"Building Section" For Passive Climatic Modifications in Sri Lankan Non Domestic Architecture

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Abstract— *Air-conditioning is commonly used to achieve thermal comfort for commercial buildings in the hot and humid climates. This practice accounts for nearly 60% of total electricity consumption in a building. Passive system is a way of integrating interventions with the capability to be operated by itself with minimum interference of manmade fossil based energy such as electricity.*

The paper used a case study approach to understand the sectional adaptations for passive climatic modifications in Sri Lankan Non domestic Architecture. Three case studies were selected by considering the use of passive climatic modification systems such as thermal mass, natural ventilation, day lighting techniques etc. Buildings were selected from an urban context with similar activities and the interplay between the "Man and the Building" was considered as an important part of designing passive climatic modification system. All three case studies have similar building material pallet such as brick and masonry building systems and roof is a steel section with lightweight building system.

Use of passive interventions can contribute to modify outdoor climate into a favourable indoor condition. However, thermal investigation of selected case studies found that having passive systems alone do not make a comfortable indoor climate due to problems with building design. These buildings are found to be supported with a contribution from active system control in maintaining indoor climate within comfort ranges. The outcome may be useful in designing non-domestic buildings in Sri Lanka.

Therefore certain amount of studies should have done in order to incorporate passive climatic modifications and active climatic modifications in hot humid climatic condition like Sri Lanka especially for non-domestic functions such as institutes etc.

Keywords— Passive cooling option, hot humid climate, Building Section

I. INTRODUCTION

Most of the tropical countries are characterized with warm humid climatic conditions where the microclimate contains the high capacity of moisture of water vapour(Johansson et al. 2004). And they are using air conditioning systems cool their building in order to gain indoor thermal comfort, which is highly expensive in terms of their energy consumption. Therefore certain types of passive climatic modifications are required in order to find out thermal comfort within the building mass(Shaviv et al. 2001).

Passive climatic modification is a way of modifying unfavourable outdoor climate into favourable indoor climate without whatsoever running cost or upkeep. Passive controlling system, by definition, is a system which processes by itself, works by itself, and left alone without any mechanical interference. Passive climatic controlling strategies are methods which are being used to modify the outdoor climate in to indoor climate in a favourable manner(Leary n.d.)

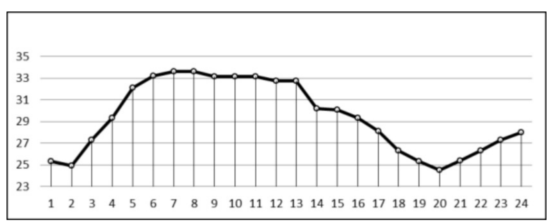


Figure 1: City of Colombo Mean temperature

In warm humid tropics, overheated building interiors are common due to high solar penetration through the buildings envelope and windows(Sadineni et al. 2011). To remove hot air from the building section certain design decisions need to be taken. These design decisions are coming from greater understanding of building section and use of materials in a smart mode.
Under these conditions, and with the presence of high levels of relative humidity, the utilization of

natural ventilation is recommended as a suitable cooling option for the prevention of overheating and indoor climate modification(Rajapaksha et al. 2003).

However in order to gain thermal comfort for human being, the most difficult climatic condition is warm humid climates where the passive climatic strategies are very difficult to implement(Ochoa & Capeluto 2008). It is much easier when comparing with other types of climatic conditions such a hot climate cold climate etc. In warm humid climates the speed of air movement is comparatively low. However, the comfort level can be developed by increasing air movement through the building section. But the passive system can be very difficult to handle to make a proper air movement through the building envelop which may favourable for the occupants of the building.

However having passive climatic modification does make a great sense for building in terms of its functional usage. In fact most of those passive climatic modifications can be very useful for a building.

A. Objective of the Study

Sectional characteristics of a building design can be effective in modifying external unfavourable climates into favourable indoor climates. Therefore by particularizing to the building section which is anticipated to make a authorize identification on how the passive climatic modification systems should work and what are their explicabilities for warm humid climate like Colombo, Sri Lanka.

With the study of building section it is expected to achieve a delimitated knowledge on how the materials and openings available to ameliorate the thermal comfort of the building in respect to passive climatic modifications.

II. ADVANTAGES OF INTRODUCING PASSIVE CLIMATIC MODIFICATIONS TO A BUILDING

a) Minimizing requirements for services

Building designs should be planned to avoid or minimize the cost of services(Roberts 2004) in order to maintain it more cost effective. Literal demand of uniform cost for services can make the buildings' running cost higher in the long run. Therefore the building design always should be there to minimize the cost of services. This can reduce the running cost by increasing the building cost. But yet which is an advantage in long run by calculating running energy consumption of the building.

Building service engineer or the architect takes the responsibility of this challenge. But the best solution is an introducing a passive climatic system where the building can resolve all the services problems. Merely at the planning stage of the building, the designer should be aware of the complexities in services.

b) Minimizing heat gain

Internal heat gain arising from the occupants 'equipment lighting and solar radiation etc.(Gratia & De Herde 2007). But the greatest source of heat gaining is the sun (Solar radiation). Hence the building envelop should be there to minimize the heat gain. The building section and envelop should have design in such a way to minimize the heat gain from outside of the building.Passive systems are introduced to minimize the heat gain or use heat gain as a passive system (example-Thermal mass). By minimizing the heat gain can reduce the energy consumption of the building(Braun n.d.) hence introducing a passive system can reduce the running cost of the building easily. And also which is important to establish a balance system where the building does cool by itself without any upkeep.

But in order to minimize the heat gain certain amount of researches should have done in order to understand the climatology of building system. "However, thorough evaluation of the performance of building designs in minimizing heat gains and facilitating natural ventilation is possible only if the required types of weather data are available"(Burnett 2003)

c) Optimizing natural ventilation

There are different types of natural ventilation techniques, but in order to optimize those techniques building sectional properties should have changed. Natural ventilation is controlled by the openings of the building. All other natural ventilation methods have similar principles as night ventilation. Among all above parameters(Zhou et al. 2008)Different types of passive ventilation techniques available in the world and they are very common in warm humid countries(Sherman 1989).

- *Single sides' ventilation*
- *Cross ventilation*

- *Stack induce ventilation*
- *Night cooling*

d) Optimizing day lighting

Day lighting should be an integral part of a building system(Kua & Lee 2002). The building system and day lighting mechanism of a building is openings and windows. Outdoor lights can arrive directly from the sun or diffuses by could surfaces, which is referred as natural sunlight. In term of natural day lighting sense is often used bit techniques. But in technical terms this is called diffuses light. Not only the lighting conditions but also environments conditions are matter in case the day lighting arrival to the building. Especially the topography and geography are machinated the day lights arrival to the building.

e) Comprising human factors (man and building)

Although human factors often have a bigger influence on energy consumption of the building than service factor and envelop design factors(Nicol & Humphreys 2002). The way people use the building has a bigger impact to the building services. Therefore the passive system is there to ensuring the management of and occupants' requirements are met is crucial for the central part of energy efficient design.

But moderating sectional characteristics of a building by considering occupants' needs and requirements can make a better built environment. However the comfort level does not need to be tight specification among building facilities management process unless there is such communication between building section and building occupant.

f) Passive systems create smart and sustainable built environment

After the industrial revolution, most of the buildings were made in superior with active climatic controlling systems(Ngowi 2001). But after centuries man had realized that the building technology should be developed to protect the nature(Smit & Wandel 2006). Therefore few decades ago scientists had started doing researches on Passive climatic controlling systems.

The buildings are utilized energy than any other man made things on the earth. Therefore minimizing the energy gain of the building is very important to minimize the environmental pollution of the earth

II. METHODOLOGY

Methodology involved a case study approach which collected building characteristic data from three buildings. Hence the study guided with architectural planning and details of the building section modulated in order to gain the thermal comfort of the building.

The study inquires the effects of the thermal comfort and the activity pattern of selected case studies. The key study is to understand the sectional modifications of a building in order to gain thermal comfort in hot humid Colombo specifically for a non-domestic building where the activity may generate more heat.

Understanding the building sectional form and the material pallet of the building does make a great impact to this study. Therefore the analysis starts from the understanding of the building form.

Analysing the climatic consideration and climatic sensitive design decisions made in the design development process of the building.

Such as

- orientation of the building
- Sectional characterises, building heights openings etc.
- Material pallet

Real world data collection

Considering the building design it is very important to make a clear understanding of the thermal behaviour of the building to this study. The building thermal behaviour in terms of the thermal comfort can only understand by considering the humidity and temperature and THI index and comparing their advancement by comparing indoor and outdoor situations.

❖ Measuring thermal levels

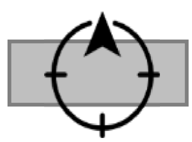
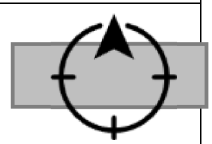
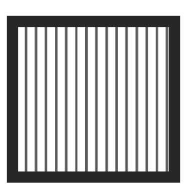
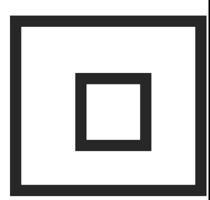
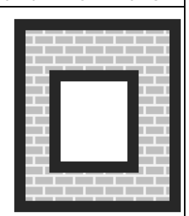
Thermal comfort can be measured by a questionnaire or numerical calculations based on temperature and humidity. This study is gaping to use both two techniques to gather information on passive climatic modification. Especial consideration is for numerical calculations like THI index etc.

III. CASE STUDY SELECTION CRITERIA

Case studies were selected by considering their sectional building design system and the key activity of the building. Hence the study discovers about the non-domestic architecture such non-residential buildings were selected. From those the study has picked up some similar activity pattern such heat generation process oriented activities such as dancing and gathering etc. Thence the survey conducted to measure the thermal comfort of the building as well. And also all the case studies were selected from city of Colombo where the city climate (Outdoor Climate) itself is unfavourable for the building user of the situation.

However the case studies were focused in order to understand the effective ability of modifying unfavourable outdoor climate to favourable indoor climate. Therefore certain amounts of thermal comfortable building were selected by understanding their thermal behaviour as well.

Table 1: Selected case studies Details Description of Selected case studies

case studies and the detail descriptions	**Selected case studies**		
	Nelung Arts centre	**Chitrasena-Vajira Dance foundation**	**Royal collegecanteen**
Location	Hyde Park corner Colombo 7	Narahenpita Colombo	Colombo 7
size	320sq.m	360sq.m	260sq.m
Building function	Institute	Institute	Institute
Activity	Dancing	Dancing	Gathering
Orientation of the Building	**East west**	**North South**	**East west**
			
Building Materials	Soil Brick	Engineering Brick	Engineering Brick
Peak Hour activities	3.00 Pm to 9.00Pm	1.00 Pm to 9.00Pm	6.00 Pm to 5.00Pm
			
Envelop System	**Colonade Shading**	**Open Envelop**	**Timber Windows and Brick Walls**
			

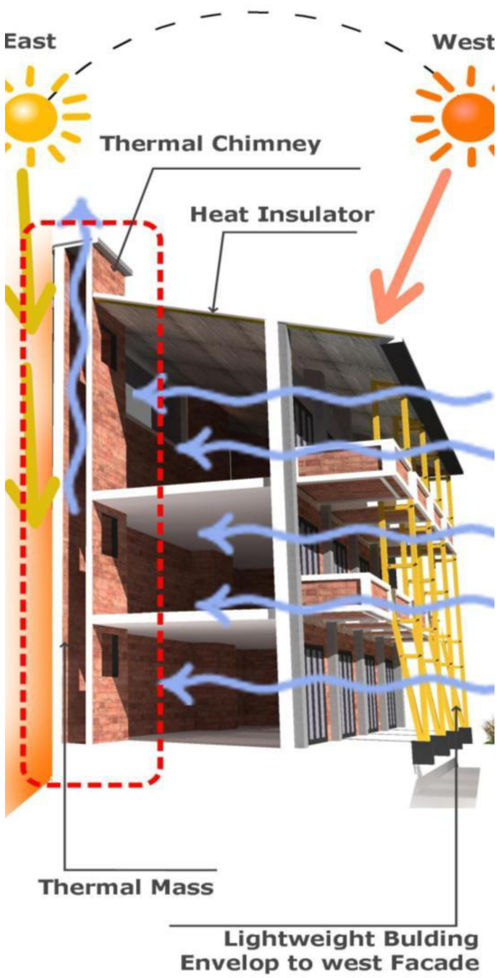
IV. SECTIONAL DESIGN STRATEGIES USED IN CASE STUDIES IN ORDER TO GAIN THERMAL COMFORT

A. Case Study one-

Nelung Arts centre, Hyde Park corner.

The Nelung arts centre is located near the Hyde Park residencies in Colombo 07 where the average temperature is about 30 ºC. The building designed in such way by considering climatic conditions of the location. Not only site constrains were tackled by the building design but also it has considered construction process of the building as well.

Fig 1: Passive Climatic modification Strategies used in Nelung Arts Centre



a) The thermal mass effect in respect to the building section

The Nelung arts centre is directly affected from the solar radiation because of its building orientation and different seasonal solar penetrations. The front facade is detailed with very light weight materials which don't help to stop solar radiation. Hence the designer has thought of solar radiation and the reflected solar radiation is stopped by a thermal mass in a three metre level at the pavement level.

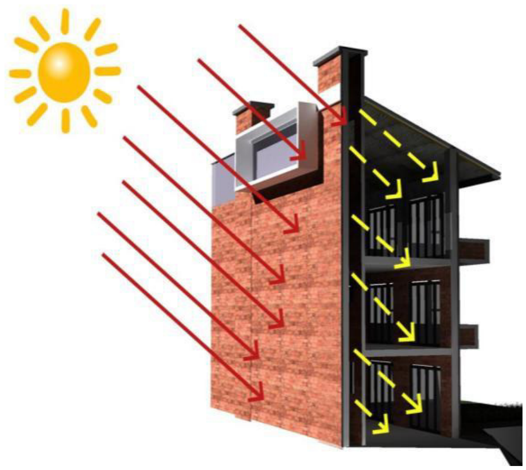


Figure 2: Use of Thermal Mass

The east wall work as a thermal barrier against direct solar radiation from morning sun. And double layer of brick does help to insulate the heat penetration to the interior spaces of the building.

b) Cross ventilation

The third floor where the research was carried out is finely ventilated with structural openings. Most of the balconies act like air sucking ducts. In fact, most of the windows are positioned to capture the south north breeze and wind circulation. Therefore natural ventilation is adequate for the dancing hall of the building.

Figure 3: Structural openings in West Facade

The thermal mass is located to the east wall where which absorb direct solar radiation in the morning time. And which create s pressure variation from top and bottom. Such situation does make natural ventilation through the building in order to cool the rooms etc.

c) Using thermal chimney effect

"Trombe Walls and solar chimneys are passive building elements which rely on solar-induced buoyancy-driven con-vection. In contrast to fan-driven (forced) convection"(Burek & Habeb 2007)

Figure 4: Thermal Chimneys in Case Study One

Using thermal chimney effect is one of the smartest passive building design technology used to minimize the internal heat in the Nelung arts centre. Solar chimneys do remove heat air from the lower levels by creating air pressure variation in different level. In another way this is stack effect ventilation system can used to enhance the internal air circulation system without any upkeep or energy consumption.

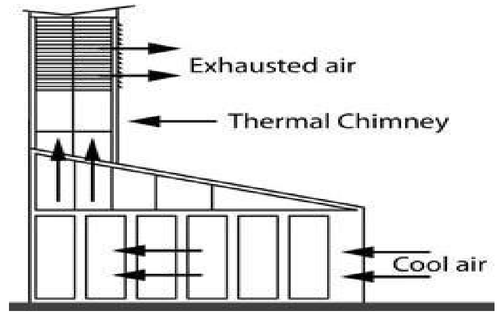


Figure 5: Mechanism of a Thermal chimney

Thermal chimney is a smart way of handling solar radiation into heat removing mechanism without having any active systems. In fact running cost of a thermal chimney is zero.

d) Diffusing Solar Radiation

Figure 6: Green Surfaces Diffuse Solar Penetration

The green Garden built on top of the parking block directly affected by the direct solar radiation after 12.00Pm. The direct solar radiation to the terrace can reflect its heat to the west building facade and increase the heat gain to the building.

However having a green roof does help to diffuse the solar penetration. Plants and green roof with different textures may help to remove absorption of heat and reflection of heat at the same time.

But the considerable fact of diffusing solar penetration is the way of handing building facade and reflecting faces of the building design in order to minimize such solar gain.

Case Study Two- Chitrasena Vajira Dance foundation at Park road

This building located where the average temperature is about 30 ºC. The annual humidity level is over 70% the surrounding environment makes the area much **cooler by plantations.**

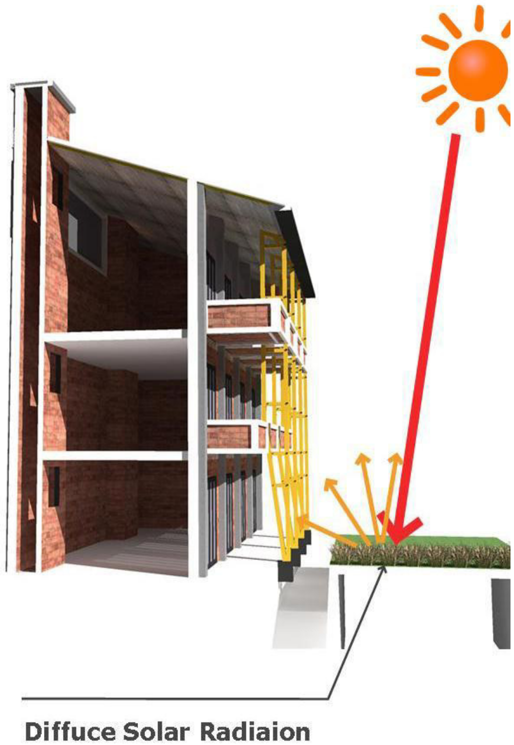


Figure 7: Diffusing direct Solar Radiation

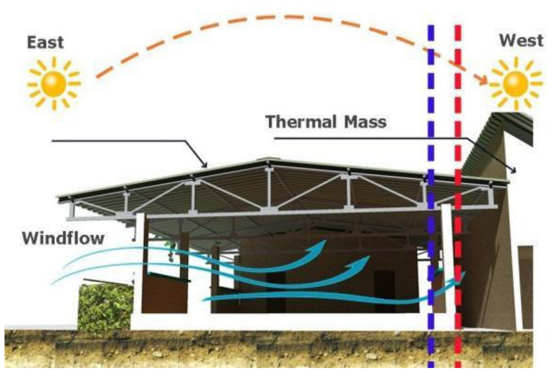


Figure 8: Passive Climatic Modifications used in Case Study Two

a. Cross Ventilation

The Orientation of the building is not favourable in order to gain natural ventilation. But the provided micro climate of the site help to create some form of wind blow within the main space of the building. However having open spaces without any barrier for wind blow doesn't help to create thermally comfortable space. The sectional characterises should involve in order maximizing the internal comfort of the building.

The sectional space in between the environment and the building is green covering and plants. This does make way to the air movement through the building. But provided wind blow comes with high humidified wind which is not comfortable for the user of the building. Therefore the building is always on to the sectional air movements.

b. Using Green As Shading For Building

Figure 9: Use of Green as shading device for case study Two

Green facades are facade systems in which climbing plants or hanging port shrubs are developed using special support structures, mainly in a directed way, to cover the desired area. The plants can be planted directly in the ground at the base of the structure, or in pots at different heights of the facade(Pérez et al. 2011).

Green shading is a common method of providing shading for buildings in urban context. But the use of green covering for case study two was not effective due to its orientation and the ability to stop diffusing solar radiation to the building.

c. The Thermal Mass Effect In Respect To The Building Section

The building section has used thermal mass effect in a smart way to minimize west solar penetration through the building. The west sun is considered as most strong radiation and the west side building (Store Room) designed in such way to minimize west facade heat gain.

And also there is an air gap between the west side thermal mass and the case study two. This is designed as circulation path but works to stop heat penetration to the building.

Figure 10: Use of Thermal Mass

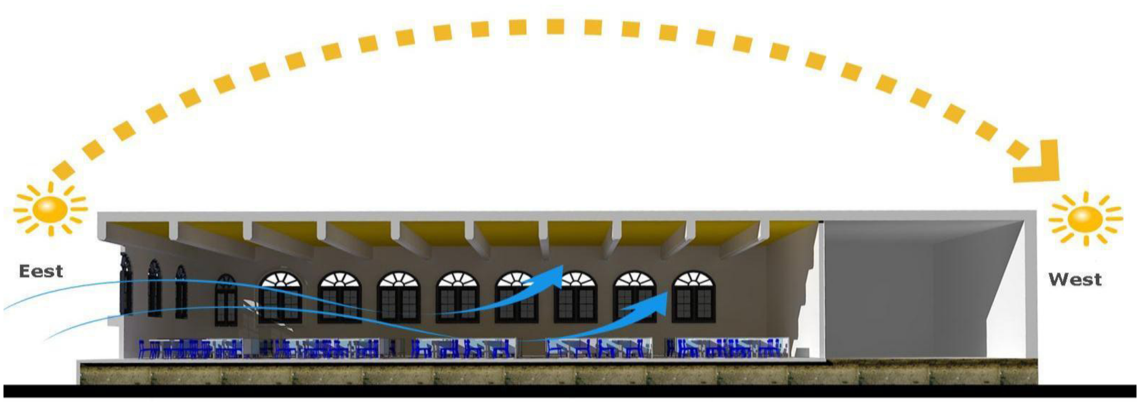
Considering the front side where the direct solar radiation could be happen is not covered. This can consider as one of the biggest weakness of the building and the building interiors may engage more heat in the building. But instead of giving thermal mass to prevent solar radiation the design has created a heat barrier.

However use of materials like half-baked brick and clay plastered wall have some form of thermal mass which may help to absorb heat produced by the occupants of the building.

Figure 11: Clay Plastered Walls in Case Study Two

C. Case Study Three- Royal college main canteen at Colombo 07

Figure 12: Passive Climatic Modification techniques used in Case study Three



Royal college main canteen is located in Colombo 07 where the average temperature is about 30ºC. The annual humidity level is over 70%.

The Royal college canteen is located in corner of the college where the building is shaded with other buildings. The advantage of the building orientation is that the direct solar radiation doesn't hit the building. But the building can gain more indirect solar radiation which can be reflecting from the ground and other sources around the building.

a. Single side ventilation

The major passive strategy used is the cross ventilation technique (Figure 12). The building is strategically opened from the four sides. Especially the south wall and north walls are oriented and purposefully opened to capture the air breeze which arrive from the main ground. So the air movement inside the building is comparatively great.
There is a huge basketball playground in front of the canteen which gets direct solar radiation from the sun. So the basketball playground heats up and makes the thermal air movement through the building. Therefore the building section is well oriented to capture the air movement which comes from main ground of the college.

Use of openings and orientation of those opening can consider as the dandiest passive techniques used in the building. Eastern faced series of windows are designed in order to catch natural air blow produced by the micro climate of the building. And the other openings are designed to remove the hot air and make better air circulation through the building.

However the opposite side of the eastern opening is closed by another space (Kitchen). Hence this works as a air barrier and makes better air circulation within

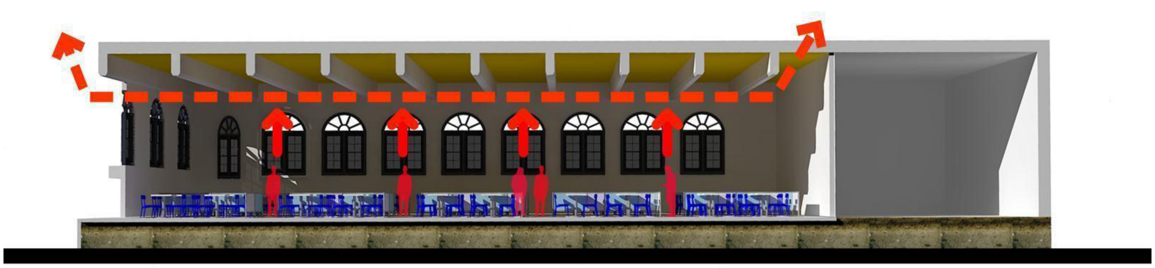
The space. Therefore the building design has optimized the use of natural ventilation in order to gain occupants'' thermal comfort.

b. thermal mass effect in respect to the building section

Walls are made out of colonial engineering bricks, and they are well heat conductive. External walls are painted white; therefore they can reflect the thermal radiation. And the thickness of the wall is very important considering the thermal mass effect. Wall thickness is 400mm so the heat gain can be minimized by slow downing the thermal radiation through the building. Exterior walls were made out of above mentioned materials except exposed dried mud bricks.

Therefore they can absorb heat which enters with the air movement during the day time. Then the air can become cooler than the outdoor air temperature. Those large walls can absorb a great amount of solar heat without increasing its temperature lot in day time. So they can reduce air temperature to develop thermal comfort. Considering the fact that thick walls can absorb the water vapour from air. And remove humidity. So it is a suitable method to control the humidity. But the thick synthetic paints can slow down the absorption of humidity from the air. It is a common problem in most of buildings where the architect had introduced the thermal walls but painted in synthetic paints and slows down the remoistening process. The best material for the wall is lime.

c. The height of the building as a passive strategy



Heat Removing from Human Body

Considering the fact that the royal college main canteen height is 4400mm.Hence the heated air can be uplifted and more cooled air can receive inside the building. The space in between the occupants' usage level and the ceiling height makes a hot air layer. And the hot air layer is removed by the series of louvers created on top of the window. Therefore the height of the building does direct impact on the thermal comfort of the building which may help to remove occupants' heat from their body to the space.

d. Using green as shading system to cool the building.

Dissimilar to other two case studies the case study three has used green as shading to its solar penetrated wall into the east. Therefore the thermal mass of the wall doesn't absorb heat which may penetrate from the direct solar radiation.

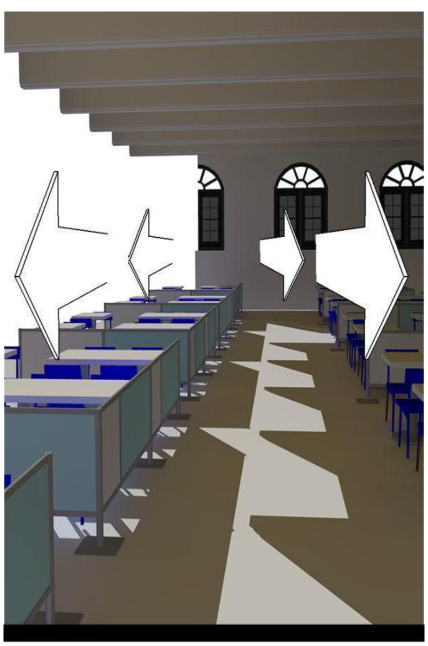
And also using green does provide essential shading for the opening and widows of the building which may consider a thermal as well as visual comfort for the building façade. But the plants are not adequately design to maximize the shading effect to the building. Thus reflected solar penetration from the front court can be reduced much more sensitive manner if they have planned properly.

Figure 13: Using plantation to cool the building

e. Air funnels as a passive strategy

Use of air funnel techniques is one of the advanced sectional design strategy used in the royal college canteen. This has created a natural wind blow in a higher position of the building which may eventually remove the hot air from the building. The main door and is located a shaded area and the place is much cooler than the outside of the building. And the exterior of the building is hotter when the day time solar radiation hit the ground of outside of the building. Hence this makes pressure variation in-between two spaces and helps to make wind funnel intercede those two space.

Figure 14: Air funnel effect in royal college canteen



Air Funnel effect in the Building

V. RESULTS AND DISCUSSION OF COMFORT LEVEL INVESTIGATION

A Building section and indoor outdoor temperature variations

The hourly air temperatures monitored at human level of 1.5m from the floor level of the building and compared with the ambient values of selected case studies. Table 2 and three shows the comparison between those two different case studies and their validity of using building section in order to gain thermal comfort within the building section.

Figure 15: Case one ambient temperature and outdoor temperature

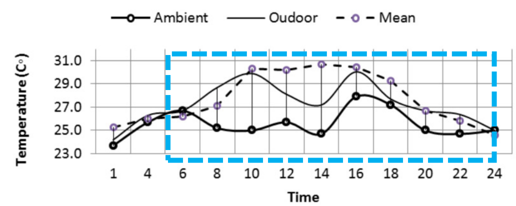


Figure 16: Case Two ambient temperature and outdoor temperature

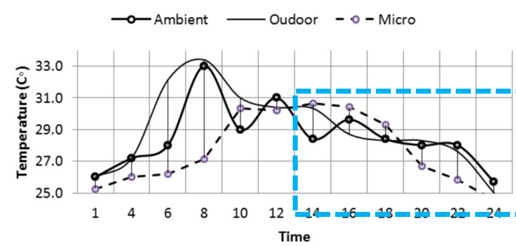
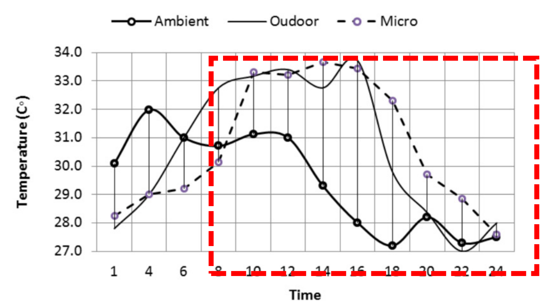


Figure 17: Case Three ambient temperature and outdoor temperature



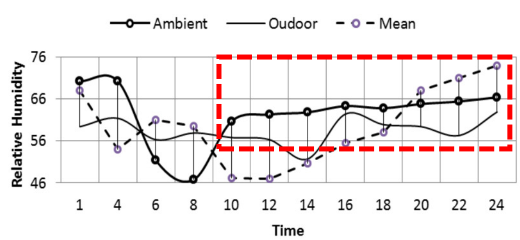
Considering collected data from different case studies shows different moderations in each and every case study. However the case one shows very effective passive climatic modification in respect to the building section. In fact from 8.00 AM to 4.00Pm shows very high temperature reduction in the ambient temperature. But the building peak functioning time starts from 4.00Pm onward and that's a disadvantage for the building user.

The case two shows very weak passive climatic modification. The use of lightweight materials and thermal mass doesn't effect on the building ambient temperature. The ambient temperature shows comparatively higher temperature in the morning time dues to excessive openings toward the east side. Therefore the building doesn't function in a favourable manner.

B Building section and indoor outdoor Relative humidity variations

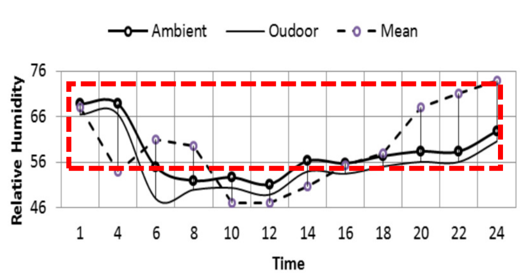
Hourly relative humidity was measured to understand the sectional behaviour of the building. By considering relative humidity may give a good indication of the indoor climate and indoor comfort level of the building.

Figure 18: Case one ambient Relative humidity and outdoor Relative humidity



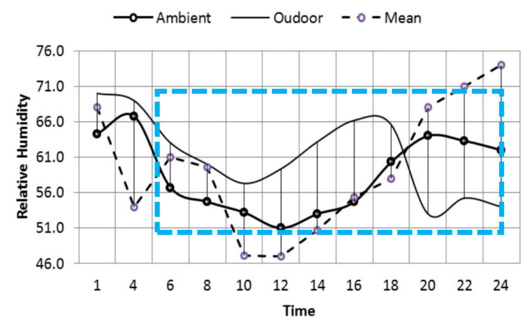
Case one shows favorable deduction of outdoor relative humidity to the indoor relative humidity. From the morning time to the evening working time the building section does help to minimize the immediate context relative humidity. Therefore this is to some degree can consider as successful building section. But the night time the indoor relative humidity is not favorable for the building user Therefore certain amount of active ventilation techniques should have used to gain the favorable indoor relative humidity condition.

Figure 19: Case Two ambient Relative humidity and outdoor Relative humidity



Case two shows unfavourable out door climatic moderation. Perhaps having enclosed openings and lightweight structure and sectional properties are not helping the building to minimize the outdoor relative humidity. And also the evening time show significant change in the relative humidity chart and deduction of relative humidity is not functional after 18.00 of the day.

Figure 20: Case Three ambient Relative humidity and outdoor Relative humidity

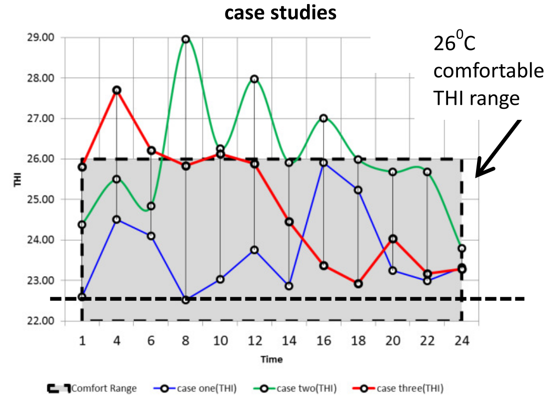


The case study three shows well-disposed outdoor climatic modification to the building user. From 6.00 AM onward the outdoor relative humidity is lower than the outdoor relative humidity. Therefore this has considerably changed in the ambient relative humidity condition.

And also this functionally advantage for the building use because the canteen itself is water vapour producing building. Addition the most of the function happening in the building are not favourable to minimise the relative humidity of the indoor climate.

C Building section and Temperature Humidity Index analysis to understand the thermal comfort level

Figure 21: THI index and comfort level of selected case studies



THI index is calculated by considering the Humidity and the mean temperature of a specific time. THI index does provide the necessary combination of temperature and humidity, in order to gain thermal comfort for human being. However THI index can used to measure such situation the comfort level of selected case studies. This index shows the building indoor thermal comfort level of the building. But regrettably most of the selected case studies show very high THI index which may not favourable for the building user.

Case study one and three shows some form of favourable indoor climatic conditions but the case study three failed to achieve the required thermal comfort level for the building user. The use of lightweight materials and exposed roof structure in the case study two may helped to increase the THI index even in the night time.

VI. CONCLUSION

In conclusion, it is quite evident that the passive climatic modifications are difficult to maintain in warm humid climatic condition such as Sri Lanka. High level of Relative humidity condition is the major discommode for the improvement the thermal comfort. The study shows that selected buildings are not working properly in order to gain required thermal comfort for occupants' throughout the day. However, findings demonstrate an understanding in approach and interventions towards passive climate modification with non-domestic buildings in Sri Lanka. Case studies show a problem with their building design.

The buildings are less efficient for passive climate modification but have showed that having active system support can meet comfort requirement. This is primarily due to the characteristics of building design of selected buildings.

Integration of passive design interventions with building sections can support the climate modification for promoting passive cooling in warm humid climates but it requires a proper understanding and integration of design strategies with areas such as sectional form of buildings.

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