical material properties as per Envi met database. Climatic values at the nearest weather station were used as a climatic input to the model. Simulated output was then used for further analysis.

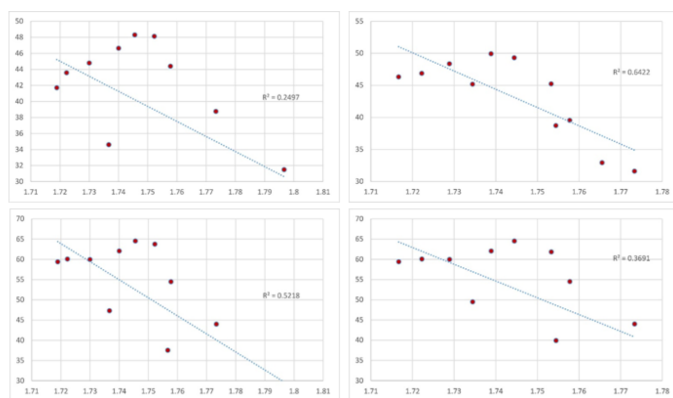

Figure 4Effect of wind on (a) Tmrt at existing site (b) PET at existing site (c) Tmrt at proposed site (d) PET at proposed site

Parameters used for the analysis:Mean radiant temperature (Tmrt)- It is defined as the uniform temperature of an imaginary enclosure in which the radiant heat transfer from the human body equals the radiant heat transfer in the actual non uniform enclosure [14]. Several previous studies [15]–[17] have used Tmrt for the evaluation of thermal comfort level. Along with Tmrt, Physiological equivalent temperature (PET) is the common used thermal comfort index. Several studies [18], [19] used PET.

III. RESULTS AND DISCUSSION

Average variation in thermal comfort: Figure shows the variation of PET. Higher PET observed near the buildings than the open space shows that the effect of built surfaces and reflected radiation is a possible cause.The effect of height also can be seen prominently. In the case of the proposed site higher PET is observed near to the built surfaces. The difference was also observed between shaded and un-shaded areas. The PET at shaded areas is significantly lower which suggests the need for maximizing the shaded areas.

The highest PET is observed at location d ofthe existing site and at location D ofthe proposed site. The lowest PET is observed at location h of the existing site and location H of the proposed site. The average PET difference at the existing site is 7.44°C and at the proposed site is 7.52°C. During peak hours the difference is 11.26°C and 11.23°C respectively. It is noteworthy to observe that certain locations from both scenarios showed a lower PET during the morning and the late afternoon hours and showed a high PET during noon. The highest and lowest values of Tmrtwere observed at similar locations as in the case of PET. The average Tmrt difference at the existing site is 9.07°C and at the proposed site is 9.04°C. In both scenarios the variation of Tmrtbetween 10 am to 2 pm is negligible.

The variation in comfort indexes occurred due to the variation in heights and orientation of the building facades. These physical parameters define the hours of solar access, shading of the open spaces, and wind pattern, which eventually contributes to the variation in the comfort indexes.

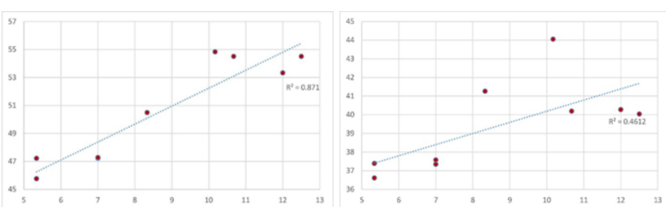

Figure 5 Effect of hours of solar access on (a) TMRT (b) PET

Effect of wind on thermal variation: Figure 4 shows the Linear regression (R2) between wind speed (Va) and thermal parameters. The relationship between Va and PET at existing site is poor to moderate negative (R2= 0.25) whereas good negative relationship c is observed for the proposed site.A moderate relationship is observed between Va and Tmrtat both the scenarios (R2= 0.52) for the existing site. and R2= 0.37 for the proposed site).The effect of Va on PET is prominently seen in previous studies. The higher correlation is the result of the regulated wind pattern due to the higher built masses than the existing scenario. It can be said that the planning in terms of morphology can help improve the thermal comfort level in the warm and humid climate of Mumbai.

Solar access on thermal comfort: The linear regression between hours of solar access and Tmrt is shown in Figure 5. The effect of hours of solar access on Tmrt(R2= 0.87) is stronger than the effect on PET (R2= 0.46). It shows that the effect of direct solar radiation is prominent on Tmrt. The consideration in design should be taken to increase the shading hours at the outdoor space in order to reduce Tmrt and improve thermal comfort level. Maximizing the building heights and orientating the buildings in such a way that the shade for an open space should be increased and hours of solar access should be decreased.

IV. CONCLUSION

This paper compares the existing and proposed development at the BDD Chawls at Worli, Mumbai to analyze the variation in the thermal comfort level. Envi-met simulation tool was used to obtain the results from both the scenarios which were then compared. Results showed that the change in the morphological character can significantly vary the level of thermal comfort in an outdoor space.

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