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# Impact of Internal and External Factors In Buiding Energy Consumption under Tropical Climatic Condition

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**Keywords:**

Room sensible cooling load; Room latent Cooling load; Energy conservation; Heating ventilating and air-conditioning; Building materials; Building environment

**Abstract:**

The most commonly used building materials were reviewed concerning their impact on cooling load and architectural interventions. The continuing increase of energy consumption of air conditioning systems suggests a more profound examination of their tropical climatic environment and the impact on the building and an application of passive cooling systems. Furthermore, in this study, mathematical expressions were developed to support decision-makers to select their optimal envelope enhancement strategies for buildings under tropical climatic conditions. Moreover, an economic analysis was also carried out to help prospective users with their energy-saving ideas. Out of selected materials, glass was found to be the most influential material, followed by timber and wall. The results obtained in this study reveals that improvement of material and their impact on energy conservation, especially double glass window over the plain glass window per 100 $m^2$ area, contributes to reducing the overall 22% monthly electricity costs and their AC capacity. Moreover, this study further reveals that improvement of the wall conserves a significant amount of energy; Improved wall over one layer brick wall per 100 $m^2$ area contributes to reducing overall energy by 12 % of their AC capacity and monthly electricity costs. **The primary object of this research** is to study the impact of internal & external factors in building energy consumption under tropical climatic conditions. There are few specific objectives identified to fulfil the main objective. Firstly, the study tries to identify the impact of building cooling load for different building orientations with the most commonly used building materials and their optimisation. Then develop a mathematical equation and graphs for cooling load and their impact of most common use building materials under tropical climatic conditions. Furthermore, this research identifies the direct impact of the capacity of the air conditioning unit and their electricity consumption for RSCL. Finally, find out the payback period for different improvements of exterior walls through economic analysis.

## 1. Introduction

Total energy consumption of building environment including residential and commercial buildings in Europe is almost 40%. Similarly, space conditioning is accountable for 40% to 60% use of total energy in European countries [1]. HVAC systems contribute to 50% of energy usage, which is about 20% of their total energy consumption in the USA building sector. In the middle east region, over 70% of energy demand is for building cooling systems. Especially in tropical countries, air condition accounts for around 56% of total building energy consumption [2]. Consequently, tropical countries use around 20% of total energy to make thermally comfortable building interiors [3]. Nonetheless, many issues arise from burning fossil fuels for energy, such as greenhouse gas emissions, acid rain, climatic change, and dependency on supplies of fossil fuels.

Typically, there are two types of cooling systems. An active cooling system is one in which involves the use of energy to cool the building environment. An active cooling solution includes fan-assisted cooling, spray cooling, refrigeration cycles, jet impingement cooling, and electrowetting cooling. Another cooling method is the passive cooling method, which is in the stage of building design approach that focuses on controlling heat gain and heat dissipation in a building to improve indoor thermal comfort with low energy consumption [4].

Although, many types of research have been developed in an active cooling method. The passive cooling method in architectural approaches ensures comfortable living spaces by utilising energy-intensive materials. That is enabled an overall reduction in energy usage. The active cooling method uses types of equipment to modify the state of the building, creating energy and comfort, while passive cooling maximises energy efficiency by the actual design itself.

Even though the sun is the major energy provider, sunrays create hot climatic conditions throughout the year up to a considerable extent, so the researchers have been identified to invent feasible solutions through a passive cooling method [5] and designed buildings to avoid these disadvantages of the local tropical hot climatic conditions by performing an accurate site analysis. Moreover, the most influential external and internal factors otto be considered as a part of site analysis. External factors included window glass, wall, roof, floor, door types, and internal factors are the number of occupants, lights, and equipment. Thus, the passive cooling method [6] can be applied most easily for new buildings. However, existing buildings can be adapted [7] by only focusing on cost minimisation, performance, and quality objectives. Subsequently, sustainable construction practices are committed to minimising resource depletion, minimising environmental degradation, and creating a healthy building environment [8].

Mostly, solar energy is being identified as the significant heat provider for the building environment. There are many reasons to control solar heat that is admitted into the building. In warm, sunny climates, excess solar heat gain may result in high cooling energy consumption. It is essential to identify the climatic conditions of this building environment. Climate means the typical condition of the humidity, temperature, atmospheric pressure, rainfall, wind and many other meteorological factors in the earth's surface for a long period. There are mainly five types of climates, as can be explained below. It was categorised by using capital letters as follows [9].

- equatorial;
- arid;
- warm temperate;
- snow;
- polar.

Mainly, this paper focuses on the equatorial (tropical) climatic condition. The equatorial, hot and wet climate is found $5^o$ to $10^o$ north and south of the equator [10]. These results from any country in the tropical region can be generalised into a whole region. Thus, this paper was analysed the internal and external factors in building energy consumption in the Sri Lankan context.

## 2. Materials and Methods

In this research, the most common use building materials were selected to study their impact on building energy consumption. The first phase of the literature survey was conducted to identify the thermal properties of those building materials in the region. The results of Table 1 indicated that those selected building materials. Building energy performance studies from tropical countries were investigated to identify these building materials. [10] [12] [13] [14] [15] [16] [17] [18] [19]. Selected building materials and their U-values were calculated and listed in Table 1.

Subsequently, this research was evaluated against the overall objectives and their specific objectives. The analytical aspect of this research was evaluated through selected case studies by utilising two types of buildings such as residential and commercial. In this process, there are four basic steps have been identified. Each step is listed below with their activity and various suggestions and limitations [20].

A detailed literature review was carried out to determine the buildings' internal and external heat gain factors and methodology. Consequently, This subsection was provided to the reader to get an idea of how the methodology was organised methodically [10].

A series of computer simulations were carried out by using DEROB LTH software. This tool was used to collect peak cooling load data for commonly use building materials of the building environment, for different building orientations [21].

**Table 1: Properties on simulation input materials**

| No | Element | Materials | Coefficient (W/m$^2$k) | Number | Element | Material | Coefficient (W/m$^2$k) |
|---|---|---|---|---|---|---|---|
| Outer wall materials | | | | | | | |
| 1 | Cement wall | Cement plaster (10 mm), cement block (200 mm), cement plaster (10 mm) | 5.45 | 4 | Adobe block | Cement plaster (10 mm), adobe block (200 mm), cement plaster (10 mm) | 2.85 |
| 2 | One layer brick wall | Cement plaster (10 mm), brick (80 mm), cement plaster (10 mm) | 4.83 | 5 | Improved wall | Cement plaster (10 mm), brick (80 mm), rigid foam (80 mm), brick (80 mm), cement plaster (10 mm) | 0.28 |
| 3 | Double layer brick wall | Cement plaster (10 mm), double brick (160 mm), cement plaster (10 mm) | 2.97 | | | | |
| Slab materials | | | | | | | |
| 6 | Slab | Cement plaster (10 mm), concrete (113 mm), cement plaster (10 mm) | 12.02 | | | | |
| Roof materials | | | | | | | |
| 7 | Roof 1 | Poly insulation (25 mm), asbestos (6 mm), asbestos (6 mm) | 1.34 | 8 | Roof asbestos | Asbestos (6 mm), asbestos (6 mm) | 18.33 |
| 9 | Roof with tile and timber ceiling | Poly insulation (25 mm), asbestos (6 mm), tile (10 mm), ceiling timber (10 mm) | 1.20 | 10 | Roof with timber | Asbestos (6 mm), timber (10 mm) | 13.76 |
| Timber materials | | | | | | | |
| 11 | Door 1 | Timber(20 mm) | 7.5 | 12 | Softwood | Softwood (20 mm) | 7 |
| 13 | Hard wood | Hard wood (20 mm) | 8 | 14 | Wood fiber medium density | Wood fiber board medium, air space at 21$^0$ C, wood fiber board medium | 0.75 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 15 | Wood fiber low density | Wood fiber board low (20 mm), air space at $21^0$ C (20 mm), wood fiber board low(20mm) | 0.61 | 16 | Wood fiber high density | Wood fiber board high (20 mm), air space at $21^0$ C (20 mm), wood fiber board high (20 mm) | 0.88 |
| Floor materials | | | | | | | |
| 17 | Floor | Earth (500 mm), concrete (50 mm), cement plaster (20 mm) | 2.48 | 18 | Floor with granite | Earth (500 mm), Concrete (50 mm) and Granite (20 mm) | 2.54 |
| 19 | Floor with tile - Floor with burnt clay | Earth (500 mm), concrete (50 mm), clay tiles(15 mm) | 2.47 | 20 | Floor with limestone and marble | Earth (500 mm), Concrete(50 mm), Marble/ Limestone (20 mm) | 2.5 |
| Glass materials | | | | | | | |
| 21 | Double glass | Sol blue<br>Air<br>Kappakla 4 | | 22 | Plain glass | Plain glass | |
| 23 | Trans glass | Trans glass | | 24 | Tinted glass | Tinted glass | |

## 2.1 impact of cooling load, for building orientations with building materials

The energy simulation program “DEROB LTH” was used to develop 3D simulation models [22]. The primary objective of the energy simulation program is to find peak cooling loads for selected building materials for different orientations. The simulation was carried out by utilising two volumes, which has one common opening (window) as depicted in Fig 1 (a), (b), (c).

Volume 1: The dimensions of volume 1 were selected as 2m x 2m x 2m (length x width x height)
Volume 2: the dimensions of the volume 2 were 10m x 10m x10m (length x width x height)

The small window with the dimensions of 1m x 1m (height x width) is a common opening outside for both Volume 1 & Volume 2. The window was positioned at the midpoint, where the centre to volume 2 and volume 1. It helps determine the peak cooling load required to maintain inside design conditions for both Volume 1 and Volume 2 during maximum outside temperatures. The interior walls of the building maintain adiabatic conditions for heat transfer from volume 2 to 1 is negligible [23].

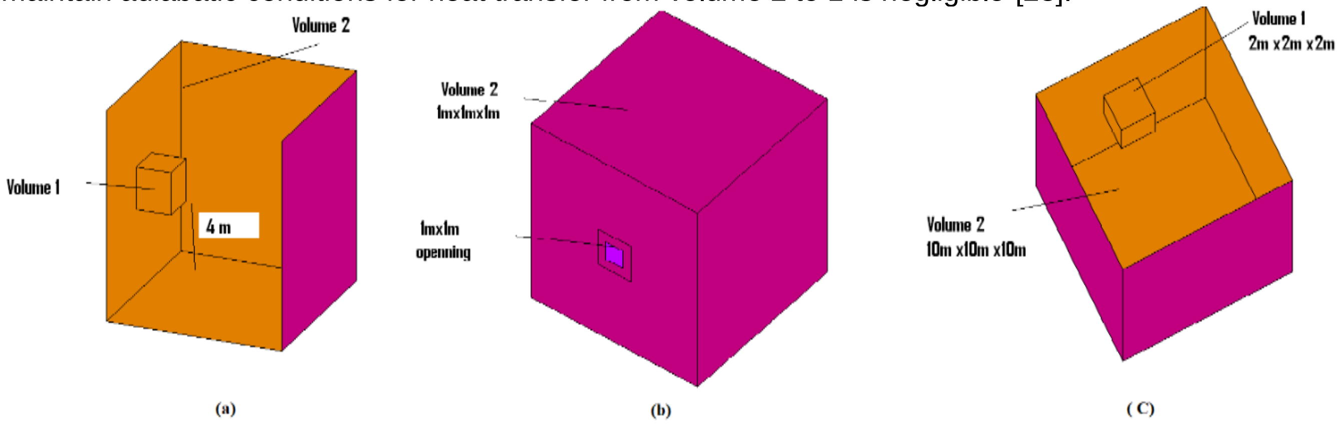

Figure 1: (a) Side internal view (b) outside view (c) plan internal view of Simulated model

## 2.2 The mathematical model for cooling load and impact of building materials

Initially, graphs were plotted against the building orientation to study the impact of individuals commonly use building materials, as shown in Figures 2 to 8. The equations of cooling load per $m^2$ area were developed for individual building materials with their U-values.

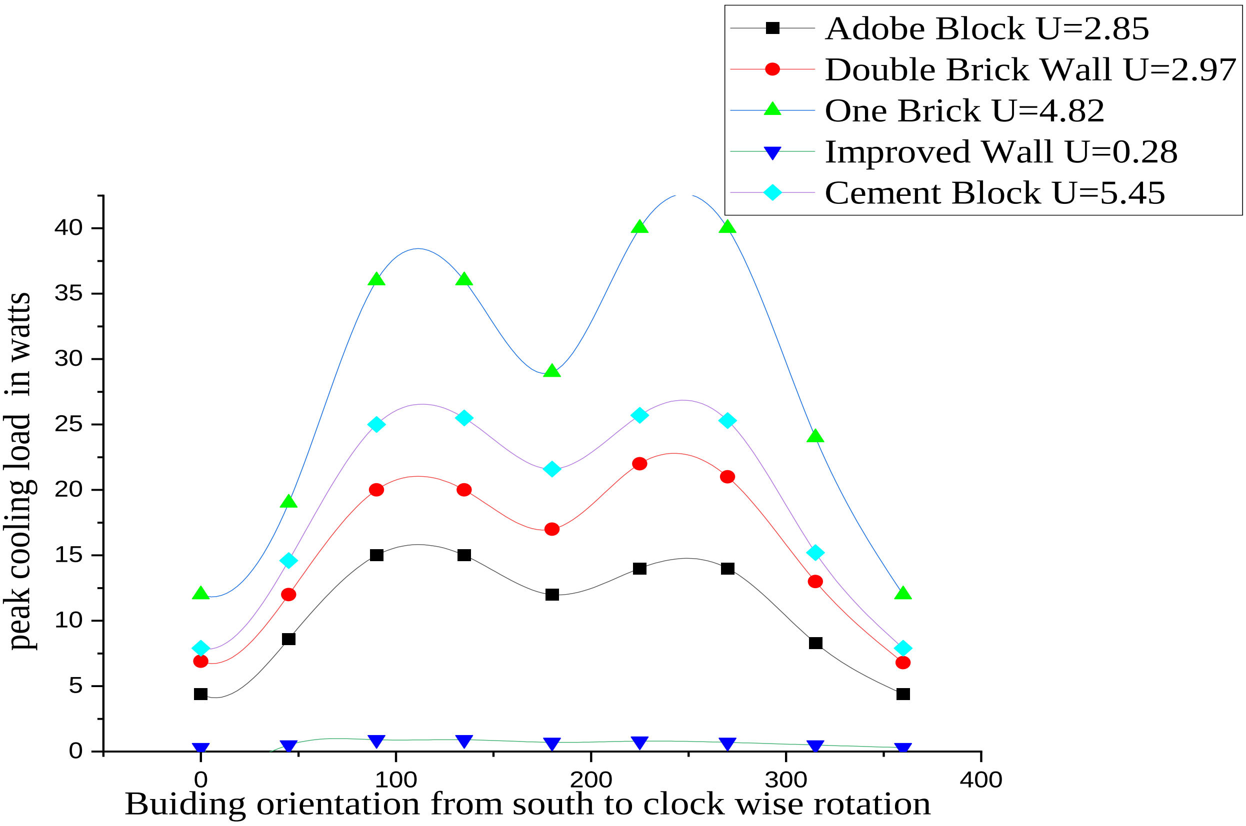

Figure 2: Peak cooling loads for different wall VS building orientations

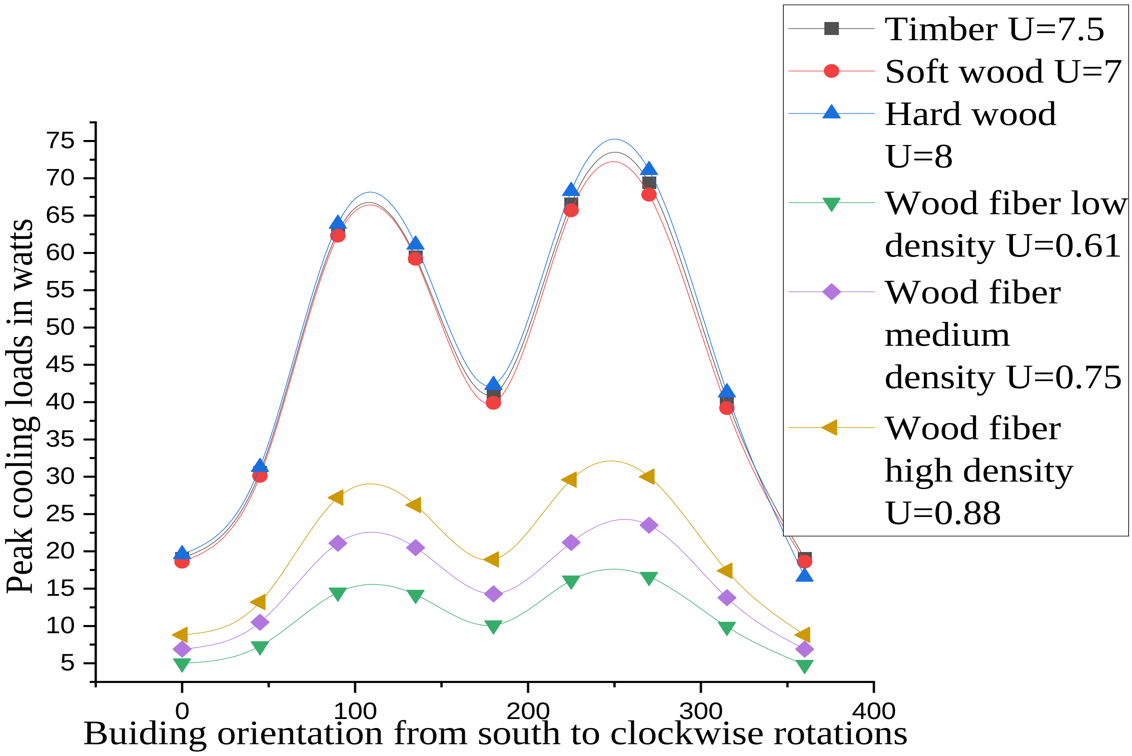

Figure 3: Peak cooling loads for different timber VS building orientations

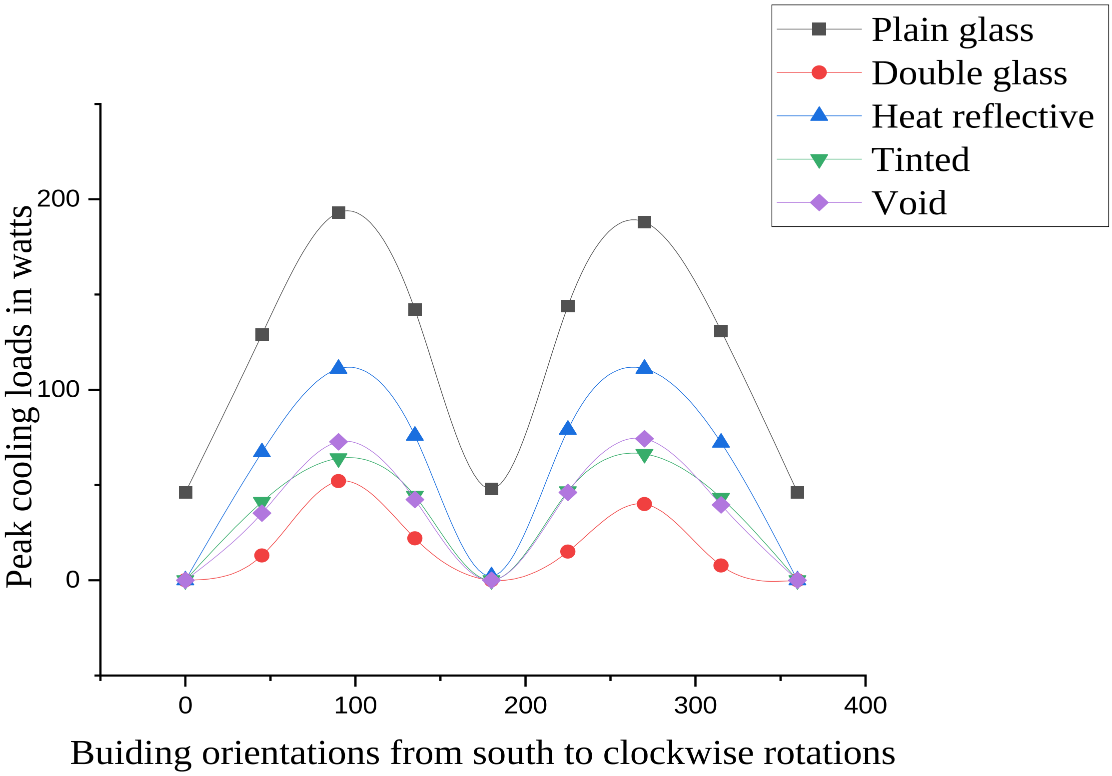

Figure 4: Peak cooling loads for different glasses VS Building orientations

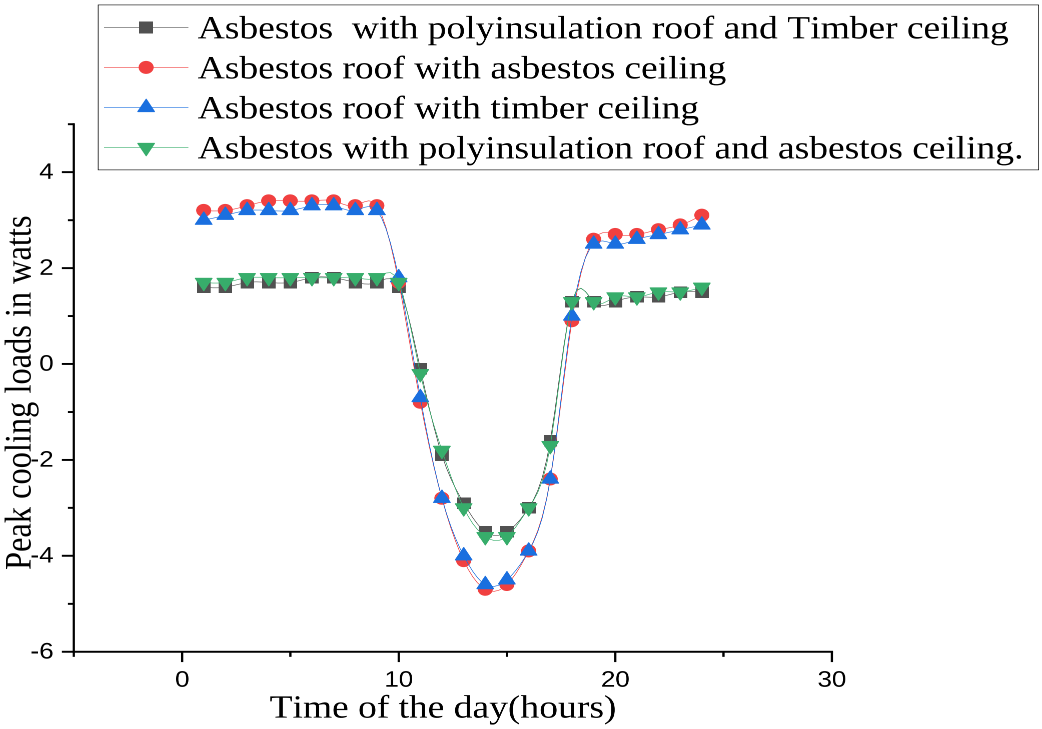

Figure 5: Peak cooling loads for different roof VS no of hours per day

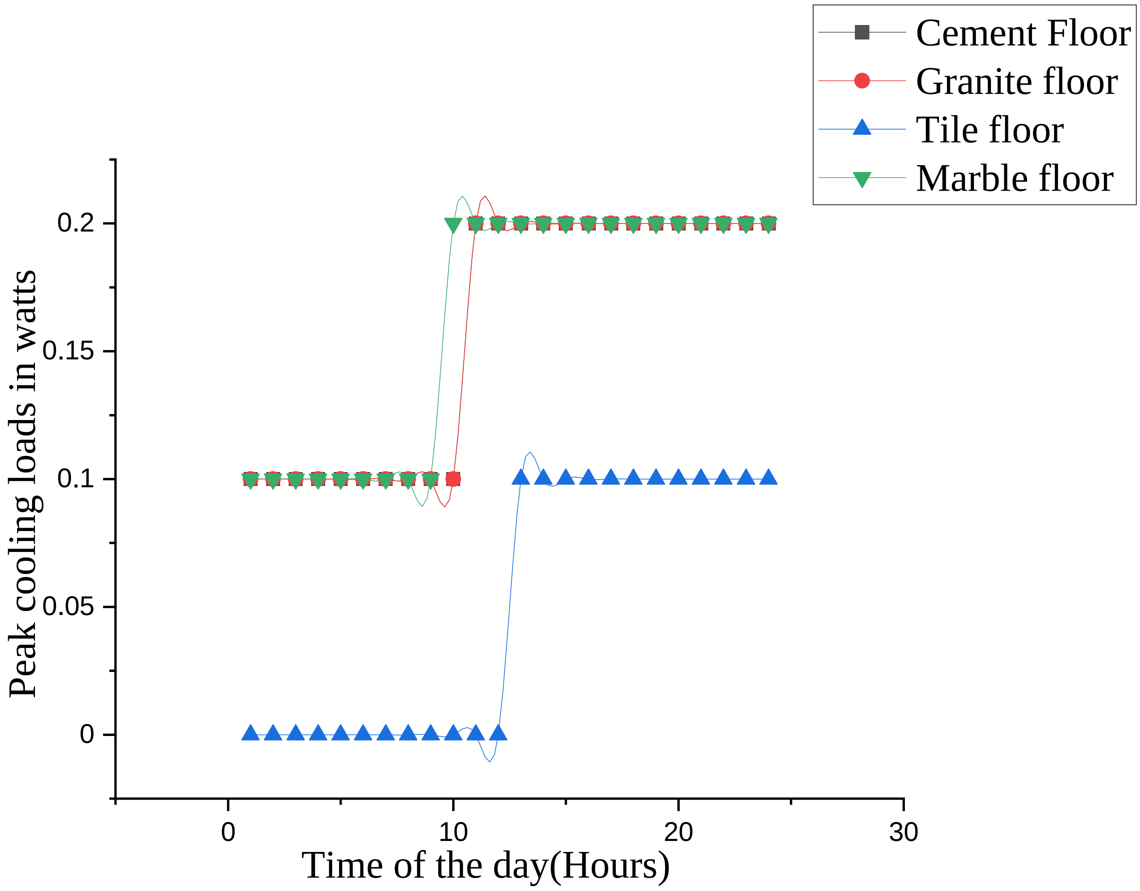

Figure 6: Peak cooling loads for floor VS No of hours per day

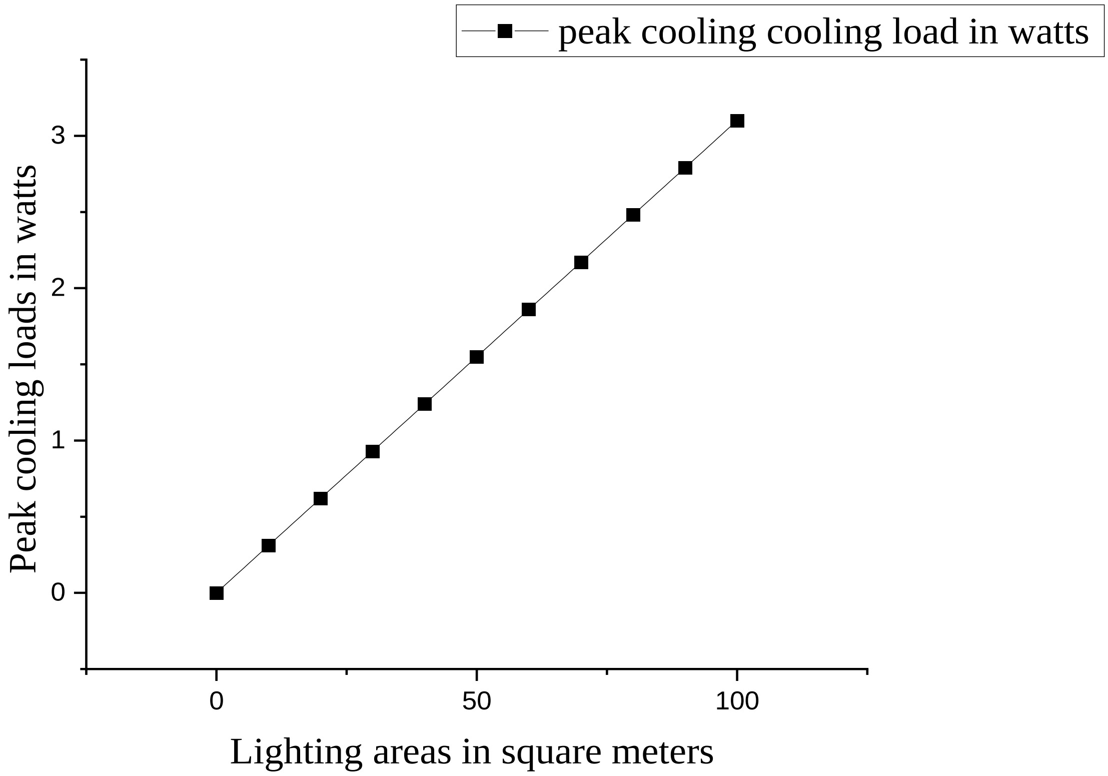

Figure 7: Peak cooling loads in watts VS Lighting area

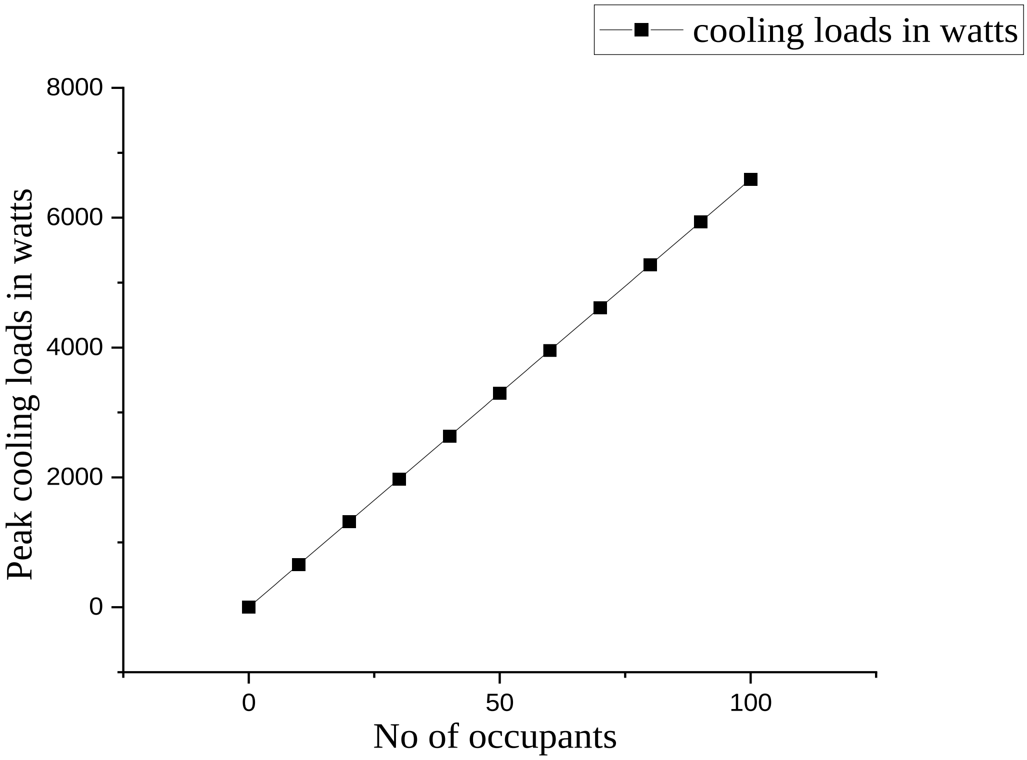

Figure 8: peak cooling loads in watts VS no of occupants

## 2.3 Validation of simulated results for Residential house

In this case study, a proper validation technique is utilised before applying their results. Therefore, the DEROB LTH thermal model is required for its accuracy to be assessed. Validation can be further defined as the calibration of a model in which the residential house peak cooling load was assessed with their theoretical exact and simulated predicted values [24]. The selected residential house in Colombo, Sri Lanka, was simulated to fulfil expectations. Some of the average climatic data on Colombo, Sri Lanka, has been considered during the simulation process. Finally, predictions are compared with their known theoretical exact values as shown in fig 9 (a), (b), (c) and (d). Moreover, the graph (Fig 10) indicates that the actual readings behave similarly to simulation outcomes under tropical climatic conditions [25].

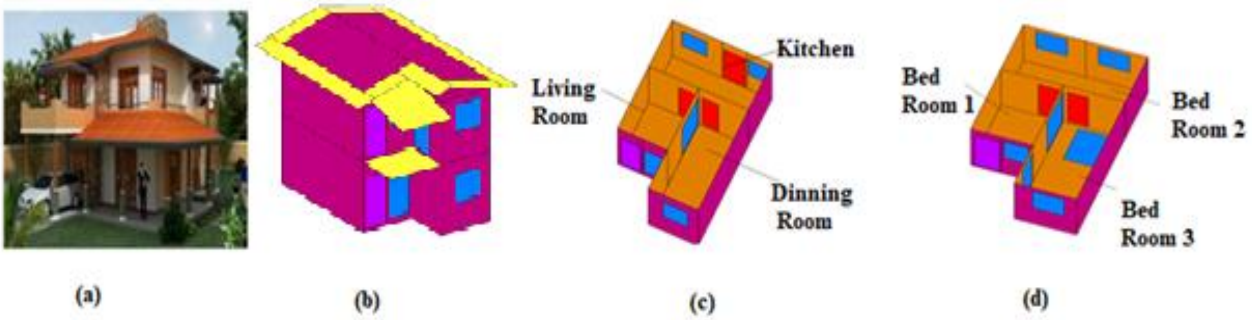

Figure 9: (a) Actual scale residential house (b) 3-D (c) first-floor plan view (d) second-floor plan view of simulated residential House

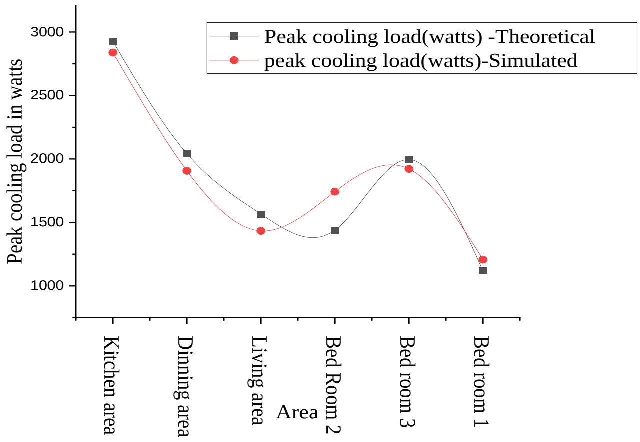

Figure 10: Peak cooling load – (theoretical and simulated) VS Area of house

## 2.4 Impact of the air condition electricity consumption for RSCL for Supermarket (commercial building)

In this case study, middle-level shopping centres were selected, as shown in Figure 11, for further application of derived equations. Furthermore, many shopping centres use air conditioning systems in tropical climates. Most researchers show their studies that modern shopping centres consume relatively large amounts of energy, and they seem to threaten their electricity costs. Most street-based retail stores (87%) appear to be relatively small, with the floor space less than 200m² compared with shopping malls and supermarkets. All these places use electric fans to face hot climatic conditions.

Furthermore, the findings show that the average floor area of street-based shops was 121 m². Most floor areas of these shops are between 13m$^2$ to 1870m² [26]. Nowadays, the State sector participates in the food supply business to regulate the market price of the food product. The prime objective of this is to provide commodities at the lowest price. Less energy consumption contributes significantly to their overall expenditure to fulfil the requirement of competitive price. Buiding design ideas and strategies were essential, especially in the design stage of these buildings. A variety of state-owned supermarkets such as the LakSathosa and Sathosa chain of supermarkets were established in most urban areas. The Private sector investors have been established modern supermarkets such as Keels, Laughs, and Cargill's supermarkets. These supermarkets have been in the main urban centres, attracting mainly upper class and middle-income customers. Also, there has been a growth of planned shopping malls in inner cities (Majestic City, Liberty Plaza, and K Zone) [26].

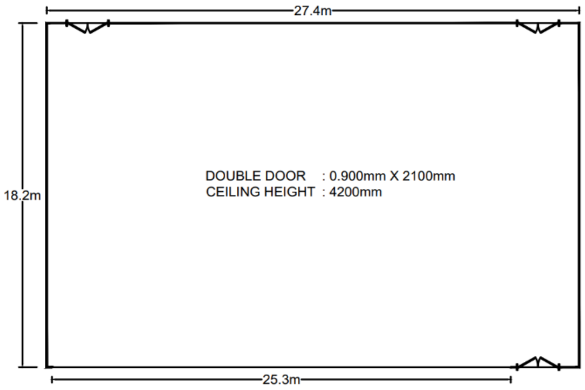

Figure 11: Plan view of selected super supermarket

### 2.4.1 Cost for different wall

Basically, the cost comparison of constructional wall type was tabulated as shown in Table 2 compared with their present price details.

Table 2: Cost comparison for construction of walls

| Wall type | Area | Brickwork | | Two cement plaster | | Material cost in | Total cost in US $ |
|---|---|---|---|---|---|---|---|
| | (1 $m^2$) | | US $ per $m^2 \cdot 10^{-3}$ | | US $ per $m^2 \cdot 10^{-3}$ | US $ per $m^2 \cdot 10^{-3}$ | US $ per $m^2 \cdot 10^{-3}$ |
| One-layer brick walls | 1 | Brick | 58.59 | Cement + Sand | 31.62 | 169.26 | 212.04 |
| | | Cement + sand | 15.81 | Labor | 39.06 | | |
| | | Labor | 24.18 | | 0 | | |
| | | Total | 98.58 | Total | 70.68 | | |
| Double layer brick wall | 1 | Brick | 108.81 | Cement + Sand | 31.62 | 260.4 | 325.5 |
| | | Cement + Sand | 47.43 | Labor | 39.06 | | |
| | | Labor | 33.48 | | 0 | | |
| | | Total | 189.72 | Total | 70.68 | | |
| Single layer cement block wall | 1 | Brick | 47.43 | Cement + Sand | 31.62 | 157.17 | 196.23 |
| | | Cement + Sand | 15.81 | Labor | 39.06 | | |
| | | Labor | 23.25 | | 0 | | |
| | | Total | 86.49 | Total | 70.68 | | |
| Improved walls | 1 | Brick | 108.81 | Cement + Sand | 31.62 | 309.69 | 386.88 |
| | | Cement + Sand | 47.43 | Labor | 39.06 | | |
| | | Rigid foam | 49.29 | | 0 | | |
| | | Labor | 33.48 | | 0 | | |
| | | Total | 239.01 | Total | 70.68 | | |

### 2.4.2 Cost comparison

Cost comparison takes place for lowest influential materials to highest influential materials of their building energy impact. A selected list of items and materials is shown in Table 3.

Table 3: Cost comparison of air conditioners for comparative walls

| Type of wall | Area ($m^2$) | Unit cost in US $ | Investment for wall in US$ | AC capacity in No of tons | Initial cost for A/C in US $ |
|---|---|---|---|---|---|
| One layer brick wall | 301.69 | 2.28 | 7,380.10 | 19.1 | 11,412.06 |
| Improved wall | 301.69 | 4.16 | 13,503.15 | 15.53 | 9,279.02 |
| | | Additional expenses | 6,123.05 | Savings on investment | 2,133.04 |

### 2.4.3 Prices of different air conditioners

An air condition unit prices were calculated for different categories popular in middle-level income consumers. Finally, average prices were taken into consideration is shown in Table 4.

Table 4: Prices for different air-condition capacities

| Capacity (BTU/h) | Ton | Price in US $ | Price in US $ per ton | Average investment per ton in US $ |
|---|---|---|---|---|
| 9,000 | 0.75 | 580 | 773 | 597 |
| 12,000 | 1 | 630 | 630 | |
| 18,000 | 1.5 | 730 | 487 | |
| 24,000 | 2 | 1,000 | 500 | |

The monthly electricity usage of domestic electricity consumers in Sri Lanka is further reviewed in this case study. If they have consumed less than 240 units, they were subsidised according to the present tariff structure. However, many air condition users' consumption levels are always more than 240 units. Electricity consumers who consume less than 240 are fully neglected in this analysis [27].

## 2.5 The payback period for different exterior walls

### 2.5.1 Different RSCL with A/C capacities and operational cost

Table 5 presents different consumers' electricity tariff structures for the operational cost calculation. All cost components in these tariffs are taken from the public utility reform commission in Sri Lanka. Furthermore, to assess economic impact with their RSCL per 100 square meter area is considered [21]. Then A/C capacity, operational cost, and constructional cost were also calculated and tabulated in Table 6. Figure 12 shows that initial investment of glass and wall materials were recovered within 3 to 4 months, respectively. Figure 13 shows the linear variation of A/C capacity for room sensible cooling load per 100 $m^2$. However, Figure 14 shows an exponential variation of monthly electricity charges for room sensible cooling load.

Table 5: Monthly Electricity prices with respect to RSCL for different consumers in Srilanka

| RSCL per 100 $m^2$ area | Domestic (D) US $ | Religious US $ | Industry I1/I2/I3 US $ | Hotel (H1, H2, H3) US $ | | | General Purpose GP -1/GP-2/GP-3 US $ |
|---|---|---|---|---|---|---|---|
| 49725 | 5378 | 1406 | 1600 | 2914 | 1861 | 1822 | 2914 |
| 58416 | 6093 | 1593 | 1808 | 3301 | 2104 | 2060 | 3301 |
| 132405 | 17469 | 4563 | 5126 | 9463 | 5975 | 5849 | 9463 |
| 186943 | 22181 | 5793 | 6501 | 12015 | 7579 | 7419 | 12015 |

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Table 6: A/C and operational cost for different RSCL values

| Material | RSCL per $100m^2$ area | Average Ac capacity (ton) $100m^2$ area | Operational cost in US \$ per annual through $100m^2$ area per month | construction cost in US \$ per $100m^2$ Area | Change in RSCL per $100m^2$ area | Average change Ac capacity (ton) $100m^2$ area |
|---|---|---|---|---|---|---|
| Improved Wall | 49714 | 5 | 2442 | 4476 | 0 | 0 |
| Onelayer brick | 58416 | 6 | 2764 | 2446 | 8702 | 1 |
| Double Glass | 132405 | 17 | 2327 | 4301 | 82692 | 11 |
| Plain Glass | 186943 | 21 | 2949 | 129 | 137229 | 16 |

# 3. Results and Discussion

## 3.1 Impact of external factors in building energy consumption

The impact of cooling load through exterior wall material was a function of building orientation and building overall heat transfer coefficient *U*. Equations 1 to 6 show the expression for exterior wall materials.

$$Q = A + B\sin\left(\frac{11\Theta}{630}\right), \quad 0 < \Theta < 180; \tag{1}$$

$$Q = A - B\sin\left(\frac{11\Theta}{630}\right), \quad 180 < \Theta < 360; \tag{2}$$

$$A = 5.02U - 1.78; \tag{3}$$

$$B = U \tag{4}$$

$$Q_{error} = 0.19\ln(\Theta) + 3.35; \tag{5}$$

$$Q_{Total} = Q + Q_{error}, \tag{6}$$

where:

$Q$ is the heat load effect to cooling load in W,

$\Theta$ is the rotated angle of the building from the south,

$A$ is the overall coefficient of heat transmission in W/m$^2$,

Similarly, the Impact of cooling load through timber material was a function of building orientation and their overall heat transfer coefficient (U). The equations (7), (8), (9), (10), (11) and Table 7 show expressions for exterior timber material.

$$Q = A + B\sin\left(\frac{11\Theta}{630}\right), \quad 0 < \Theta < 180; \tag{7}$$

$$Q = A - B\sin\left(\frac{11\Theta}{630}\right), \quad 180 < \Theta < 360; \tag{8}$$

$$A = 130.4\ln(U) + 17.89; \tag{9}$$

$$B = 5.31\ln(U) + 8.46 \tag{10}$$

$$Q_{Total} = Q + Q_{error}, \tag{11}$$

where:
$Q$ is the heat load effect to cooling Load in W,
$U$ is the overall coefficient of heat transmission in W/m$^2$k,
$\Theta$ is the rotated angle of the building from south.

**Table 3: Q $_{error}$ and U-value relations**

| U-values | $Q_{\text{error}}$ |
|---|---|
| *U*=7, *U*=7.5, *U*=8 | $17.5\ln(X) - 87.26$ |
| *U*=0.61, *U*=0.88, *U*=0.75 | $X^{2.97}$ |

Moreover, mathematical expressions for the impact of cooling loads of individual glass material is tabulated in Table 8.

**Table 8: Equations for average cooling load for different glass material**

| Window glass | Equation | Window glass | Equation |
|---|---|---|---|
| Plain glass | $Q = 120 + 73\sin(\Theta)$ | Tinted glass | $Q = 60\sin(\Theta)$ |
| Trans glass | $Q = 110\sin(\Theta)$ | Double glass | $Q = 20\sin(\Theta)$ |
| No glass (void space) | $Q = 62\sin(\Theta)$ | | |

Here $Q$ is the average cooling load required in watts

## 3.2 Impact of internal factors in the building energy consumption

Equation (12) shows the expression for the impact of cooling loads due to a number of the occupant:

$$Q = M \cdot P. \tag{12}$$

Here $M = 66.7P$ is the number of occupants.

Equation (13) shows the expressions for the impact of cooling loads due to a number of occupants:

$$Q = M \cdot N, \tag{13}$$

where $M = 0.003$, depending upon the properties of light fittings, $N$ is the number of light fittings $Q$ is the cooling load required because of lights.

## 3.3 Life cycle cost analysis

This research uses Net Present Values (NPT) technique to assess the payback period for most influential building materials. In addition, monthly electricity charges due to room sensible cooling loads were analysed for different electricity users. Moreover, Common equations were developed to estimate monthly electricity costs due to room sensible cooling load [28].

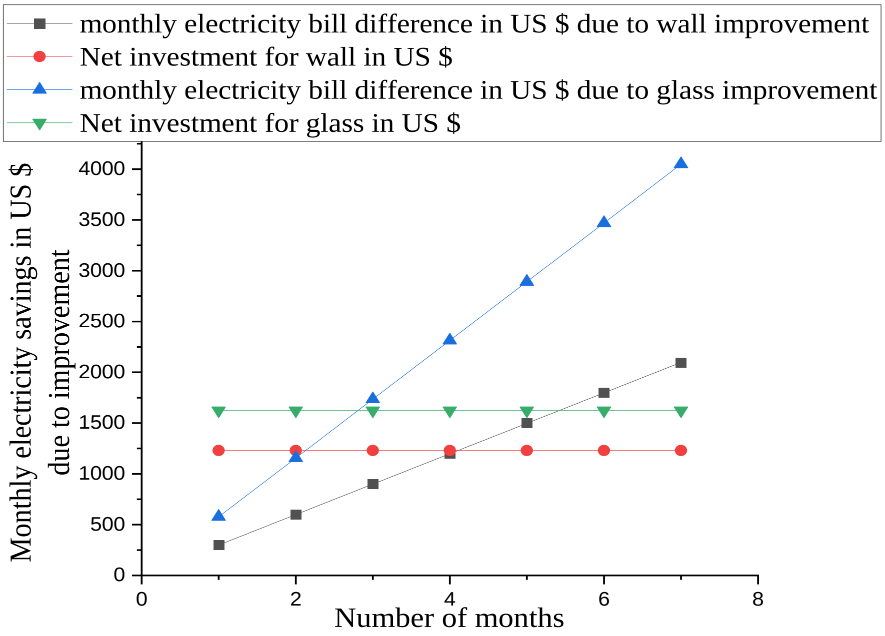

Figure 12 Monthly electricity costs VS Net investment for improvement

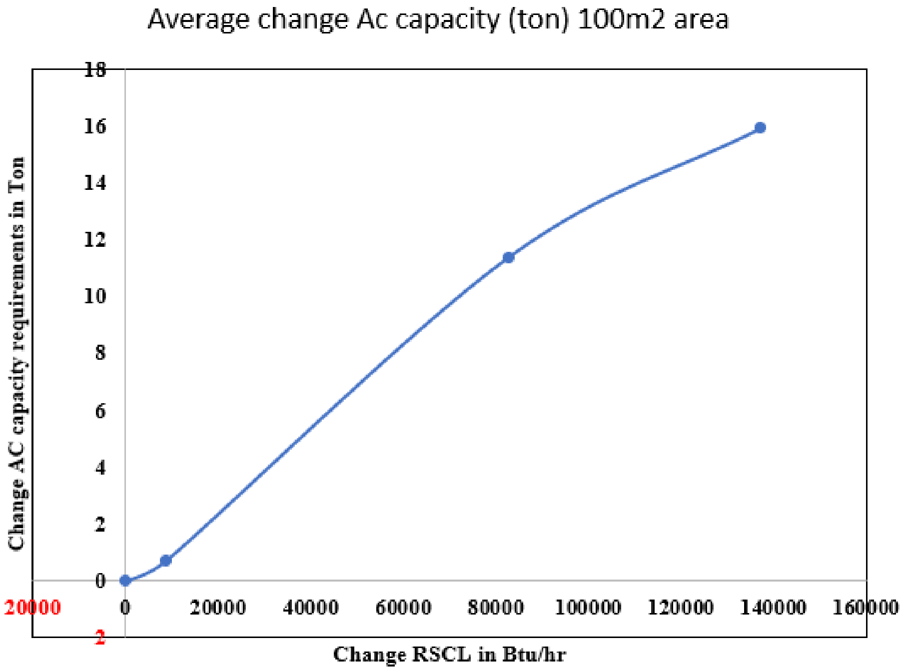

Figure 13 Change in A/C capacity VS change in RSCL

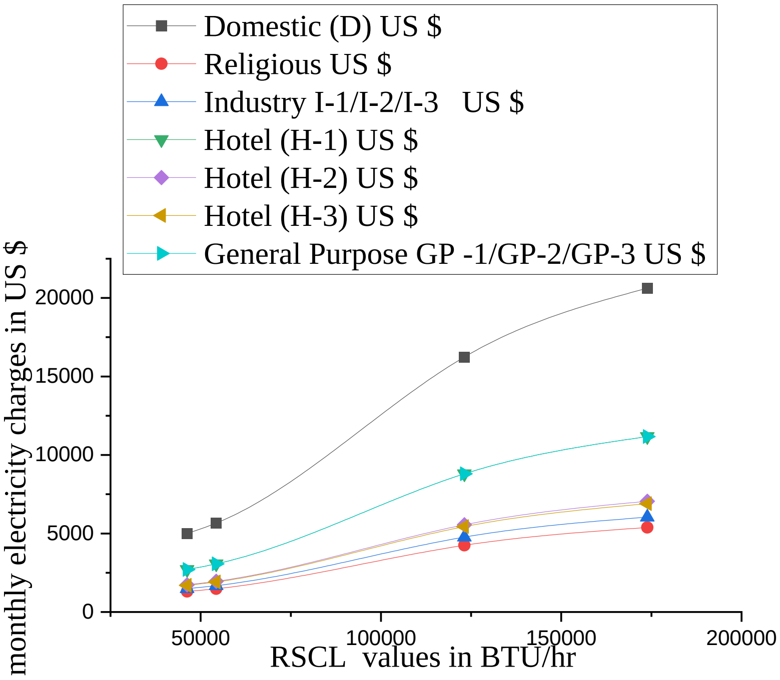

Figure 14 Monthly electricity charges in US $ VS RSCL values in BTU/hr

Table 4: P and Q for different unit price

| Electricity Tariff | Unit price after 240 units US $ (T) | *P* or *Q* | Electricity tariff | Unit price after 240 units US $ (T) | *P* or *Q* |
|---|---|---|---|---|---|
| Domestic | 0.36 | 12 | Industry | 0.10 | 3.5 |
| General purpose | 0.20 | 6 | Religious | 0.09 | 3.1 |
| Hotel -3 | 0.12 | 4 | | | |

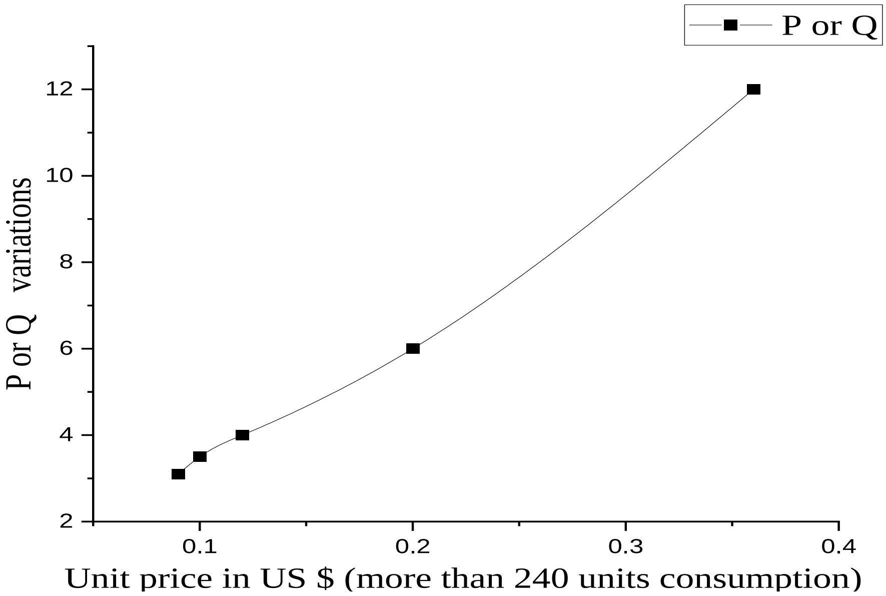

Figure 15 P/Q Vs Electricity unit price in US $

The expressions (14) and (15) was derived for different types of electricity tariff:

$$M \cdot E = P\ln(R) - Q, \tag{14}$$

$$Q = 32.58T + 0.05, \quad (15)$$

where:
$R$ is the room sensible cooling load (RSCL),
$M \cdot E$ is the monthly electricity charges in US $,
$Q$ is the variable as shown in Table 9,
$T$ is the unit price after 240 units in US $.

**Table 5 Net investment in US $ for improved glass and wall**

| No of months | Monthly electricity costs difference in US $ due to wall improvement | Net investment for the wall in US $ | Monthly electricity costs difference in US $ due to glass improvement | Net investment for glass in US $ |
|---|---|---|---|---|
| 1 | 299.57 | 1229.97 | 578.41 | 1623.32 |
| 2 | 599.15 | 1229.97 | 1156.83 | 1623.32 |
| 3 | 898.72 | 1229.97 | 1735.24 | 1623.32 |
| 4 | 1198.30 | 1229.97 | 2313.65 | 1623.32 |
| 5 | 1497.87 | 1229.97 | 2892.06 | 1623.32 |
| 6 | 1797.44 | 1229.97 | 3470.48 | 1623.32 |
| 7 | 2097.02 | 1229.97 | 4048.89 | 1623.32 |

**Table 6 conceiving feature of a relevant solution**

| Elements | Features |
|---|---|
| Timber | The peak cooling load of the timber is determined in the range of 4 to 70 watts per 100 $m^2$ area. The timber's maximum and minimum impacts were revealed on the east/west surfaces and north /south surfaces, respectively (Sinusoidal variation). |
| Walls | Impacts of the selected walls were analysed, and the peak cooling load of the walls reached under the range of 0 to 40 watts per 100 $m^2$ wall area. The maximum and minimum impacts of the walls were revealed on the east/west surfaces and north /south surfaces (Sinusoidal variation). |
| Glasses | Selected glasses were analysed. Impacts through glasses felt in the range of 0 to 200w per 100 $m^2$ glass area. East and west glasses gave the maximum impact, and the minimum impact was given by north and south glasses (Sinusoidal variation). |
| Roof | Impacts of cooling load through the floor were not related to building orientation. The cooling load through the floor was changed after 9:00 am to 6:00 pm (Pulse variation) |
| Floors | Impacts of cooling load through the floor were not related to building orientation. The cooling load through the floor was changed after 10 am (Pulse variation). |
| People | Impacts of cooling load are proportional to the number of people (Linear variation). |
| Roof | Impacts of cooling load through the floor were not related to building orientation. The cooling load through the floor was changed from 9:00 am to 6:00 pm (Pulse variation). |

In addition, the graphical results can be used for any relevant application. Primarily, the room sensible cooling load can be determined by the graph. The A/C capacity requirement can be assessed with their room sensible cooling load. A significant amount of energy can be conserved by altering their architectural views, as shown in Figure 16 (a) and (b) [29].

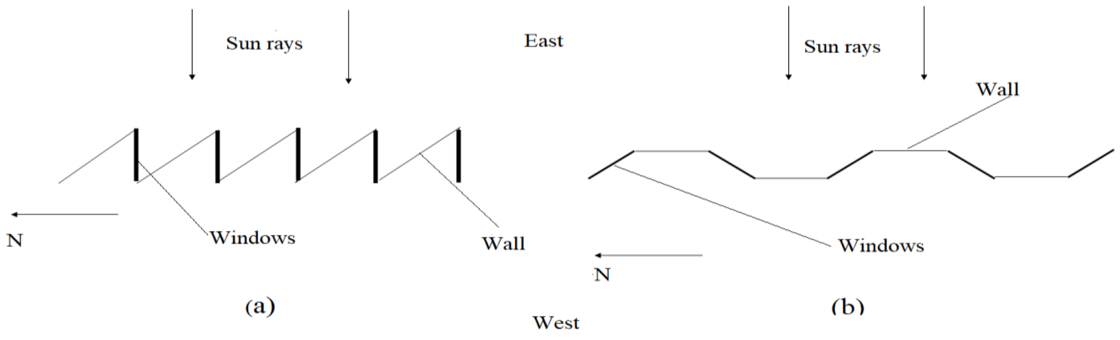

Figure 16 (a) and (b) Different improved architectural views

Skylights can be introduced to provide adequate daylight illumination of buildings. This effort will be helpful to conserve a significant amount of energy. Daylight costs, considerably low and less heat to space than equivalent amounts of illumination from electric lights. Then impacts of the cooling load and the amount of heat contribution to a building by electric lighting can be minimised. Moreover, an application of skylight for the north and south surfaces is highly profitable [30].

## 4. Conclusions

Common building materials were reviewed with their overall impact of cooling load with their external and internal interventions. The research shows a continuous increase in energy consumption of air condition systems. Then they suggest a more in-depth examination of their tropical climatic conditions and their impact on buildings. Furthermore researchers review that the double glass over plain glass window per 100 $m^2$ area reduces overall saving of 22%, including reducing AC capacity from 19.89 to 15.67 tons and electricity charges from US $ 2742.34 to US $ 2163.93. Similarly, the study reveals that the improvement of wall elements conserves a significant amount of energy. An improved wall over one layer brick wall per 100 $m^2$ area reduces overall saving of 12%, including reducing AC capacity from 5.74 to 5.07 tons and electricity costs from US $ 2570.51 to US $ 2270.94.

Furthermore, in this study, expression was developed to support decision-makers to select necessary strategies for optimal envelope enhancement of buildings under tropical climatic conditions.

Therefore, the authors are planning to extend their analysis of different building applications with recent inventions and integrate the life cycle in the next phase of the study.

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