Landscape as a Tool in Achieving "Adaptive Comfort", a Study on Multi-Storied Residential Buildings in Tropics

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Abstract— *Maintaining indoor thermal and visual comfort has become the basic means of energy consuming modes in residential buildings in tropical climates. The amount of energy consumption in domestic building activities per year has become greater compared to nondomestic buildings. Meanwhile High – rise apartments in urban areas have become a regional trend in the present. Yet, livability of such constructions with respect to thermal comfort is less experimented. The research focuses on high rise residential apartments, which have been built surrounding natural sceneries or artificial built environs in urban settings. It investigates the impact of surrounding view of any artificial/natural landscape along with habitual and behavioral patterns in achieving 'Psychological Comfort' of dwellers with respect to its vertical level. The research highlights the aspect of "Human Comfort" ;(physical and psychological comfort) with respect to Effective thermal comfort, Neutrality temperature and Predicted Mean Vote (PMV) taking as measurement indexes. The "adaptive comfort level "of the occupants has been investigated to* identify its impact on "Human comfort". *A naturally ventilated high-rise apartment within Colombo region has been selected as the case study. The thermal investigation was done in two steps. The first investigation was to identify physical thermal behaviour and thermal patterns of the selected case study. On site measurements of indoor air temperature and relative humidity were taken using HOBOs while the wind velocity is measured using wind velocity meters, for 48 hours in selected occupied floor levels of the case study. Additionally the applicable ambient air temperature measurements are taken from meteorological Department of Sri Lanka. The Secondary thermal investigation was further done with a physical data collection of indoor air temperature, RH%, and wind velocity and also a questionnaire survey was conducted, focusing on PMV value and effective thermal comfort within the research limits. This investigation was helpful for the inurement of the first investigation results and to identify the adaptive comfort levels of the occupants' in comparison with the physical measurements taken. The readings of air temperature, humidity and wind velocity were super imposed with results of the questionnaire survey and a comparative analysis was done. It highlighted a clear contradiction of 'physical condition' in to 'adaptive condition', with respect to human comfort. Research outcomes suggest that the* ***"thermal"*** *comfort of occupants did not vary within expected and accepted comfortable temperature levels. The outcome suggested that '****Visual Comfort****' can be used as a* ***Psychological tool*** *in enhancing 'Thermal Comfort'.*

Keywords— *Thermal Comfort, Adaptive Comfort, PMV*

I. INTRODUCTION

Tropical urbanization is an enticing global phenomenon. With people moving to the city, land is getting limited for the urban population. High – rise apartments within densely populated cities have speedily increased within this context. Urban high rise apartments can be mainly categorized into two, in terms of energy usage. Income level / the social level of the users also have become an additional fact for the categorization. Nonetheless, they are,

1. Mainly naturally ventilated and lighted (low and middle income class)
2. Mainly mechanically ventilated and lighted (high income class)

Literature proves that Buildings emit more than 39% out of total CO2 emission. Out of that, 21% is emitted from residential buildings while 18% from commercial buildings (Source: U.S. Department of Energy (DOE), 2008 Buildings Energy Data Book, Section 1.1.1, 2008) this reveals that Residential buildings acts a major role in energy use in urban contexts thus there is a global obligation of research on energy conservation for residential buildings.

The research investigates the impact of landscape in achieving adaptive thermal comfort assuming that it varies with its vertical level due to the visibility of the surrounding.

II. RESEARCH RATIONALIZATION

Enough research has been done on the field of climate for outdoor canyon thermal behaviours and indoor thermal behaviour. Nevertheless the studies based on high rise residents are less focused with respect to thermal comfort

Considering the situations, a special attention should be paid to promote **naturally ventilated high rise residential buildings** in energy conservation point of view, even though enough research on this field has not been carried out to identify the challenges and in order to make productive suggestions.

The term “thermal comfort” has been more complicated along with psychological and social factors. Exposure to diversified environmental features of outdoor microclimates greatly affects People’s thermal sensitivity and influence their behaviour and psychological state of mind. Occupants in naturally ventilated buildings are supposed to be tolerant for a wider range of temperatures, which is gained through both psychological and behavioural adaptations.

According to de Dear, R.J., and G.S. Brager, 1998., the static model of thermal comfort is represented in contemporary thermal comfort standards such as the current *ANSI/ASHRAE Standard 55-1992* (1992) prescribe relatively constant indoor design temperatures. These standards have come to be regarded as **universally applicable** across all building types, climate zones, and populations (e.g., Parsons 1994). Nonetheless these universal standards have been set out; researches have started to challenge the assumption of universality, since it ignores the important facts such as **cultural, climatic, social**, and contextual dimensions of comfort.

Griffiths, et al., 1987 says ***“People in natural environments are able to tolerate extensive variations of physical environments when there is a direct relationship with the natural settings”.*** Accordingly, it has been identified that field research is best for evaluating the impacts of behavioural or psychological adaptations as they occur in realistic settings.

III. METHODOLOGY

The focus of the methodology is to identify the prevailing physical thermal behaviour of the selected research area and compare them with the opinions of the dwellers especially relating to the thermal condition they feel while using the dwelling units.

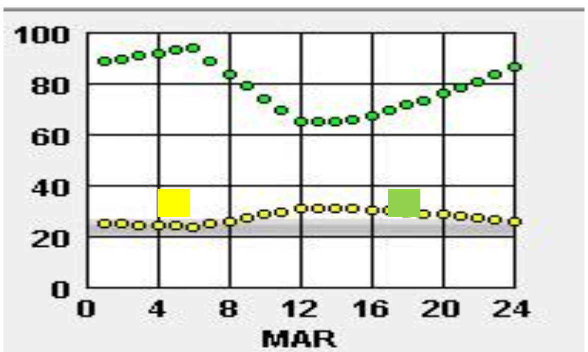
Case study selection

Dematagoda, “Mihindusenpura” housing scheme was selected as the case study. It is a naturally ventilated 10 storied high rise. The purpose of selecting these apartments as the case study is to identify the vertical thermal behaviour. There is a courtyard in the middle of the apartment and all the houses are connected by a continuous balcony type corridor which faces to the internal court yard and also each house consist of another balcony facing outside of the block.

Figure 3. Internal and external images of the case study context

The two balconies either side have different sceneries of natural/ artificial landscape. Visibility of scenery differs with its vertical level. The outside balconies which are separate from each other, facing towards the surrounding city and natural greeneries while the continuous internal corridors are facing to the middle courtyard which has more social interaction with the Neighbours as well. The field study has been conducted in two phases. The first investigation was to identify physical thermal behaviour and thermal patterns of the selected case study. On site measurements of indoor air temperature and relative humidity were taken using HOBOs while the wind velocity is measured using wind velocity meters, for 48 hours in selected occupied floor levels of the case study. Additionally the applicable ambient air temperature measurements were taken from meteorological Department of Sri Lanka.

The ambient data were also further analysed using 'climate consultant 6.0 beta'- (*ASHRAE Standard* 55-2004 using PMV). March has been selected for the field study since, the previous weather data proves March as a month with a higher variation of temperature and wind velocity.



Temperatur RH

Figure 2. Temperature & humidity distribution throughout the month

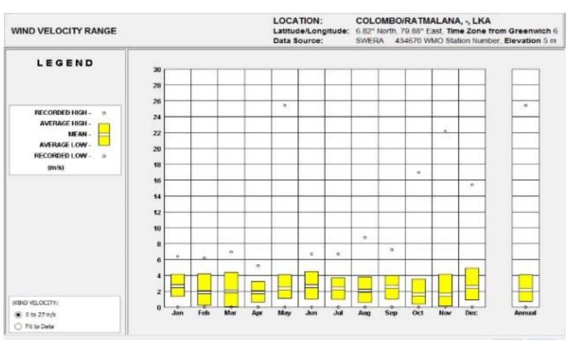


Figure 3. Wind velocity distribution throughout the year

A Secondary thermal investigation was further done with a physical data collection of indoor air temperature, RH%, and wind velocity. Also a questionnaire survey was conducted, focusing on PMV value and effective thermal comfort within the research limits. Purpose of this was inurement of the first investigation results and to identify the adaptive comfort levels of the occupants' in comparison with the physical measurements taken.

Questionnaire was basically focused on **house wives** as they live within the house for a maximum time during the day. Also literature reveals that the female are much sensitive to the thermal variations. (de Dear, R.J., and G.S. Brager, 1998)

The questionnaire survey focused in identifying the behavioural pattern of the selected cases. The habituating time period inside the house, their activity patterns, personal preferences and their clothing pattern has been investigated.

Important outcomes of the questionnaire were,

- During the thermally critical period most of them are wearing cotton mixed clothing.
- Most of them are considering surrounding sceneries as an effective factor for relaxing
- Almost all the openings are opened during day time except the lower floors.
- Most of the cases has selected an uncomfortable time period as their relaxing time, where they use different strategies to overcome the psychological impact of the thermal condition.

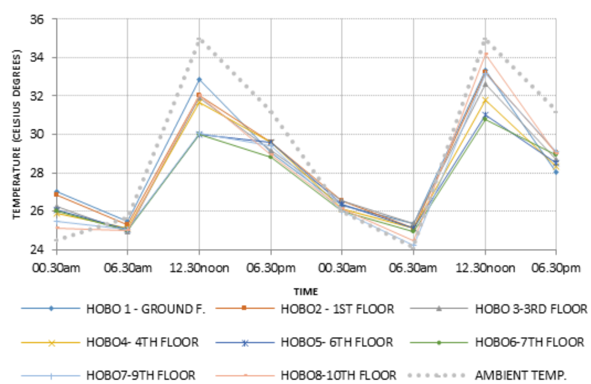


Figure 4. Phase 1 air temp. Data analysis

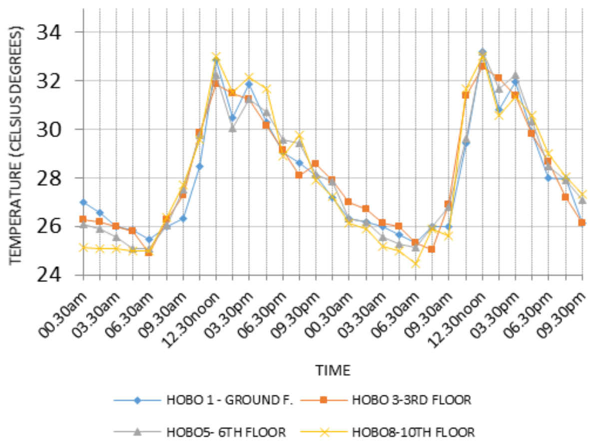


Figure 5: Ground, 3rd , 6th and 10th floor temperature distribution (phase 2)

Preferred space of the house was extracted from the questionnaire survey. The **comfortable temperature range** was **22°C – 30°C** (extracted from the ASHRAE standards) while the **physically measured temperature** range was between **24.5°C – 34°C**.

The results from the questionnaire survey and the outcome of the physical temperature analysis have been compared. The case study analysis can be graphically shown as in the figure below. The phase 2 data collection was based on these observations. Four floors have been selected for the second phase data collection with respect to phase 1 conclusions. The similar behaviour of the adjacent floors has been taken into an account.

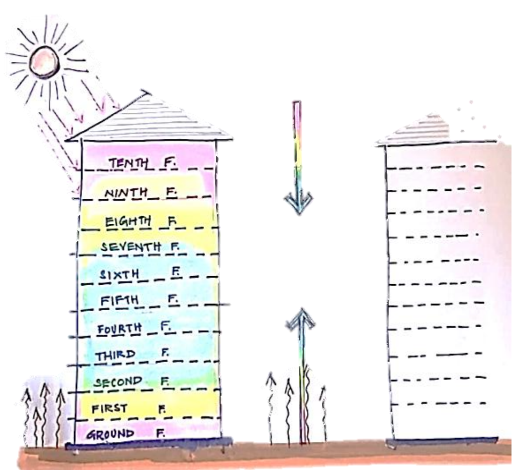


Figure 6. Identified building thermal patterns, vertically

IV. EXPERIMENTAL DESIGN

Particularly in naturally ventilated high rise residential buildings, temperature data analysis can be done according to its, Vertical & Horizontal behaviour.

When taking the thermal behavior of the vertical levels, the highest levels gets most heated during the ambient peak temperature time due to direct solar heat gain from the envelope, especially from the roof. Heated ventilation flow through building also affect in the upper levels. The second highest Indoor air temperature records in the ground floor. But the air temperature gets comparatively low at the middle floor levels. Horizontal thermal behavior was analyzed with the questionnaire survey. Four respective floors were selected and 10 questionnaire results from each floor considered to identify there usage of space during the thermally critical time period.

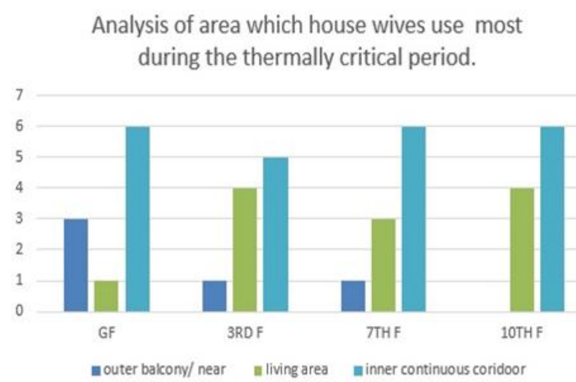


Figure 7. Questionnaire survey analysis of horizontal space usage during thermally uncomfortable time period

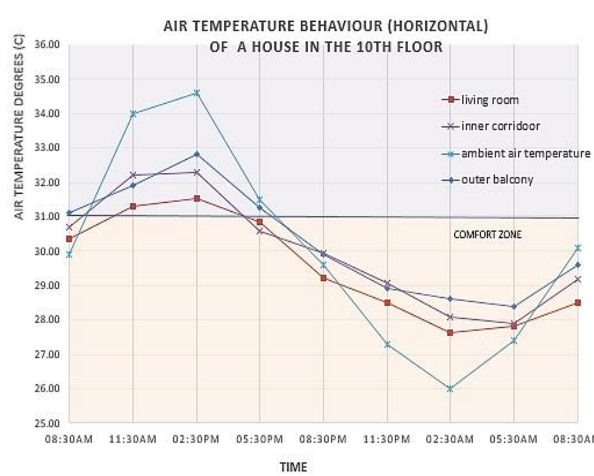


Figure 8. Phase 2, horizontal thermal behaviour of the spaces (10th storey)

V. RESULTS

It is identifiable that the ground and tenth levels are heated most compared to the middle floor levels. Further, it can be identified that in most cases this high temperature time period is used as their relaxing time where they have adapt themselves in certain behavioural patterns related to their life styles.

Ex. Majority of house wives prefer to spend the thermally critical period in the continuous inner corridor which faces to an artificial landscape (courtyard), where also is a socially and culturally interactive space. Comparatively lower number of people use outer balcony (Refer fig. 6).

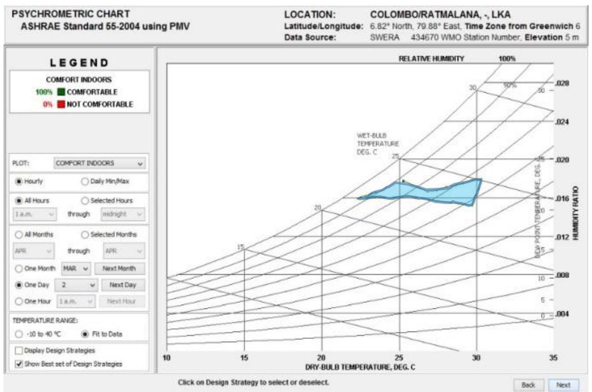


Figure 9. Psychometric chart indicating the standard comfort temperature zones (comfort zone)

3. CONCLUSION

The mismatch between observation and prediction in naturally ventilated buildings implicate **adaptive factors beyond the body's heat-balance.** After the analysis, it was possible to examine the difference between building occupants' neutrality and their preferred operative temperatures. **The adaptive comfortability has encountered the thermal comfort standards except during the extremes. More over the sceneries of the natural and artificial landscape have become one governing factor of their psychological and behavioural thermal adaptation while the culture has become another prominent factor.** This was evident with the results obtained through the surveys. Even though the initial hypothesis became "thermal adaptation will have a direct relationship with the vertical level due to the increasing light conditions and ventilation levels, **the outcomes revealed the internal courtyard (artificial landscape) act more effective since it create a socially / culturally favourable atmosphere.**

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