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Impact of Building by-laws on microclimatic elements of residential building layouts. Case Nagpur

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Abstract: *This paper tries to address the parameters that affect the microclimate in residential building layouts. The experiment tries to investigate the effect of radiation and wind in residential building layouts of urban areas of Nagpur. The findings of this research reveal that microclimatic parameters are influenced by buildings and building layouts which highlight the need for consideration of climate and microclimate while designing and formulating building by laws of residential building layouts.*
Keywords: *Microclimate, building by-laws, Residential building layouts.*

I. Introduction

In last few years microclimate of city areas has got altered due to manmade surfaces and construction. Increase in number of surfaces due to presence of building and its interface with climatic elements like radiation, wind and other surrounding conditions create microclimate of a place. Building acts as a heat generator and cause for temperature rise, due to its presence. Number of buildings coming together creates microclimatic pockets in city areas. The microclimate created due to presence of buildings thus influences heat gain and heat loss process of buildings. Residential buildings layouts of mid and low rise buildings and its parameters are resultant of development control regulations.

Literature study reveals study on significant effect on climate due to existence of built up mass and atmospheric layer. Every urban area has its own microclimate which is subset of Urban Boundary Layer (UBL). The complete UBL is defined as entire volume of the air above the city that is influenced by its surface characteristics and the activities within it UBL grows in height I as the air passes over the built up terrain. (Evyatar ErelL, 2011)It generally extends upward to about ten times the height of the building and also extends beyond the urban area. Various atmospheric layers such as mixed layer roughness sub layer, urban canopy layer are classified with hierarchy below UBL. Within these layers the atmosphere is influenced by the presence of the urban surface. Urban canopy layer extends from ground level to the height of buildings, trees and other objects. Due to the inherent heterogeneity of the UCL, a unique microclimate is established within any given urban space, with air temperature, wind flow, radiation balance and other climatic indicators being determined by the physical nature of the immediate surrounding as well as by the regional environment. (Evyatar ErelL, 2011) Fabric of building and open spaces in terms density and other physical properties that influence the micro scale climate. Microclimates in building layouts are mainly get affected by solar radiation in building layout, Wind and vegetation. (G. Z. Brown, 2001)

Building layouts get developed as per development control regulations (Building by-laws) of city. Development Control Regulations (DCR) specifies plot sizes, margins, height and open spaces and road width which is outcome of Statutory process of master plan formulation in India inspired by the erstwhile comprehensive planning system envisaged under the Town and Country Planning Act, 1947 of United Kingdom. (J.Kshirsagar, 2014) A building in tropics is confrontation of construction and function with intense climatic condition. Tropical climate regions are characterized with high humidity, excessive rainfall and considerable sunshine. Typical features of tropical climate have the negative as well as and positive impact on the building design. The climate causes extreme impact through its climatic parameters such as temperature, solar radiation, relative humidity, rainfall and wind. It is ideal medium state for rich of tropical plants and rainforest. A successful indoor environment much depends on the understanding of the environmental factors, including building design and setting. (Yeang, 2006). However, Experimental study of residential building layouts to identify the effect of development control regulations on creation of microclimate is not found in the literature. The experiments carried out in the residential city areas to learn the microclimate and its variation in residential building layouts of Nagpur city. Wind and radiation being important microclimatic parameters, the primary objectives of this experimental investigation are

- To Identify the air flow within residential building layouts
- To identify radiation in the residential building layouts

- To understand the impact of development control regulations on microclimate in residential building layouts.
- To check the applicability of existing development control regulations for climate responsive building layouts.

II. Experimental framework

The experiments were carried out for congested and non congested residential layouts of Nagpur city. Two layouts from congested and four from non congested zones were selected. Selection of layout was based on variation of pot size, and orientation.(Fig.1) All the layouts include plot sizes of 125 Sq.m to 500 Sq.m. plots with change in orientation as East –West, North – south. After studying all the layouts research scholar formulated a base model for experimentation. Four types of plots were selected based on layout study and building by laws study for experiments. Height to width ratio of open spaces were found out for 125 Sq.m., 240 Sq.m., 300 Sq.m., 500 Sqm plots.(Fig.2) Building parameters were fixed for all pot sizes. Height of plinth is 1m, height of floor 3m. Roof of building is considered as flat roof as it is commonly found in the city. Microclimatic variables for experimentation were Radiation and wind. Vegetation was not calculated in the experiment as presence of vegetation is not constant and cannot be generalized. Experiment was carried out for critical months throughout the year i.e. for May as extreme hot, July for rainy season and December for cold month. Morning 9Am to 5 Pm was time period for calculations.

Fig. 1 – Building layout and types of canyon spaces

Method of experiment

Radiation and wind calculations were done with theoretical methods and with simulation experiments. Two software were used for simulation. Radiation simulation was carried out with Ecotect software.(Fig.4) Ecotect can carry out radiation thermal, dayighting and acoustical analysis. In case of incident solar radiation on surfaces and points within models. Solar radiation calculation uses hourly recorded direct and diffused radiation data from weather file. Wind simulation is done with flow design. It is virtual wind tunnel for visualizing airflow around building. (Broekhuizen, 2016)

III. Data analysis

3.1 Radiation analysis

Simulation readings for four types of plot sizes and height to width ratio of open spaces in layouts were analyzed to obtain the total amount of radiation and microclimatic information in building layouts. All plots were found rectangular in shape. Smaller side of plot faces approach road and longer sides are facing adjacent build was observed that total radiation on building for east west orientation is less as compared to North south orientation in all plot sizes layouts

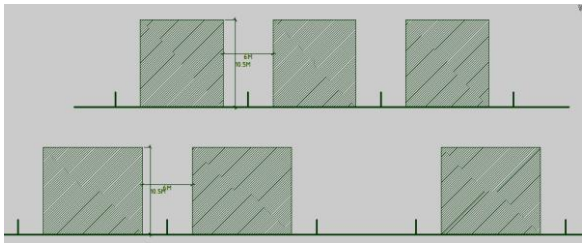

Fig. 2 – Building canyons & H/W ratio

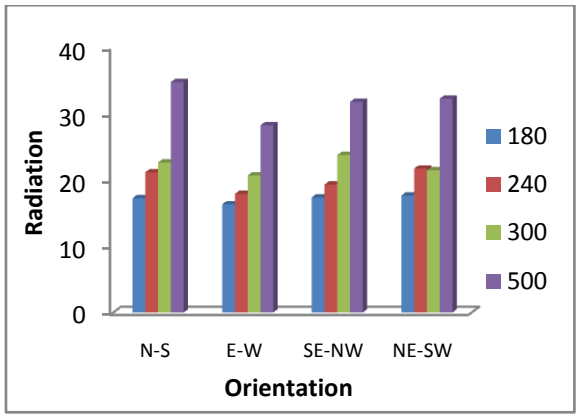

Fig.3 - Total radiation in four orientations

Of congested and non congested zones. Maximum radiation was found on east and west face of the building (Fig.3). The figure shows readings of orientations with change in various plot sizes. In East –West orientation building had longer faces from east to west. In North – South orientation more surface area is approximate normal to east and west which increases direct, diffused and reflected radiation between two structures increasing temperature in layout canyons. When analysis was done on height to width ratio of canyons and total amount of radiation received it was found that shaded area increases on larger faces of structure with increase in height to width ratio. (Fig. 5,6,7,8) To check whether there is any correlation or association between Shaded area on walls and height to width ratio, here Karl Pearson correlation coefficient was found out. Calculated value is found to be r =0.8 which shows positive relationship between the variables. This eventually reduces radiation on building surfaces and also helps to reduce hot air pockets in canyons. It is also observed that in case of north south orientation more height to width ratio keep canyon spaces relatively cooler. Increase

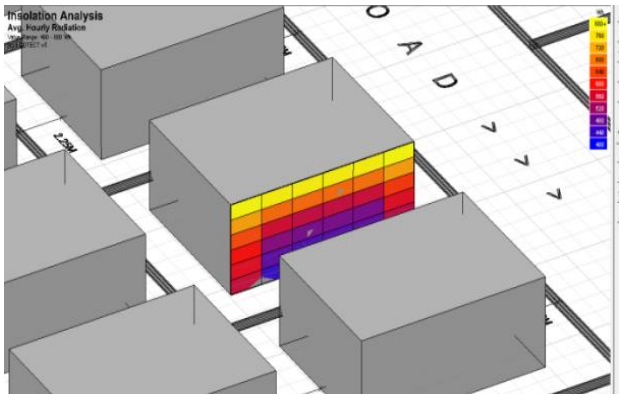

Fig. 4 – Radiation simulation with Ecotect

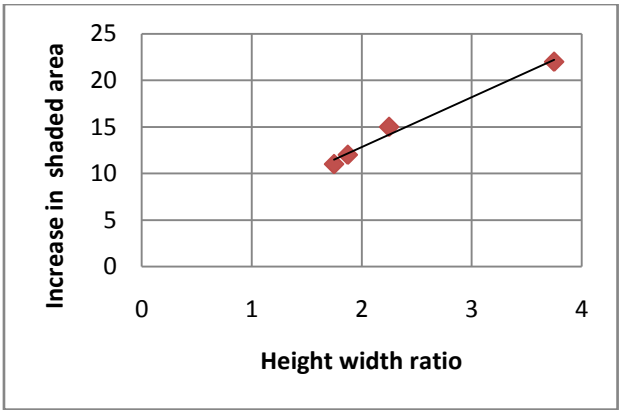

Fig 5. Congested zone – N-S orientation

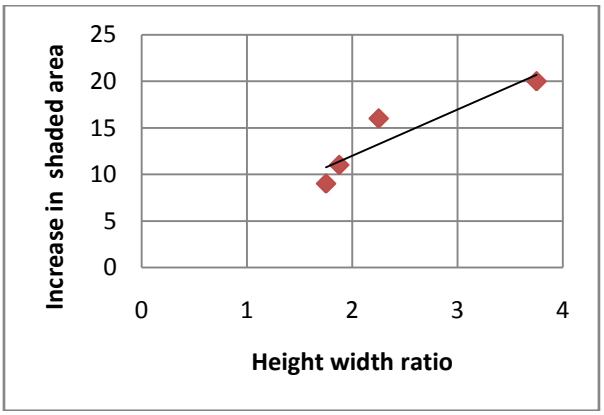

Fig 6. Congested zone – E-W orientation

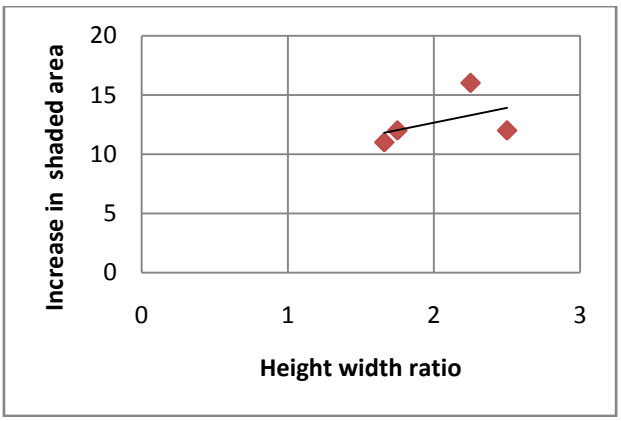

Fig 7. Non congested zone – N-S orientation

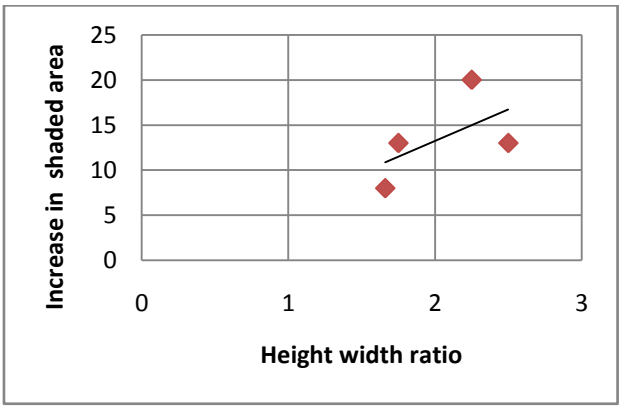

Fig 8. Non congested zone–E-W orientation

3.2 Wind analysis

Wind speed analysis

Wind was calculated for two parameters. One was ventilation effectiveness and second was wind speed in canyons. To check whether there is any correlation or association between wind speed and height to width ratio, here Karl Pearson correlation coefficient was found out. Calculated value is found to be r =-0.8 which shows negative relationship between the variables. It was observed wind velocity reduce with increase in height to width ratio in both congested, non congested zones in all identified cases (Fig.9, 10,11). This facilitates less convective heat gain during summer. As air temperature and wind speed in summer at Nagpur are very high. Surface contact with air amplifies heat gain of building as well as canyon temperature in shade. During monsoon drop in wind speed reduces possibility of ventilation in canyons and during winter reduction of wind speed minimizes heat loss. Wind speed available in all the existing cases of height to width ratio is less than 1.5m/s proving least chance for ventilation during monsoon when it is required. This gives advantage in summer and winter.

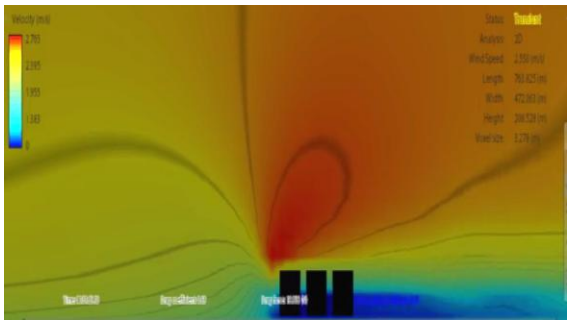

Fig 9 – Wind simulation with Flow design

All the side open spaces between buildings of buildings comes under skimming flow regime providing less than 1% wind effectiveness in canyons. Skimming flow regime doesn't provide any opportunity of ventilation on building faces and hence minimizing possibility of wind or ventilation inside the structure. With increase in height to width ratio ventilation effectiveness reduces. This situation is advantageous in summer as high temperature air reduces thermal comfort. During winters also this situation is favorable but create problem for ventilation during monsoon.

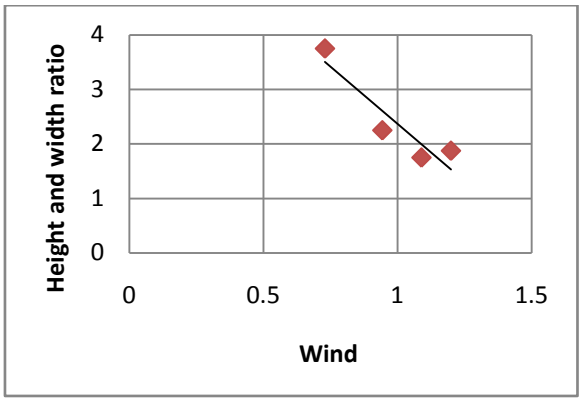

Fig 10. Wind speed – Non congested

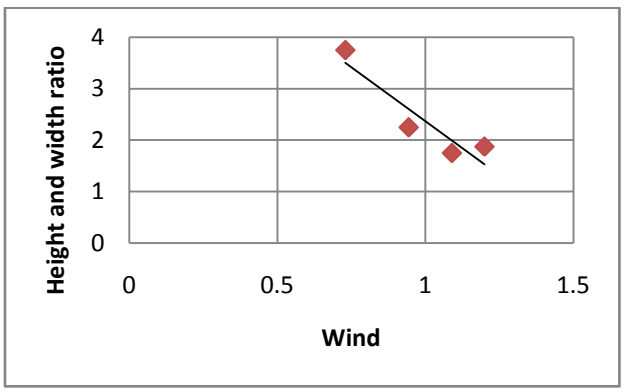

Fig 11. Congested – Wind speed

IV. Result and discussion

Thermal comfort requirement of Nagpur. , In such a climate, it is imperative to control solar radiation and movement of hot winds, resist heat gain in summer and Resist heat loss in winter, Decrease exposed surface area, Increase thermal resistance, promote heat loss in summer/ monsoon, increase air exchange rate (Ventilation) in monsoon. The design criteria should therefore aim at resisting heat gain by providing shading, reducing exposed area, controlling and scheduling ventilation, and increasing thermal capacity. The presence of water bodies is desirable as they can help increase the humidity, thereby leading to lower air temperatures. The ground and surrounding objects emit a lot of heat in the afternoons and evenings. As far as possible, this heat should be avoided by appropriate design features. Maximizing cross ventilation is desirable in the monsoon period. Use of Courtyards/ wind towers/ arrangement of opening is desirable. (J.K. Nayak, 2006)

In existing condition of building layouts, as per development control regulations, the building remain expose to the surrounding from all four sides. In such cases each building is prone to receive radiation and heat from all sides increasing the heat gain. Space available on plot as per building by laws does not allow courtyard design due to space constraints. This minimizes possibility of shading with available plot sizes after deduction of margins, space available and eliminates chances of cross ventilation during monsoon.

V. Conclusion

Study of residential building layouts of Nagpur city for low rise buildings is presented in this paper. The experimental measurements are for solar radiation, wind speed, and ventilation effectiveness. The experiment and its outcomes have demonstrated that

1. Building layouts are responsible for change in microclimate from one location to another
2. Increase in height to width ratio of open spaces between buildings increases shading in canyons on building surfaces.
3. Increase in height to width ratio of open spaces reduces radiation on building surfaces reducing the heat gain
4. Building by laws and open space requirements are responsible for heat gain from all sides of building.
5. Findings suggest that there is a need for appropriate consideration for reduction on radiation of building facades and appropriate ventilation during monsoon while formulating building by laws. Study shows that both the requirements are not fulfilled.

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