Sustainability, Agri, Food and Environmental Research, (ISSN: 0719-3726), 11(X), 2023:
http://dx.doi.org/10.7770/safer.v11i1.2973

Thermal performance of residential structure with respect to climate change: case - tropical climate.
Comportamiento térmico de la estructura residencial con respecto al cambio climático: caso - clima tropical

Ajinkya Niphadkar[1], Shobhan Kelkar[2], Akshay Wayal[3]
1-Research Scholar, Shri J.J.T.U., Rajasthan, India. Email: ar.ajinkya.niphadkar@gmail.com
2- Research Scholar, Shri J.J.T.U., Rajasthan, India. Email: shobhan.kelkar7447@gmail.com
3- Research Scholar, Shri J.J.T.U., Rajasthan, India. Email: akshaywayal69@gmail.com

ABSTRACT

Research paper expresses analysis of current research involving a definite Urban expansion project for Mumbai city. The developers-builders enquired for technically supported information relating to the future microclimatic transformations in the growth area and their probabilities for the thermal behaviors of the proposed building. To deal with this inquiry, the structure's thermal behaviors were calculated by using simulation techniques for the current and proposed climatic conditions i.e. extreme climatic conditions. Thereby, substitute structures design (exclusively, a range of façade design alternatives) were well thought-out in vision of their mitigation efficiency vis-à-vis environmental changes projections. The outcome helps in providing capable assessment of such structure design features.

Keywords: urban expansion, simulation, building design feature.

RESUMEN

El artículo de investigación expresa el análisis de la investigación actual que involucra un proyecto de expansión urbana definido para la ciudad de Mumbai. Los desarrolladores-constructores solicitaron información técnicamente respaldada relacionada con las futuras transformaciones microclimáticas en el área de crecimiento y sus probabilidades para los comportamientos térmicos del edificio propuesto. Para hacer frente a esta consulta, se calcularon los comportamientos térmicos de la estructura utilizando técnicas de simulación para las condiciones climáticas actuales y propuestas, es decir, condiciones climáticas extremas. Por lo tanto, el diseño de estructuras sustitutas (exclusivamente, una gama de alternativas de diseño de fachadas) fue bien pensado en la visión de su eficiencia de mitigación frente a las proyecciones de cambios ambientales. El resultado ayuda a proporcionar una evaluación capaz de tales características de diseño de estructuras.

INTRODUCTION

To address amongst the others, building's energy, thermal and visual performance, and calculated structure behavior simulation can be used. It helps in designing Energy efficient buildings. The location of building plays an important role to set up the parameters of microclimatic conditions on base of which simulation prediction of the initial pointers of structure's thermal performance (energy necessities, thermal comfort circumstances) needs among rest of data, the requirement of the micro-climatic uniqueness of position wherever the structure will be erected. Selected research area is New Mumbai because of the Tropical climate conditions and development growth ratio. IMD derived various long period climate records consistent “weather files were used” for this purpose. Two sources of uncertainty were concerned in using such data in the design method. Initially, Controlled weather station information accessible for selected weather locations: A specific structure site and the associated topographic & microclimatic situation may remarkably diverge from those of location of the closest appropriate weather station. Later on given the character of structure as long-lasting goods, & known concerns pertaining to climate modification, weather records should reflect the predictable upcoming climate circumstances & as far as possible the microclimatic states of the construction site. Conditions may cause wrong results for prediction of forthcoming performance of structure if historic results implemented uncritically (Charde *et al.*, 2013).

Various effects of changes in climate on the projected future response of structures were collected by performing various experiments and studies (Jentsch *et al*., 2008) similar to earlier studies which expressed the impact of the facade attribute of outside structure components on the thermal performance of buildings (Shi *et al*., 2011). With respect to the background of these ongoing works, this paper reports on a current study linking a real urban progress project in coastal side cities of Maharashtra (Hasan *et al.,* 2016) Builders demand for technically based info relating to future microclimatic variation in the hot spot area and their possible outcome for the thermal performance of predictable buildings. The primary stage of research concerned the present state as well as future proposals of the climatic conditions on a scale of 10 Km grid. Thereby, mean and extreme conditions were predicted for a time horizon of 30 years (Jentsch *et al*., 2010).

Further 4 representatives of housing and office areas with various densities were selected. Building performance simulation replicas were produced for these four areas via thermal performance simulation application. (Energyplus, 2011). Afterward, simulation results were calculated to check the building’s thermal performance for current as well as future 50-year time horizon microclimatic conditions. In this manner optional structure designs (particularly a variety of façade design alternatives together with conventional and green facades and roofs) were well thought-out. Hence the result of solar reflectance & long wave emissivity of a variety of surface designs on heating & cooling needs of buildings could be explored. Moreover, the impact of vegetation is also studied (Mahadavi *et al.*, 2008).

2.0 Approach

Various diplomatic regions in the development limits of aforesaid town expansion project were focused. (See Fig. 1). In area I, 2 buildings were chosen, one in L-shape East – West oriented & the other one is U-shape (95% apartments & 5% offices) (See Fig.2). Buildings in region I have an average elevation of 17.50 Meters. The second region is situated close to an artificial pond in the heart of the progressing area. Structures in such areas have an average height of 22 meters. The building block which was identified from this location consists of 63% of housing structures and 37% offices (See Fig. 3).

Simulations input assumptions related with U-value of structure components, wall to window ratio, and internal gains are summarized in following Table 1. These assumptions are based on the appropriate principles and project needs. Various software which are used for simulations are ecoTect, Revit, eQuest.

Calculations were carried out for the active process circumstances to calculate “heating and cooling loads”. Linked statements regarding air changes rates and set point solar radiations in terms of temperature are expressed in Table 2.

Mean overheating = (Indoor air temperature at hour I - Reference indoor air temperature for overheating in 0C.) / The actual count of considered hours. Note that internal air temperature at hour I - Reference indoor air temperature for overheating in ^{0}C is considered only for those hours when internal air temperature at hour I is greater than Reference indoor air temperature for overheating in ^{0}C.)

Overheating was analyzed for a reference overheating temperature of 26^{0}C and air change rates of 0.43 h-1 (day) and 1 h-1 (night). Consider that, in the condition of overheating temperature calculation, we measured – in totaling to the shading result of plants – also the potential of outside venetian blinds. In the relevant simulation runs, these blinds were considered to mechanically shut once “incident irradiance” on the façade goes above 155 W/m-2. (Energyplus, 2011).

Fig. 1. Shows Urban development area with selected areas 1 & 2 (Source: www.nmmc.gov.in)

Table 1. Represents Simulation assumptions pertaining to U-values, glazing transmittance, glazing area percentages, internal gains & occupancy density (Source: https://www.combustionresearch.com/U-Values_for_common_materials.html)

U value: external walls and roofs	0.125 w.m^2 k^{-1}
U value: windows	1.15 w.m^2 k^{-1}
Total solar transmission through glazing	0.475
Glazing areas as percentage of façade area	31.5%
Glazing areas as percentage of the net floor area	18% area I
	15% area II
Internal gains	Apartments: 3. 21W.m^2
	Offices: 4.11W.m^2
Occupancy density	Apartments:
	32 m^2/ person
	Offices: 11 m^2/person

Table 2. Statement for air change rate (h-1) and temperature set points (0C) for active process (Source: https://smartairfilters.com/en/blog/ashrae-air-changes-per-hour-office-residential/)

	Apartments	Offices
Air change rate	0.43	Day:1.0 Night:0.2/1.5 (Winter/Summer)
Set point for heating	20	Day:20 Night:13
Set point for cooling	27	26

Fig. 2. Selected Building Area I (Source: Authors)

Fig. 3. Selected buildings Area in II (Source: Authors)

With respect to examining thermal routine suggestions of various building facade alternatives, various alternatives (counting conventional and sustainable facades and roofs) were well thought-out. Table 3 expresses a review of connected characteristics (long wave emissivity, surface reflectance etc.) Note that, in this table, façade data states effective values counting 32% glazing. Ground data states likewise effective values 41% asphalt and 59% grass. Trees were considered to be 15.5 M. high (considering trunk). Moreover, the transmissivity of the trees was adapted according to season (0.63 winter, 0.154 in summer and 0.348 during swing seasons.)

Table 3. Surface Characteristic assumptions

(Source: https://beeindia.gov.in/sites/default/files/Residential%20Code_Building%20Envelope_Draft_rev4.pdf)

Material	Emissivity	Solar Absorptance	Visible Absorptance	Surface Reflection
Roof Surface				
Pebble	0.91	0.62	0.62	0.35
Green Roof	0.93	0.78	0.78	0.20
Façade Surface				
White	0.90	0.18	0.14	0.62
Dark	0.905	0.67	0.65	0.19
Green	0.93	0.605	0.585	0.18
Other Surfaces				
Trees	0.95	0.48	0.82	0.145
Ground	0.93	0.815	0.80	0.175

A number of simulation scenarios were defined depending on the surface type of roofs (Green or Pebble) and facades (Green, White or Dark) and also the occurrence or nonexistence of trees. Scenarios are specified in Table 4.

Table 4. Simulation Scenarios (Source: Self assumptions)

Scenario	Roof	Façade	Trees
GG_T	Green	Green	Yes
GG_N	Green	Green	No
GW_T	Green	White	Yes
GW_N	Green	White	No

Climate Assumptions:

To consider the impact of the upcoming climate situation, climate models have been applied, referring to various spatial scales showing data for building performance simulation. By using local climatic models, surrounded areas climate model outcomes were calculated out from macro climatic simulations were carried out. As mentioned earlier, results will be capable of achieving thermal comfort for current and proposed climatic conditions, this means, with respect to current climate changes, future extreme conditions were considered. In this paper, results are based on higher temperature numbers. To investigate uncertainty range, local climate mock-up has been analyzed from software & manual observations & IMD climatic data for consecutive 5 years. By evaluating model outcomes for the climate model's raster cells covering the research area were plotted in graphical format which expresses the uncertainty investigation. Result shows a high correlation of multiple sets which states unexplained variance of around 16% between observed & modeled results. As a result, it can be predicted that the simulations of the future climate with increasing greenhouse gas provides analogous results for further decades till 2040.

3.0 Results

The structure behavior simulations were carried out for a variety of climatic data files. The outcome however, was pooled to contrast present and future conditions. When we say "present" in the following, we indicate mutual conclusion for weather files (2005 and 2007) and when we talk of "Future" we denote mixed conclusions for weather files 2033 and 2040. The entire study ended up with following results. Where "T" denotes scenarios with trees and "N" denotes scenarios without Trees.

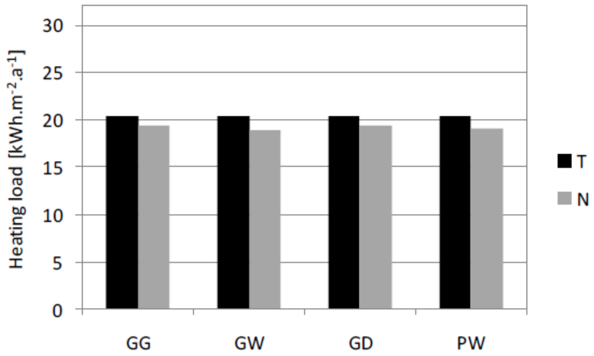

Fig. 4. Heating loads, area 1, present climate (Source: EnergyPlus Version: 22.1.0)

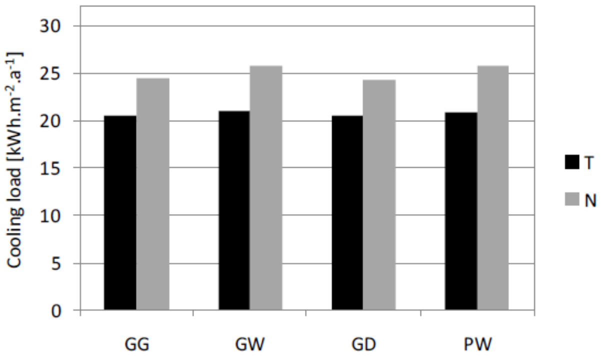

Fig. 5. Cooling loads, area 1, present climate (Source: EnergyPlus Version: 22.1.0)

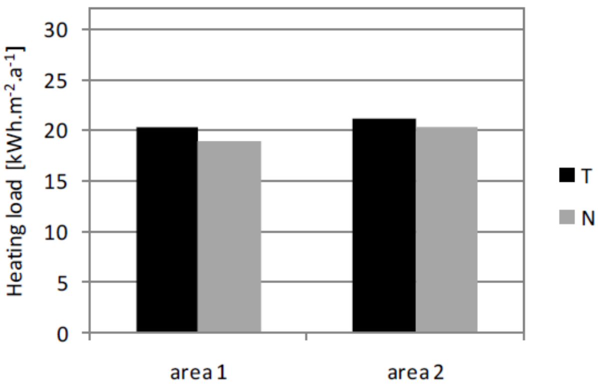

Fig. 6. Comparison of heating loads between area 1 & 2 (present climate) (Source: EnergyPlus Version: 22.1.0)

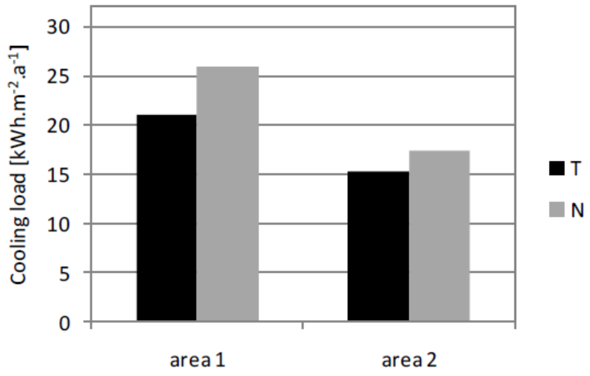

Fig. vii.

Fig. 7. Comparison of cooling loads between area 1 & 2 (present climate) (Source: EnergyPlus Version: 22.1.0)

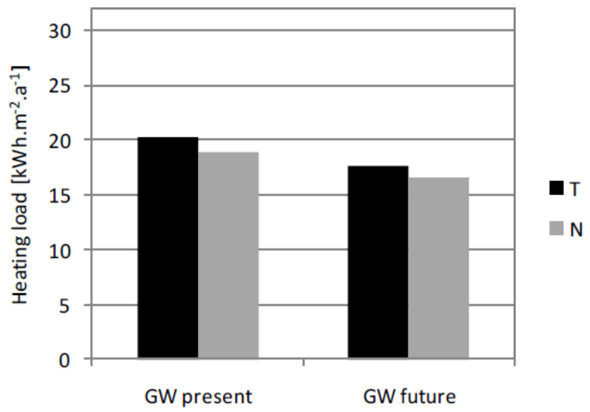

Fig. 8. Comparison of present and future heating loads (area 1) (Source: EnergyPlus Version: 22.1.0)

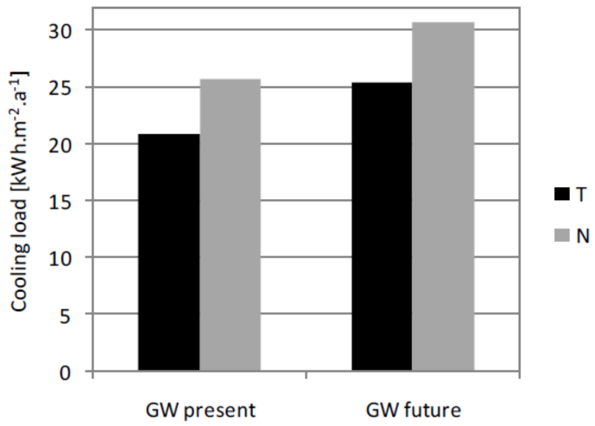

Fig. 9. Comparison of present and future cooling loads (area 1) (Source: EnergyPlus Version: 22.1.0)

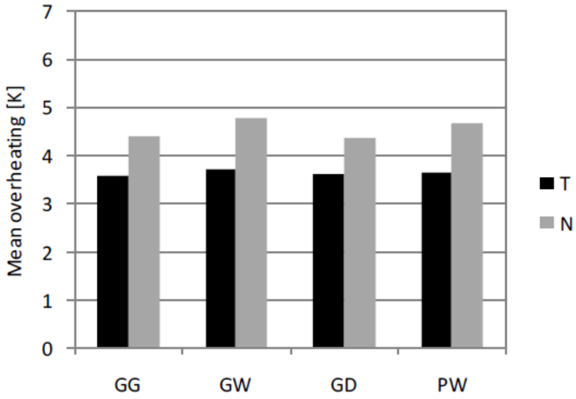

Fig. 10. Mean overheating, area 1, present climate (Source: EnergyPlus Version: 22.1.0).

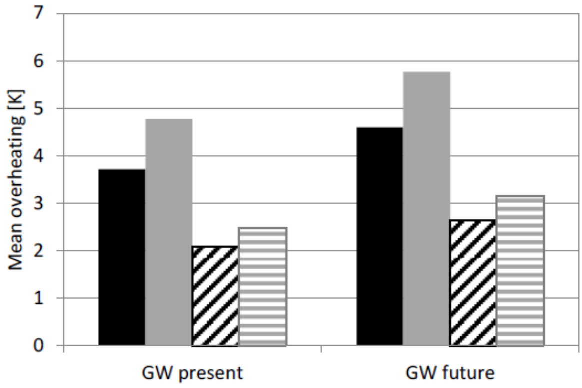

Fig. 11. Comparison of present and future mean overheating for scenarios (Source: EnergyPlus Version: 22.1.0).

4.0 Discussions

The simulation outcome direct to several of observations:

Known for the relatively consistent structure elevation in the chosen urban enlargement area, no notable energy exchange linking building's roofs and facades arises. As a result, the choice between 2 roof planes considered in the present study (green/pebble as per table no.4) had no effect in terms of resulting cooling/heating loads.

Similarly, the 3 façade alternatives won't influence considerably different heating loads. The cause for this outcome is reflected in part of short-wave radiation from nearby buildings: the shading effect of vegetation would efficiently counterattack this result.

Area 1 demonstrates upper cooling loads (for dual situations that is with and without vegetation) this can be accredited to the bigger window area (in relation to net carpet area) in area 1 and the corresponding higher solar gains.

The future heating loads will be lower (about 16%), and cooling loads will considerably increase (24%) as recommended by the simulated inference of the unsaid variations in climate trend.

5.0 Conclusion

We presented an ongoing research effort regarding an urban development project. Henceforth, substitute structure designs ideas were analyzed in view of respective building improvement efficiency and weather change projections. In case of buildings with highly insulated envelopes, surface reflectance and long wave emissivity of envelope elements do not significantly affect building's heating and cooling loads is the final outcome of this research proposal. With the help of insulated building envelope, cross ventilation, and elevation, currently active cooling is not requisite in research areas. However, should this change due to the projected warming trend, a spectacular raise in energy demand has to be predictable. This highlights the value of suitable adaptation and improvement, hard work and their addition in urban development processes.

6.0 Acknowledgement

Department of building physics and building ecology, Maharashtra helped and guided a lot during this proposal. The authors also gratefully acknowledge members of the department of urban planning and Landscape architecture.

REFERENCES

Assan H. (1998), *Effects of wall's insulation thickness and position on time lag and decrement factor*, Energy and Buildings **28(3)**:299-305

Azar F. (2013), *Investigation on reasons and consequences of Climate changes in International systems,* World Applied Sciences **25(5)**:739-746

Borah P., and Muralidhar S. (2014), *Estimation of degree days for different climatic zone of India*, Sustainable cities and society **2**:70-81.

Bostancioglu E., and Telatar B. (2013), *Effect of Window size on Residential buildings: Energy cost,* World Applied Sciences **21(4)**:631-640

Charde M., and Gupta R. (2013), *Design development and thermal performance evaluation of static sunshade and brick cavity wall: An experimental study*, Energy and buildings **(6)**:497-507

Choi K., and Yu C. (2011), *Sustainable design for Asian Housings: Traditional culture, Lighting,* Indoor Built Environment **20(5)**:485-487

Hasan R., Haslin I., Mohd F., and Raihana B. (2016), *Effect of Solar Radiation to the Building Materials Properties: A Review,* Scientific Research Journal **13(1)**:30-43

Jentsch M. F., Bahaj A. S., Patrick A. B., and James P.A. (2008), *Climate change future proofing of building - Generation & Assessment of building simulation weather files*, Proceedings of the Energy & Building **40(1):**2148-2168.

Jentsch M.F., Bahaj A. S., Patrick A. B., and James P.A. (2010), *Climate change future proofing of building- Generation and assessment of building simulation weather files*, Proceedings of the Energy & Building **40(5)**:367-372.

Kalogirou S., Florides G., and Tassou S. (2002), Energy analysis of buildings employing thermal mass in Cyprus, Renewable Energy **27(3)**:353-368

Mahadavi A., Leinich V., and Orehounig K. (2008), *Implications of varying weather data sets for predictions of thermal performance of buildings*, Proceedings of the Plea 2008 - 25th conference on passive and low energy architecture Dublin:178-187.

Manjubath G., Radhakrishna C., and Jadhav M. (2011), *Compressive strength development in Ambient Cured Geo-polymer mortar*, International journal of Earth Sciences and Engineering **4(6)**:830-834

Nazhatulzalkis J., Mohd F., Suriani N., and Mustafa M. (2014), *E3S Web of conferences 3,* EDP Sciences **3**:1-6

Plus, E. (2011, July 15), Energy plus. Retrieved October 7, 2020, http://apps1.eere.
energy.gov/buildings/energyplus/ (Visited on 06th June 2022)

Radhakrishna A., and Udayashankar B. (2008), *Use of fly ash in construction industries for sustainable development*, Journal of Environmental research and Development **3(4)**:331-344

Shah K. (2008), *A study sustainable urban environment with climatic consideration in House planning*, Energy & Building environment - Residential **2(1)**:12-17

Sharuddin A., Noorazuan M., Kadaruddin K., and Mahamod M. (2011), *The effects of different land uses on on temperature distribution of a humid tropical urban centre*, World Applied Sciences **13**:63-68

Shi Z, and Zhang X. (2011), *Analyzing the effect of longwave emissivity and solar reflectance of building envelopes on energy savings in building in various climates*, Solar Energy **85(1)**:28-37.

Singh M K, m. Singhal (2010), *Thermal performance study and evaluation of comfort temperatures in vernacular buildings of India*, Building and Environment **6**:320-329.

Vijai K., Kumutha R., and Vishnuram B. (2012), *Experimental investigations on Mechanical properties of Geopolymer concrete,* Asian Journal of Civil Engineering (Building and Houing) **13(1)**:89-96

Yu., K.C. (2011), *Sustainable design for Asian housings: Traditional culture, Lighting,* Indoor built environment **20(5)**:485-487,

Received: 19th October 2022; Accepted: 19th October 2022; First distribution: 04th November 2022.

Special edition procedure.