SIMULATION MODELING TO INVESTIGATE THE EFFECT OF NEIGHBORHOOD BUILDING CONFIGURATION ON BUILDING HEAT GAIN. CASE –NAGPUR.

1st Author (Prof. Komal A. Thakur) 2nd Author (Prof. A. J. Sanyal)

Abstract:

The paper tries to address the effect of neighborhood geometry and building configurations on building heat gain. The simulation modeling is used to find the effect of change in building configuration and results are presented in form of comparative analysis. The simulation models are developed with references of the study of previous researches on microclimate and neighborhood geometry. The findings reveal that due consideration is required while planning neighborhood building configuration.

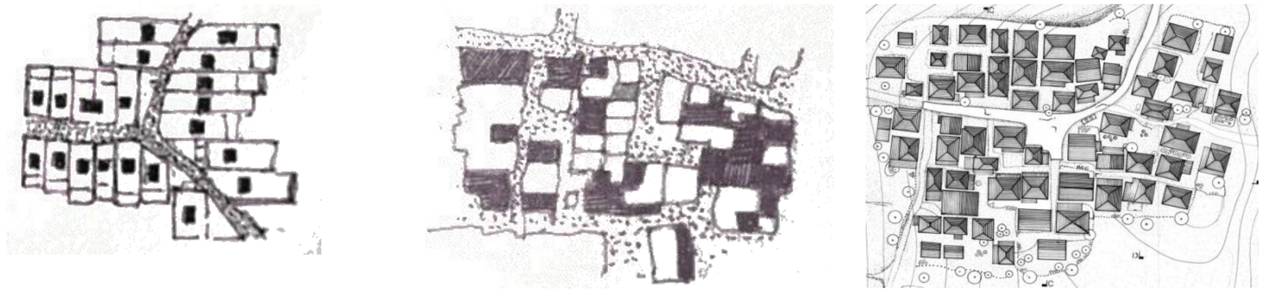
Key Words: Neighborhood geometry, building heat gain

1. Introduction

India is urbanizing rapidly. In 2010, about 31% of India's population was residing in urban areas and this is expected to increase to 50% by 2050, adding 441 million to the urban population. (United Nations department of economics and social affairs, 2014) Projections based on 2011 census data indicate that the number of urban households is expected to double by 2032. (Greentech Knowledge solutions, 2011) Population increase, economic development, and urbanization are resulting in an increased demand for constructed built-up area. It is estimated that India would potentially have to build 700–900 million Sq.m. of residential and commercial spaces in the urban areas every year for the next 20 years. (Mckinsey Global Institute, April 2010) Residential buildings accounted for 20.4% of India's total electricity consumption, and the electricity consumption in residential buildings is about 2.3 times more than that for commercial buildings. Projections done by the Planning Commission show that the electricity consumption in residential buildings is expected to increase seven-fold during the period 2012 to 2032, and the residential sector will become the largest consumer of electricity in the country with a 36.5% share of the total electricity consumed in 2032. (Planning commision, 2012)

Electricity consumption of residential building is directly related to electrical equipments and mechanical devices used. The analysis of electrical consumption time series data (2006—2013) from one of the residential complexes in Delhi indicates that the electricity consumption for space cooling is more than double when shifting from a situation where space cooling is predominantly met by desert cooler situations and the space where space cooling is met by room air conditioners. It is to be anticipated that better thermal comfort is an aspirational trend and this leads to a greater demand for installing air conditioning systems. Detail analysis of electricity consumption in three sample flats shows that the contribution off electricity consumption of space increases with increase use of air conditioners and vary from 33% to 65% (BEE, 2014). Need for cooling in the building is a result of thermal discomfort which is outcome of heat gain in the building from the surrounding. Heat gain and heat loss of building is majorly governed by the orientation, plan form, etc and envelope of the building coming in contact with the surrounding and climatic elements. The heat dissipation of building creates heat pockets and is responsible for increase in temperature in urban areas.

The configuration of neighborhood in today's context is found to be the same in all cities of India. If considered for low rise residential neighborhood, it does not show any significant change in configuration with respect to different climatic regions. Whereas the climate responsive design guidelines for planning and rural settlement in pre independent India were found to be region specific.



Jaisalmer settlement Panjab village Daman village

Fig (1.1) showing rural settlements of pre independent India. Source: *CEPT project folio*

It reflected culture and considerations of climatic aspects of that region. Fig (1.1) shows different regional settlements. This pattern was seen to be change after independence. Urbanization took place at fast pace. Town panning act implemented and development control regulations were formulated for development of cities as need of hour. Since then residential buildings neighborhood of mid and low rise buildings and its parameters are resultant of building by laws. Building by laws specifies margins, height and open spaces, road width etc. in the layouts which defines the canyon aspect ratio (Height to width ratio of open space between buildings). it is found that the exposure of urban street canyon to solar irradiation, which is mainly controlled by its height to width ratios (H/w) and orientations, can have a profound impact on the thermal and mass exchange between the canyon facets and the canyon air volume (Nunez and Oke 1977). As a result, this has been found to have a great influence on both the outdoor and indoor microclimate conditions (Ali-Toudert and Mayer 2006). Building acts as a heat generator and cause for temperature rise, due to its presence. Number of buildings coming together in particular manner creates heat pockets in city areas. The research tries to question that can change in present building configuration at neighborhood level can reduce building heat gain. What should be the building configuration to reduce the heat gain? The case of Nagpur city in composite climate region is taken under the study. The aspect ratio of canons and so the building surfaces exposure to surrounding is taken as focus in changing the configuration and understanding its impact on heat gain.

1.1 Geometric descriptors in neighborhood geometry.

The geometric descriptors stated by Oke with respect to the urban canyons are the height to width ratio (H/W - Aspect ratio), the canyon axis orientation - the closest cardinal direction and the Sky view factor (SVF). The Urban canyon refers to linear space such as street which is bounded on both sides by vertical elements such as walls of adjacent buildings. Nunez & Oke (1976) *Source: Oke (2002) & Erell et al. (2011)*

Urban geometry plays an important role in determining the environmental condition within the lower layer of urban atmosphere – the so called UCL (Oke, 1988) (Arnfield, 2003). Hence, any Alteration in the condition of this lower layer of urban atmosphere caused by the changing in urban geometry can have direct influences on the human well-being and comfort, whether indoors or outdoors. Thus, considerable amount of research effort has been dedicated to assess the environmental behavior of urban geometries over a number of urban settings (e.g. Lobo ;Golany 1996; Pinho et al. 2003; Santamouris 2006). Nevertheless, a representative urban geometry is quite impossible to find if all modifying parameters have to be considered including, archetypal building form, urban degree of compactness, street aspect ratio, and orientation. (Martin, 1972.)have introduced simplified archetypal building forms in order to limit the complexities found in real urban textures and to examine and compare the impact of geometry alone. In their study, they have classified buildings into three basic types, that is; the Pavilion, the Street and the Court, Figure (1.2).

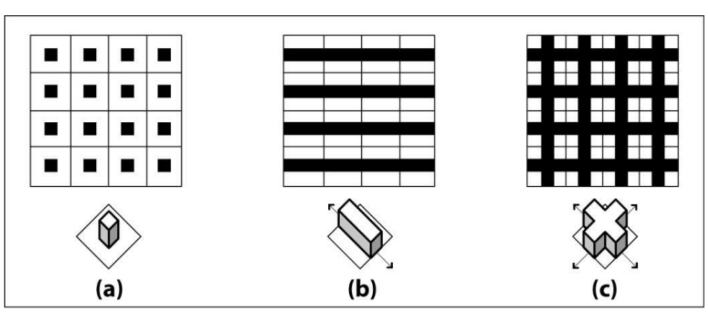


Fig. (1.2) Three archetypal urban form and patterns introduced by Martin and March (1972) including pavilion (a) Street (b), and court(c).

Source Martin and March, 1972

Many other researchers to utilize these forms in number of studies related to urban design and environmental performance (e.g. Gupta 1984, 1987; Ratti et al. 2003). Based n the above aspects the approach for the formation of hypothetical model has been decided.

2. Experimental framework

2.1 Approach in formation of hypothetical building configurations.

As study is oriented towards evaluating effect of building configurations on heat gain, researcher has proposed various building configurations as per typical urban form being used for which utilized typologies are adopted from Martin and March (1972) who carried out a general analysis of building forms based on their land utilization, and these are the Pavilion, the Court and the Street, Fig (1.2)

These three archetypal forms simplify the complexity of urban texture found in urban areas. It is important to put up here that pavilion type of geometry exist in Nagpur city at present. Researcher had combined remaining two street and court typologies in hypothetical proposals. The climate responsive guidelines for composite climate are also taken into consideration. It states that minimum surface areas should be exposed to the surrounding and building should have moderately compact planning in composite climate. With reference to above points researcher has proposed building configurations as shown in fig (2.2)

One portion of existing Neighborhood is selected to propose new building configuration. However, and for the purpose to generate different neighborhood configurations and to evaluate their impacts on the building heat gain, the following rules were followed in regards to the building regulation used in Nagpur city.

- F.S.I. for individual plot residential development is given to be 1 in development control regulations. It is kept same in proposed configurations.
- The proposal has followed height restrictions as per development control regulations.
- While proposing new built mass over individual plot, ground coverage is kept unchanged from the existing buildings.

Aspect ratio and building surface exposure keep changing with configuration. Knowing the fact that front façade is always exposed to all weather conditions, all the proposals are planned to achieve same aspect ratio on open sides of building except front side.

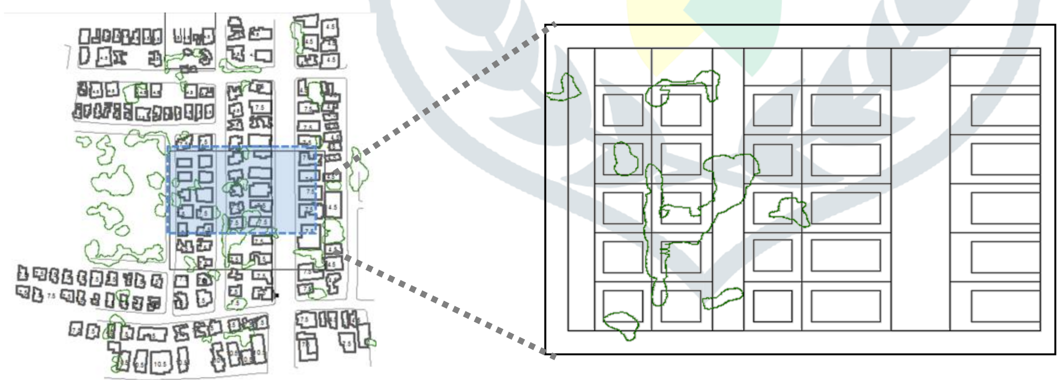


Fig (2.1) Showing existing neighborhood on which various building configurations are proposed and simulated

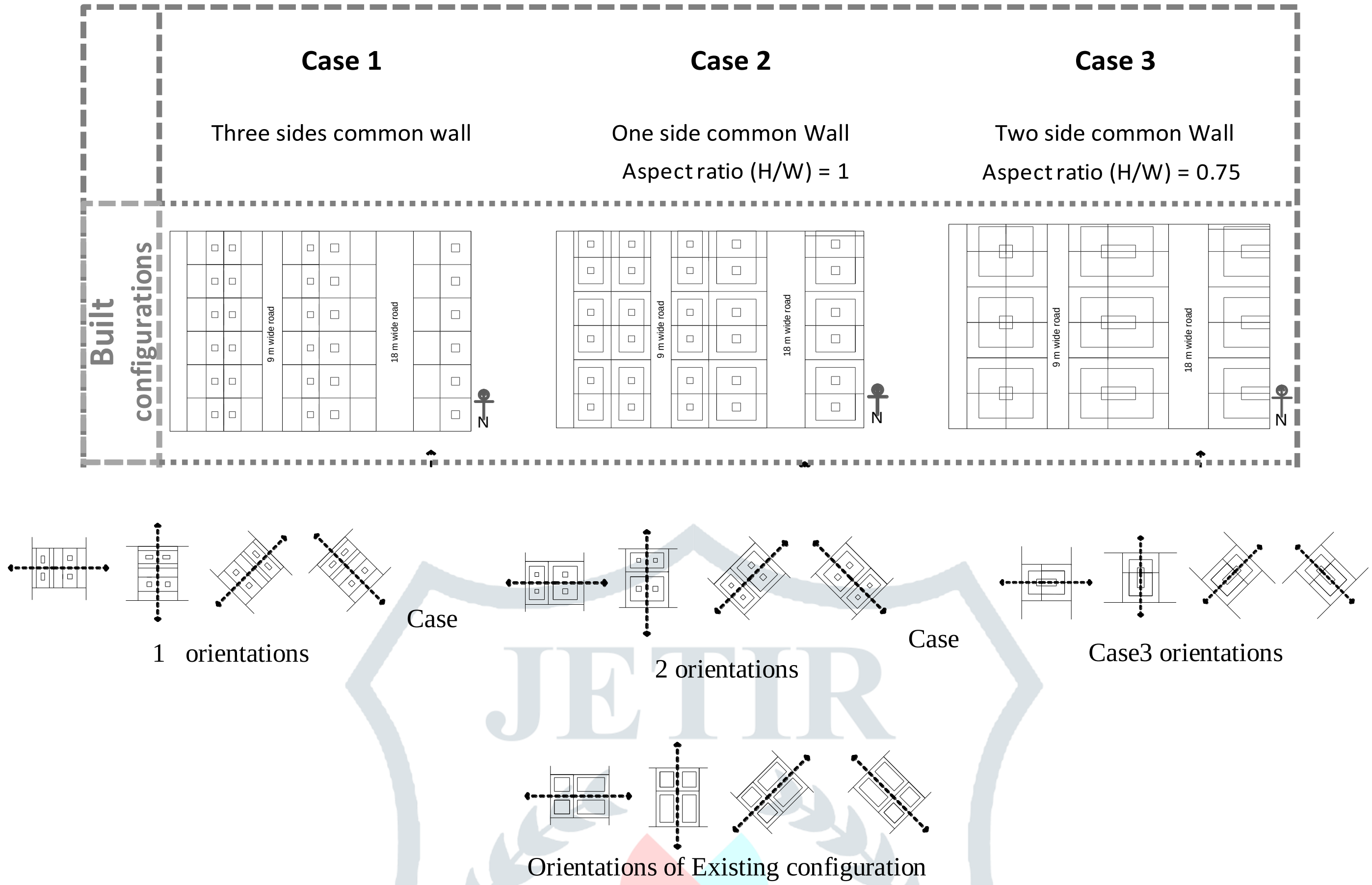
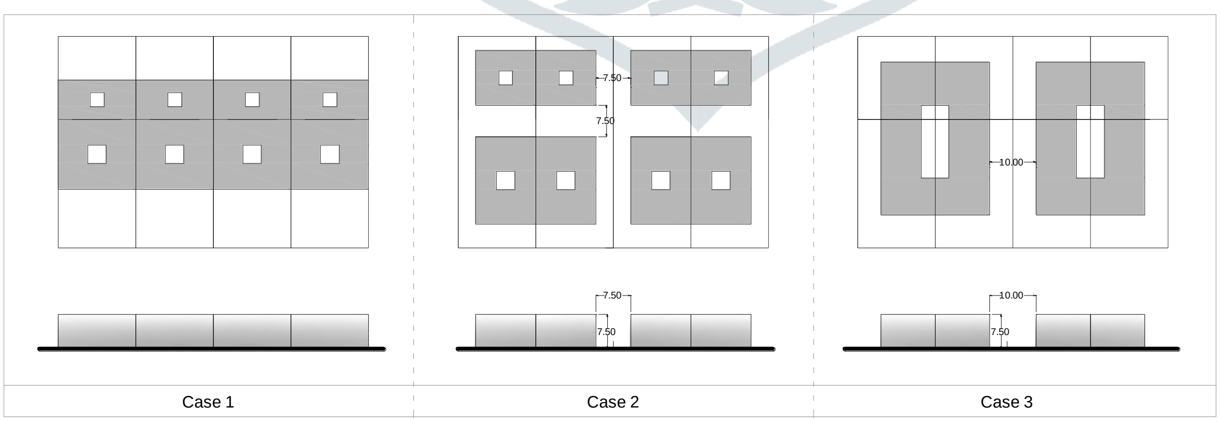


Fig (2.2) Hypothetical building configuration models.

2.2 Physical characteristics of hypothetical building configurations

This section explains the physical characteristics of hypothetical building configurations which were categorized into three models depending on aspect ratio on three sides of buildings. The first model has three walls as common walls with surrounding buildings and courtyard at center. Second model is having 0.75 as aspect ratio and open from tree sides having courtyards on common wall side. In third model one residential unit has two common was sharing with adjacent buildings and courtyard at corner of each residential unit. Fig (2.3) shows all the physical attribute and permutation combinations required for simulation.



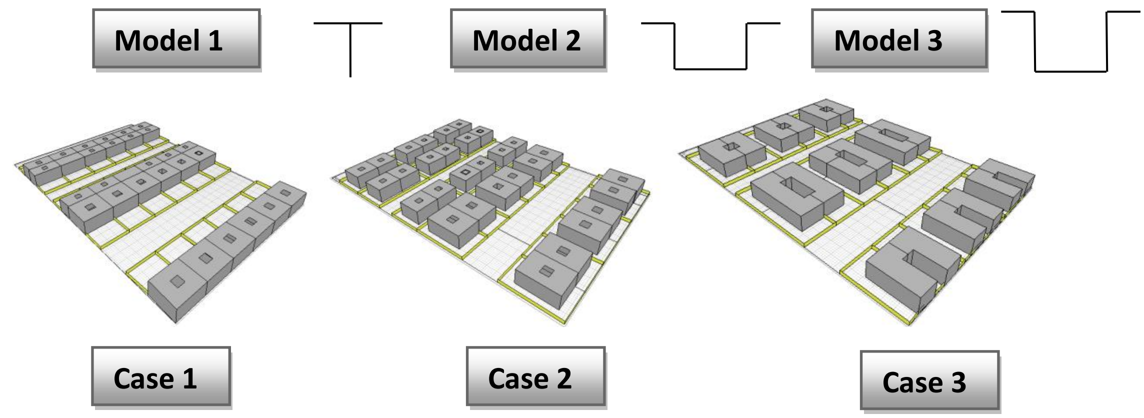


Figure (2.3). Physical Attributes of three hypothetical proposed cases

3. Result and Discussion

3.1 Existing condition

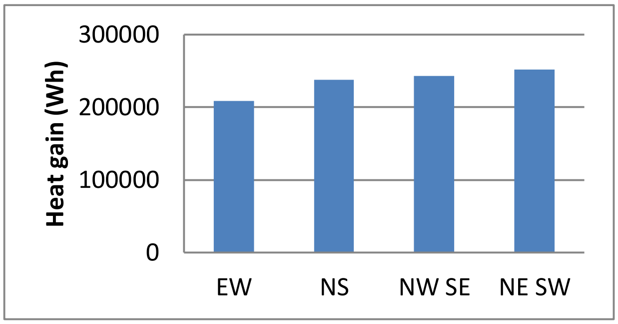
Building heat gain was calculated by simulation modeling with Ecotect analysis 2011 for existing condition in two cardinal and semi cardinal directions. The results are as shown in the graph (3.1). Heat gain varies in each orientation between 200KWh to 250 Kwh. The highest heat gain is observed in Northeast – Southwest orientation. Least heat gain is observed in East-West orientation. The percentage of decrease in heat gain as compared to existing is shown in chart (3.1)

Orientations	Case 11	Case 2	Case 3
East –West (EW)	35%	30%	29%
North –South (NS)	39%	17.39%	23.91%
North West- Southeast (NE-SE)	27.08%	33.3%	25%
Southwest – Northeast (SW-NE)	28%	16%	24%

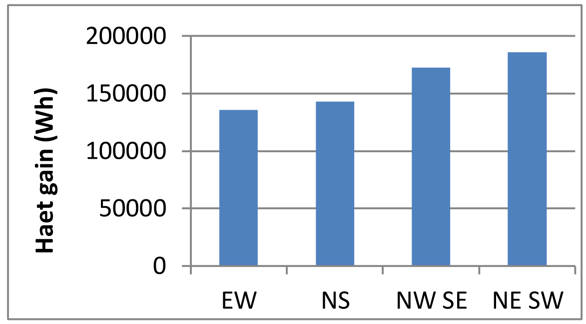
Chart (3.1). Percentage of decrease in heat gain as compared to existing condition

3.2 Case 1

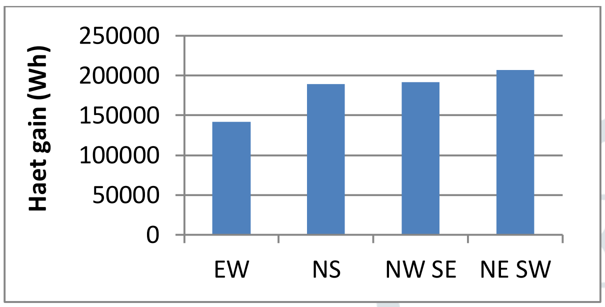
Case one represents the building having thee sides common wall and one side exposed to solar radiation. Centrally paced courtyard is open to sky and exposed to solar radiation. Heat gain by this type of arrangement is minimum in all four cases (Three proposed and one existing). The Heat gain is found to vary between 130Kwh to 180Kwh. Minimum heat gain is observed in East-West orientation and maximum in NE-SW orientation. The difference in EW oriented existing and case one building is observed as 35%. Case one arrangement helps to reduce 35% of heat gain if compared to existing condition. Results are shown in graph (3.2) and chart (3.1)



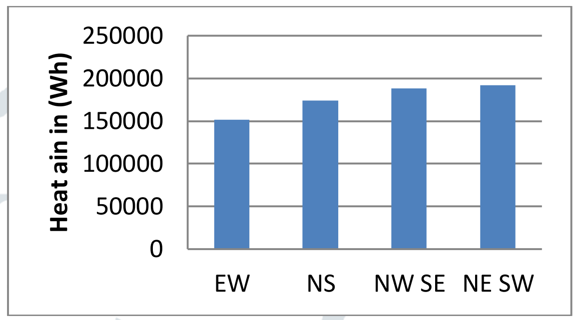
Graph (3.1). Building heat gain during summer in existing case



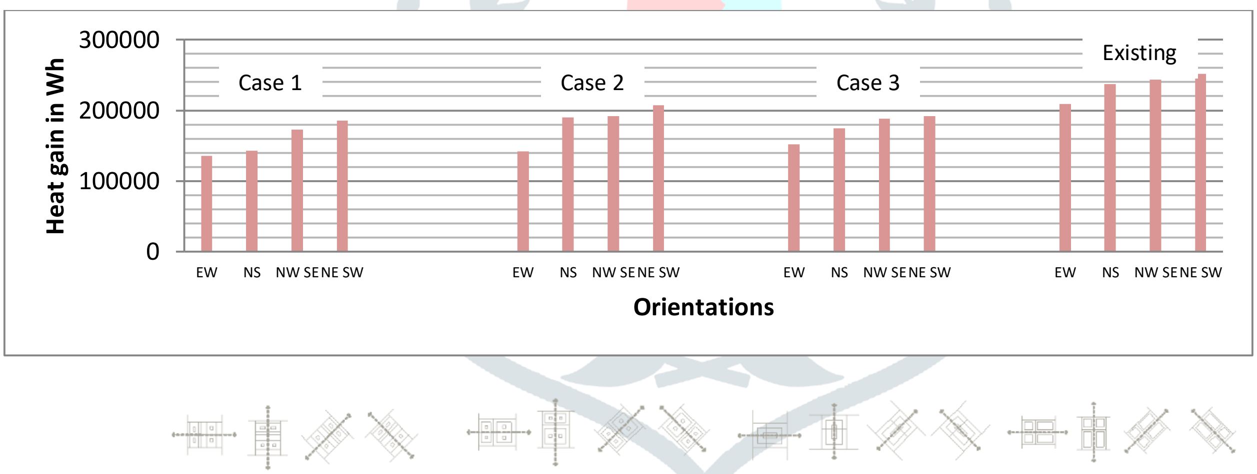
Graph (3.2). Building heat gain during summer in case 1



Graph (3.3). Building heat gain during summer in case 2



Graph (3.4). Building heat gain during summer in case 3



Graph (3.4) Comparison of building heat gain in all cases

3.3 Case 2

This case arrangement represents one common wall and courtyard surrounded by building on three sides. In this case the range of heat gain is found to be 140 Kwh to 210 Kwh which is more than case 1but less than existing condition. EW orientation is found to have least heat gain as compared to other orientations of this case. The heat gain in East west orientation is 30% less than existing condition. Results are shown in graph (3.3) and chart (3.1)

3.4 Case 3

In case 3, two facades of building are exposed to sun and two are acting as common wall. Four units form a cluster having common courtyard at the center. The range of heat gain in all orientations is found to be 150KWh to 190KWh. The minimum heat gain in this arrangement is observed in EW orientation but seen to be more than case 1 and 2. This is due to the longer courtyard in EW orientation which reduces the shaded area. The EW orientation is having 29% less heat gain than existing condition. Results are shown in graph (3.4) and chart (3.1)

4. Conclusion

The modeled effect of building configuration shows difference in heat gain. Three different cases having one two and three sides exposed to surrounding and having courtyard were simulated for building heat gain. Simulation was carried out for E-W, N-S, NE-SW, SE-NW orientation and compared with existing building configuration. East West orientation was found to be 35% - 29% reduction in heat gain. North South orientation found to have 17-39% reduction. 25-33.3 % reduction was observed in NE-SW and 23-30% in NW-SE direction was observed. Maximum reduction in heat gain was observed to be in Case 1 East West orientation. And minimum was found to be in case 2 NE-SW directions i.e. 16-28%. Here more effect of surface exposure is found as compared to aspect ratio. Case one with zero aspect ratio is having less heat gain. Case 2 with more aspect ratio as compared to case one has more heat gain but not less than case three, whereas case three has more aspect ratio but the heat gain is determined here by surface exposure. All proposed cases are found to have less heat gain than existing condition. Minimum 16% heat gain is reduced and maximum it can be up to 39%. Figure (3.4) Shows comparison of building heat gain in all cases

Compared all the cases for heat gain during summer. The findings showed clear evidence in the effect of building configuration on building heat gain in Nagpur city. The research should be taken forward to understand the impact of the open spaces in form of courtyard change in space around as compared to existing in social aspects of neighborhood. Once all aspects are considered, the effective configuration can be applied to new layout patterns and in building by laws of Nagpur city.

References:

- Arnfield, A. J., 2003. Two decades of urban climate resarch: A review of turbulence, exchange of energy and water, and the urban heat island . In: *International journal of Climatology* . s.l.:s.n., pp. 1-26.
- BEE, 2014. *Design Guidelines ffofr Energy efficient Multistory Residential Buildings*, New Delhi.: Bureau of Energgy Efficiency.
- Greentech Knowledge solutions, 2011. s.l.: s.n.
- Martin, M. a., 1972.. *Urban Space and Structures. Cambrige* ., s.l.: Cambrige Univeristy Press.
- Mckinsey Global Institute, April 2010. *Indias Urban Awakening: Biuldingg inclusive citiies Sustaining economic growth,* s.l.: s.n.
- Oke, T., 1988. Street Design and Urban Canopy Layer Climate. In: *Energy and Building.* s.l.:s.n., pp. 103-113.
- Planning commision, G. o. I., 2012. *India Energ security senario, 2047,* New Delhi: s.n.
- United Nations department of economics and social affairs, 2014. *World urbanization prospects :The 2014 revision New yorkk United Nations,* s.l.: s.n.
- Emmanuel, R. a. (2007). Urban heat island in humid and arid climates:. In *Role of urban form and thermal properties in Colombo, Sri Lanka and Phoenix, USA climate resarch* (pp. 241-251).
- Gupta, V. K. (1984). Solar-Radiation and Urban Design for Hot Climates. In *Environment and Planning B-Planning and Design* (pp. 435-454).
- Gupta, V. K. (1984). Solar-Radiation and Urban Design for Hot Climates. In *Environment and Planning B-Planning and Design* (pp. 435-454).

About the Authors

Prof. Komal Thakur, B.Arch, M.Arch, Presently working as Associate Professor at Institute of Design Education and Architectural Studies, Nagpur, since 2011. She has submitted her PhD. thesis in Rashtrasant Tukdoji Maharaj Nagpur University. She is Director and Senior Architect of TA Ngp architectural firm. Institute: Institute of Design Education and architectural Studies Nagpur Maharashtra. Email id:

Prof. A. J. Sanyal, Master's Degree in Town-Planning, worked in various organizations such as Bose Brothers Calcutta, UPPWD Lucknow, Town & Country Planning Department of Pondicherry, Ministry of Works & Transport Bauchi State, Nigeria etc. Worked as professor at Dept. of Arch. Of M.I.E.T; As Head of the department in KITS Ramtek, as Principal in Dignity College of Architecture, Durg, Chhattisgarh State, Head of Course in Hitakarini College of Architecture & Town-Planning. Ex Chairman, BOS (Arch), Member of Faculty of Engg. & Member Academic Council of Nagpur University from 2000 t0 2005. Presently working at M.I.E.T; Gondia as Prof. Design Chair. Institute: Manoharbhai Institutue of Engineering Technology Gondia.