ANALYSIS IN ENERGY CONSUMPTION BY VARIOUS CONSTRUTION MATERIALS USING BUILDING INFORMATION MODELING

S. Binil Sundar[*]

ABSTRACT

The normal energy consumption of any building has been on the rise since the past few decades. And the majority of the energy that one spends goes into HVAC. Due to the increasing heat from global warming, vehicular heat and urban heat island effect etc. the indoor temperatures have gone beyond livable conditions. And so almost every building is equipped with one or more air conditioners. As a result of that the energy consumed by each house increases, resulting in an overall energy scarcity. Studies show that the exterior walls and roofs of a building absorb heat during the day and conduct the heat absorbed into the building, which increases the indoor air temperature. This project is an attempt to identify the building materials that contribute very little to indoor air temperature and their effects on energy consumption. The indoor air temperature may vary based on several factors such as, thermal conductivity, emissivity, reflectance etc. of the materials used in construction. Based on these factors, computerized analyses in various Building Information Modeling softwares are done to identify the best suited materials for our climatic conditions. And a comparative study is done to show the variation in construction and operational costs of a building when these materials are used over conventional materials.

KEYWORDS: Building Information Modelling, Thermal Conductivity, Sun Study, Heat load Calculations, Energy Analysis.

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1.0 INTRODUCTION

Energy is a very scarce resource in our country do to the huge population rising every day. The growing population along with the increasing temperatures due to global warming has made HVAC the major energy consumer. Studies show that 30-50% of the total energy generated by the country goes to domestic HVAC alone. Generally speaking, the residential sector accounts for the major part of the energy consumed in buildings; in developing countries the share can be over 90%. Thus, the building sector has a considerable potential for positive change, to become more efficient in terms of resource & energy use, become environmentally less intensive and hence become more profitable.

The scope of the project lies in the study & comparison of various eco-friendly building materials available to the conventional materials. It deals with the proposal of cost-effective & eco-friendly materials for each element of a house an alternative to conventional houses. The project also deals with cost comparison between the conventional & the proposed eco-friendly house.

BUILDING INFORMANTION MODELLING (BIM)

The National Building Information Model Standard Project Committee has the following definition:

Building Information Modelling (BIM) is a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition.

Traditional building design was largely reliant upon two-dimensional drawings (plans, elevations, sections, etc.). Building information modelling extends this beyond 3D, augmenting the three primary spatial dimensions (width, height and depth) with time as the fourth dimension (4D) and cost as the fifth (5D), etc. BIM therefore covers more than just geometry. It also covers spatial relationships, light analysis, geographic information, and quantities and properties of building components (for example, manufacturers' details).

2.0 LITERATURE REVIEW

2.1 The Impact of Anthropogenic Heat on Formation of Urban Heat Island and Energy Consumption Balance

P. Shahmohamadi, A. I. Che-Ani, K. N. A. Maulud, N. M. Tawil, and N. A. G. Abdullah

This paper investigates the impact of anthropogenic heat on formation of urban heat island (UHI) and also determines which factors can directly affect energy use in the city. It explores literally the conceptual framework of confliction between anthropogenic heat and urban structure, which produced UHI intensity and affected energy consumption balance. It then discusses how these two factors can be affected and gives implication to the city and then focuses on whether actions should be taken for balancing adaptation and mitigation of UHI effects. It will be concluded by making the three important strategies to minimize the impact of UHI on energy consumption: landscaping, using albedo materials on external surfaces of buildings and urban areas, and promoting natural ventilation.

2.2 Effects of Solar Absorption Coefficient of External Wall on Building Energy Consumption

Jian Yao, Chengwen Yan

The principle concern of this paper is to determine the impact of solar absorption coefficient of external wall on building energy consumption. Simulations were carried out on a typical residential building by using the simulation Toolkit DeST-h. Results show that reducing solar absorption coefficient leads to a great reduction in building energy consumption and thus light-colored materials are suitable.

2.3 Reducing urban heat island effects: A systematic review to achieve energy consumption balance *A. I. Che-Ani1, A. Ramly, K. N. A. Maulud1l*

Considering the current energy consumption worldwide, it has become increasingly important to study the effects of urban heat island on energy consumption in order to improve the environment. This paper investigates the impact of Urban Heat Island (UHI) on energy consumption and also determines which factors can directly affect energy use in the city. The UHI current knowledge and literature are reviewed, as well as how UHI can affect energy consumption. This paper explores literally the conceptual framework of confliction between population and urban structure, which produce UHI intensity and affected energy consumption balance. It is then discussed how these two factors can be affected and gives implication to the city and then, focuses on whether actions should be taken for balancing adaptation and mitigation UHI effects. It will be concluded by making the three important strategies to minimize the impact of UHI on energy consumption: providing an appropriate landscape, using appropriate materials on external surfaces of buildings and urban areas and promoting natural ventilation.

3.0 METHODOLOGY

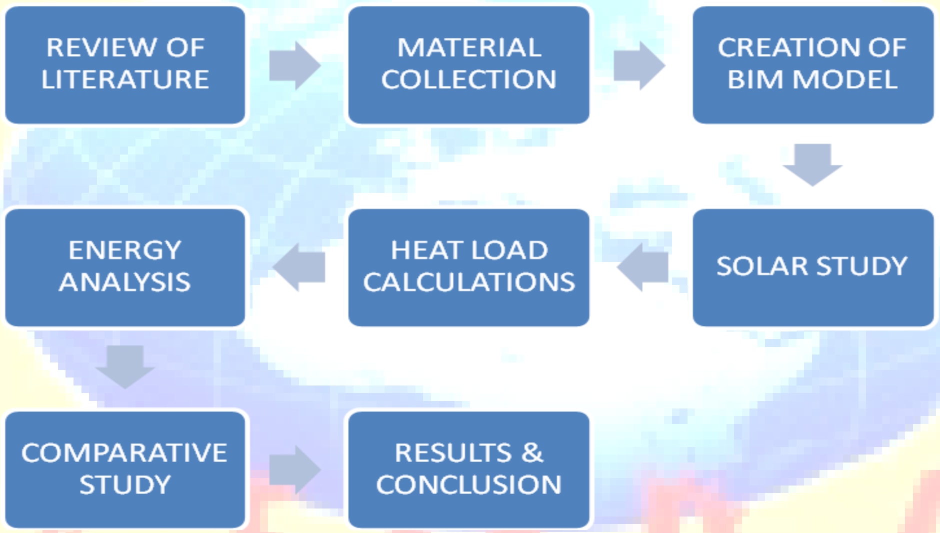


FIGURE 3.1 METHODOLOGY

3.1 METHODOLOGY:

A BIM model of the building under study was created in Revit Architecture with the below materials. The model was then imported to Autodesk Vasari to perform Solar Study to determine the faces of the building that are exposed to high temperatures during the day. The model was later imported into Revit MEP to perform Heat load calculationsand predict the cooling loads present inside the building. Then the model was finally uploaded into Green Building Studio to perform Energy Analysis co calculate the energy consumption of the building. Since all the above analyses are location based, the site was selected in Aminjikarai near Ampa

Mall (Skywalk). I had selected this site for my study since it is located in a mixed urban environment.

4.0 MATERIALS USED IN STUDY

A. ROOF MATERIALS

Fig.4.1 Insulla Tiles

Fig.4.2 Terracotta tiles

INSULLA TILES:

Insulla Heat Insulation Tiles are made from PCM (Phase Change Material) Technology by using micro encapsulated PCM's which is being leak-proof and stable and it has selected geo-in-organic products as binders using a special mechanical process. They are designed to control the flow of heat from roof and used as surface resistant about 60 % of saving in energy as compared to normal roofing.

TERRACOTTA TILES:

Roof tiles are designed mainly to keep out rain, and are traditionally made from locally available materials such as terracotta. Roof tiling has been used to provide a protective weather envelope to the sides of timber frame buildings. These are hung on laths nailed to wall timbers, with tiles specially moulded to cover corners and jambs. Often these tiles are shaped at the exposed end to give a decorative effect.

B. WALL MATERIALS

Fig.4.3 Aerocon Blocks

Fig.4.4 Porothern Blocks

Fig.4.5 Burnt clay bricks

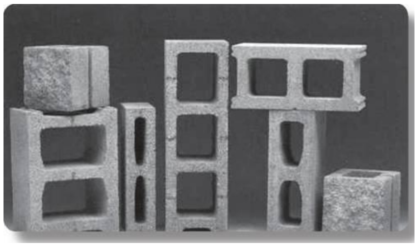


Fig.4.6 Hollow concrete blocks

AEROCON BLOCKS:

Aerocon blocks are an Autoclaved Aerated concrete blocks used in the construction of walls. The raw materials used in the manufacture of these blocks are environmentally friendly and are certified green products. Fly ash is also used as an alternative building material which is a waste from thermal power plants. Since, these materials are light weight with high thermal insulation, they are highly fire resistant. These blocks save water during construction and ensure long term sustainability of the building.

POROTHERM HP:

Porotherm Horizontally Perforated Clay Bricks - a natural walling material providing high thermal insulation, ease of construction and high structural stability. These are factory made clay bricks with horizontally perforated holes to act as a thermal Insulation.

BURNT CLAY BRICKS:

A brick is a block or a single unit of a ceramic material used in masonry construction. Typically bricks are stacked together or laid as brick work using various kinds of mortar to hold the bricks together and make a permanent structure. Bricks are typically produced in common or standard sizes in bulk quantities. They have been regarded as one of the longest lasting and strongest building materials used throughout history.

CONCRETE MASONRY UNITS:

Concrete blocks are made from cast concrete, i.e. Portland cement and aggregate, usually sand and fine gravel for high-density blocks. Lower density blocks may use industrial wastes as an aggregate. Lightweight blocks can also be produced using aerated concrete. Concrete block, when built in tandem with concrete columns and tie beams and reinforced with rebar, is a very common building material for the load-bearing walls of buildings, in what is termed "concrete block structure" (CBS) construction. American suburban houses typically employ a concrete foundation and slab with a concrete block wall on the perimeter.

C. WINDOW MATERIALS

Fig.4.7 UPVC windows with Double Panel Low-E glass

UPVC WINDOWS:

Insulated glazing (IG), more commonly known as double glazing (or double-pane, and increasingly triple glazing/pane) are double or triple glass window panes separated by an air or other gas filled space to reduce heat transfer across a part of the building envelope.

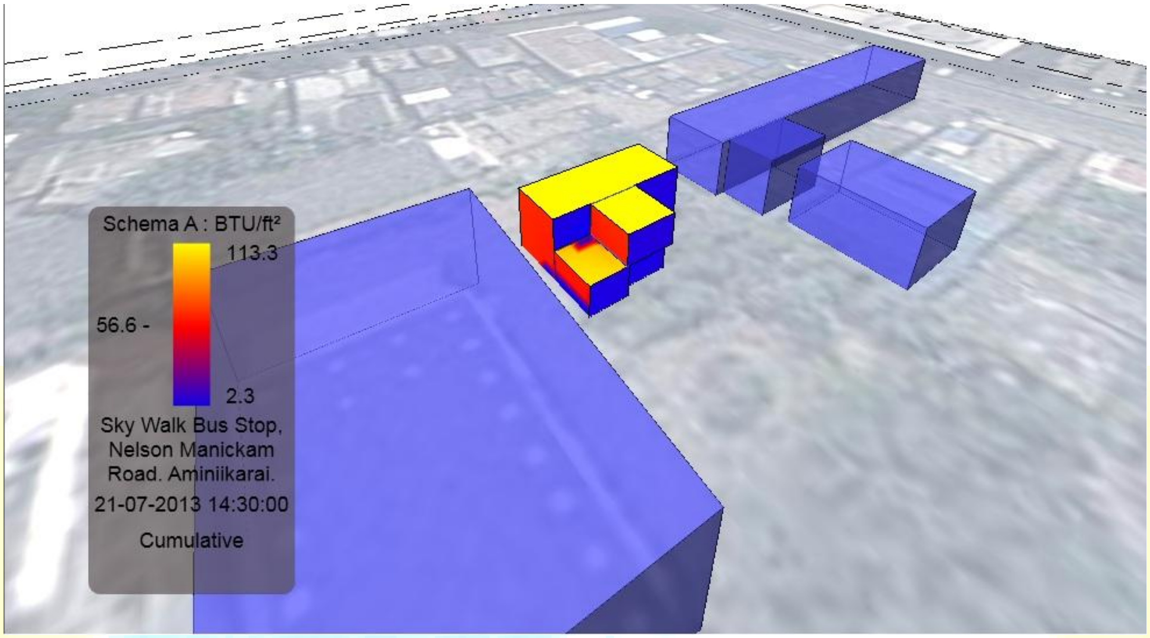


FIGURE HEAT INTENSITIES AT 2:30 p.m.

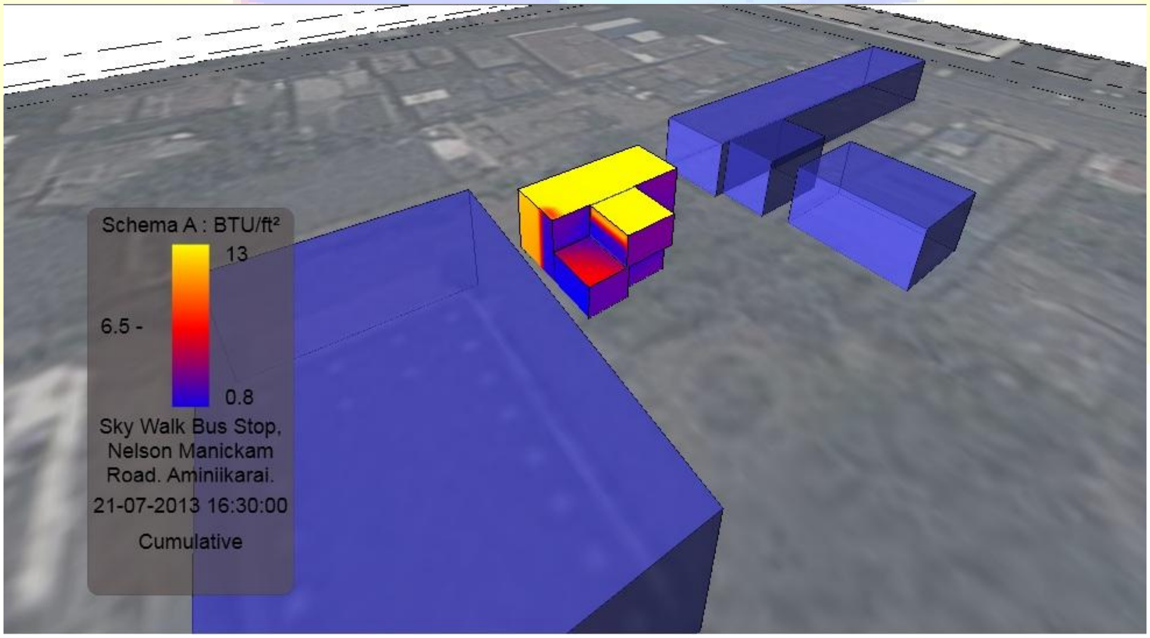


FIGURE HEAT INTENSITIES AT 4:30 p.m.

5.0 OBSERVATIONS:

The **yellow colored areas** depict areas of **high heat intensity** and the **blue areas are cold**. Therefore the **faces of the house experiencing high intensity of the sun are the east, west and the roof.**

6.0 CALCULATION OF CONSTRUCTION COSTS:

6.1 Cost incurred for 100CFt of 9" Brickwork with 1:6 CM

Size of 1 brick = .6233x.2952x.2952 = **.0543 CFt**

Number of bricks per 1 CFt = 1/.0543 = **19 bricks**

Number of bricks per 100 CFt = 18.4162x100 = **1842 bricks**

Mortar joints constitute 25% in brickwork

Therefore actual number of bricks including 5% of wastage

= 1842 – 25 % (1842) + 5%(1842) = **1475 bricks**

Volume of mortar = 25% of bricks x size of brick = 25% (1842) x .0543 = **25 CFt**

Volume of Cement = (1/7) * 25 = 3.5714 CFt = **3 bags**

Since 1 (50kg) bag =1.225CFt

Volume of Sand = 25 - 3.5714 = 21.428 or **22 CFt**

TABLE.1 Cost incurred for 100 CFt of 9" Brickwork with 1:6 CM

MATERIALS	QUANTITY	COST (Rs)	TOTAL COST (Rs)
BRICKS	1475 Bricks	6	8844
CEMENT	3 Bags	300	900
SAND	22 CFt	25	550

*Cost incurred for 100 CFt of 9" Brickwork with 1:6 CM = **Rs. 10294***

6.2 Cost incurred for 100 CFt of 9" AEROCON Block work with 1:6 CM

Size of 1 AEROCON Block = 1.9685 x.6561x.6561 = **.8473CFt**

Number of bricks per 1 CFt = 1/.8473 = **1.1802blocks**

Number of bricks per 100 CFt = 18.4162x100 = **118 blocks**

Mortar joints constitute 25% in brickwork

Therefore actual number of bricks including 5% of wastage

= 118 – 25 % (118) + 5% (118) = **95blocks**

Volume of mortar = 25% of bricks x size of brick = 25% (118) x .8473 = **25 CFt**

Volume of Cement = (1/7) * 25 = 3.5714 CFt = **3 bags**

Since 1 (50kg) bag = 1.225 CFt

Volume of Sand = 25 - 3.5714 = 21.428 or **22 CFt**

TABLE.2 Cost incurred for 100 CFt of 9" AEROCON Block work with 1:6 CM

MATERIALS	QUANTITY	COST (Rs)	TOTAL COST
AEROCON	95 Blocks	120	11400
CEMENT	3Bags	300	900
SAND	22 CFt	25	550

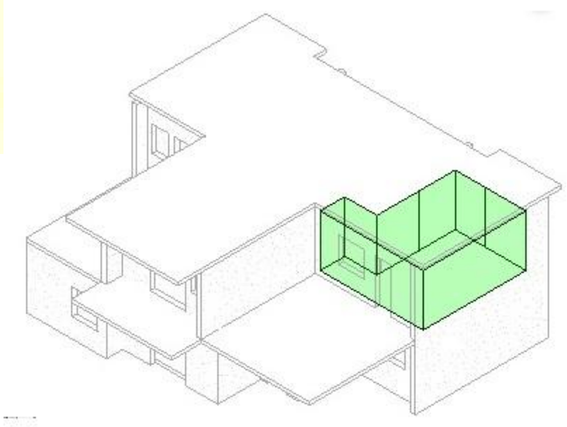
Cost incurred for 100 CFt of 9" AEROCON block work with 1:6 CM = ***Rs. 12850***

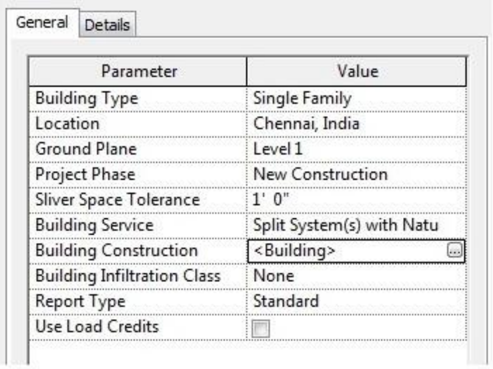
7.0 HEAT LOAD CALCULATIONS

7.1 HEAT LOAD CALCULATIONS IN REVIT MEP:

Heat load calculations are done to determine the heating and cooling loads for one or all rooms in a building. It also gives us the amounts of airflow required to heat or cool the load in the room.

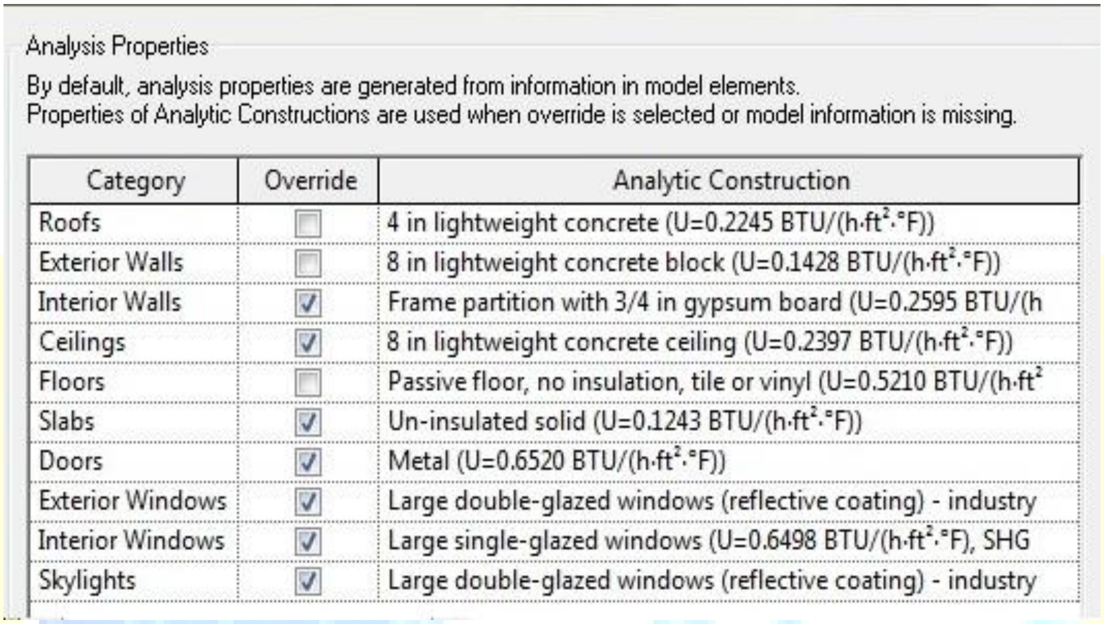
A room was selected on the second floor towards the eastern side since that is the room having two faces exposed to high heat intensities. The **building type** was set to **Single family**and the **building service** was set to **Split air condition.**





Parameter	Value
Building Type	Single Family
Location	Chennai, India
Ground Plane	Level 1
Project Phase	New Construction
Sliver Space Tolerance	1' 0"
Building Service	Split System(s) with Natu
Building Construction	<Building>
Building Infiltration Class	None
Report Type	Standard
Use Load Credits	☐

Fig.7.1 HEAT LOAD SETTINGS



Analysis Properties

By default, analysis properties are generated from information in model elements.
Properties of Analytic Constructions are used when override is selected or model information is missing.

Category	Override	Analytic Construction
Roofs	☐	4 in lightweight concrete (U=0.2245 BTU/(h·ft^2·°F))
Exterior Walls	☐	8 in lightweight concrete block (U=0.1428 BTU/(h·ft^2·°F))
Interior Walls	☑	Frame partition with 3/4 in gypsum board (U=0.2595 BTU/(h
Ceilings	☑	8 in lightweight concrete ceiling (U=0.2397 BTU/(h·ft^2·°F))
Floors	☐	Passive floor, no insulation, tile or vinyl (U=0.5210 BTU/(h·ft^2
Slabs	☑	Un-insulated solid (U=0.1243 BTU/(h·ft^2·°F))
Doors	☑	Metal (U=0.6520 BTU/(h·ft^2·°F))
Exterior Windows	☑	Large double-glazed windows (reflective coating) - industry
Interior Windows	☑	Large single-glazed windows (U=0.6498 BTU/(h·ft^2·°F), SHG
Skylights	☑	Large double-glazed windows (reflective coating) - industry

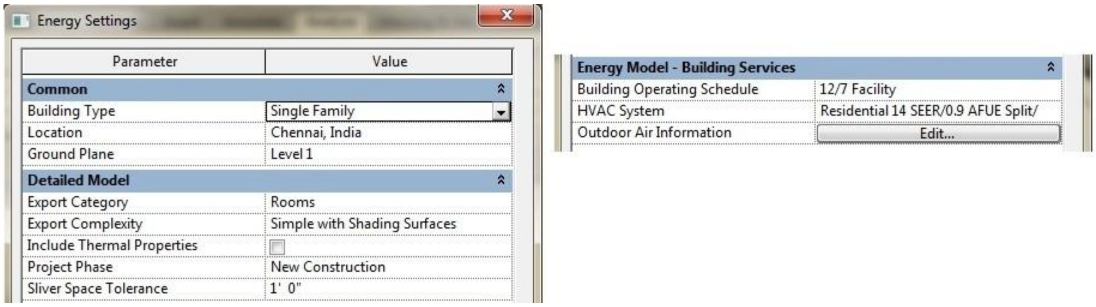
Fig.7.2 MATERIAL SETTINGS

8.1 ENERGY ANALYSIS

8.1 ENERGY ANALYSIS IN GREEN BUILDING STUDIO:

Energy analysis is done to determine the ***annual energy consumption*** of the building under study based on the type of ***materials*** and ***equipment*** used in the building. It also gives us the ***areas of the building*** where we can make necessary changes to ***further reduce the energy*** consumed.

The **building operation schedule** was set to **12hrs** in a day and **7 days** in a week since in a residential family people are only home for the later part of the day.

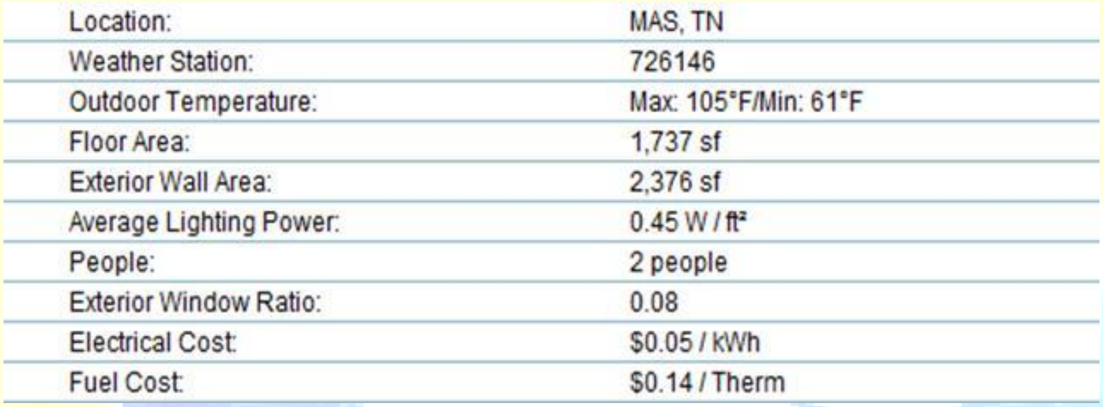


Energy Settings

Parameter	Value
Common	
Building Type	Single Family
Location	Chennai, India
Ground Plane	Level 1
Detailed Model	
Export Category	Rooms
Export Complexity	Simple with Shading Surfaces
Include Thermal Properties	☐
Project Phase	New Construction
Sliver Space Tolerance	1' 0"

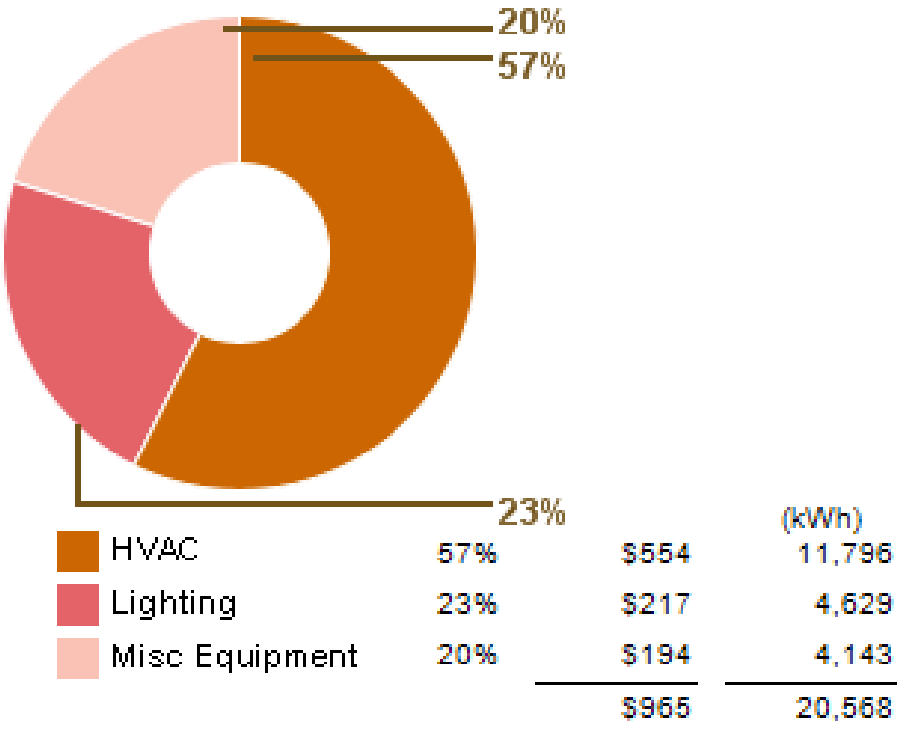
Energy Model - Building Services	
Building Operating Schedule	12/7 Facility
HVAC System	Residential 14 SEER/0.9 AFUE Split/
Outdoor Air Information	Edit...

Fig.8.1 ENERGY SETTINGS



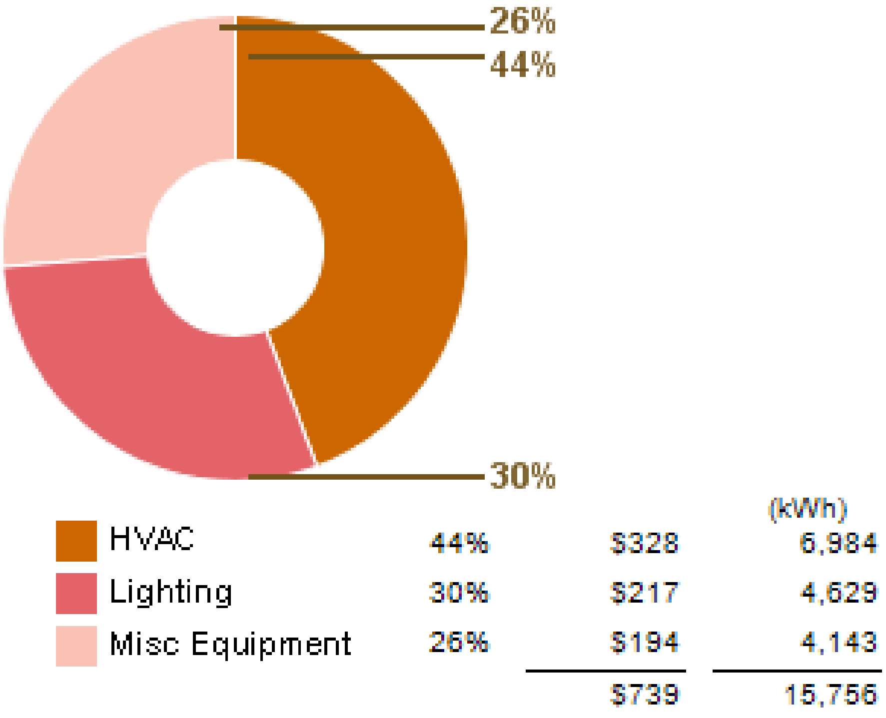
Location:	MAS, TN
Weather Station:	726146
Outdoor Temperature:	Max: 105°F/Min: 61°F
Floor Area:	1,737 sf
Exterior Wall Area:	2,376 sf
Average Lighting Power:	0.45 W / ft²
People:	2 people
Exterior Window Ratio:	0.08
Electrical Cost:	$0.05 / kWh
Fuel Cost:	$0.14 / Therm

Fig.8.2 SITE PROPERTIES



			(kWh)
🟧 HVAC	57%	$554	11,796
🟥 Lighting	23%	$217	4,629
Misc Equipment	20%	$194	4,143
		$965	20,568

Fig.8.3 ENERGY USAGE CONVENTIONAL MATERIALS



			(kWh)
🟧 HVAC	44%	$328	6,984
🟥 Lighting	30%	$217	4,629
Misc Equipment	26%	$194	4,143
		$739	15,756

Fig.8.4 ENERGY USAGE GREEN MATERIALS

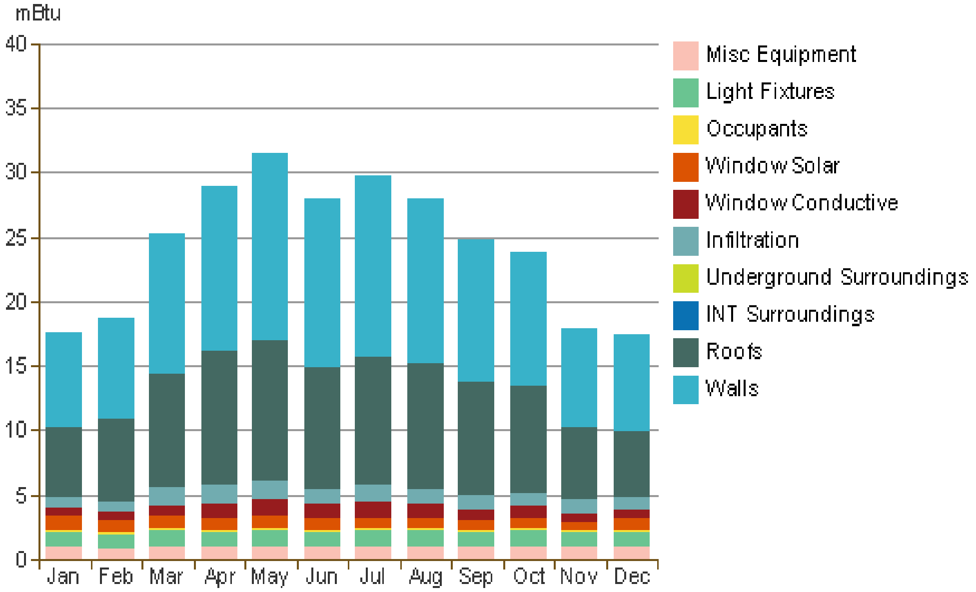


Fig.8.5 MONTHLY COOLING LOADS CONVENTIONAL MATERIALS

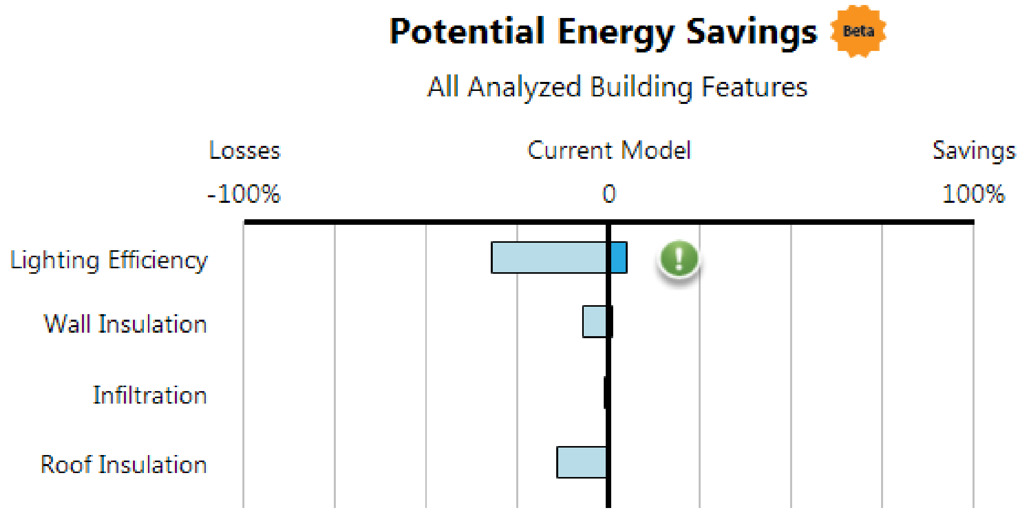


Fig.8.9 ENERGY SAVINGS CONVENTIONAL MATERIALS

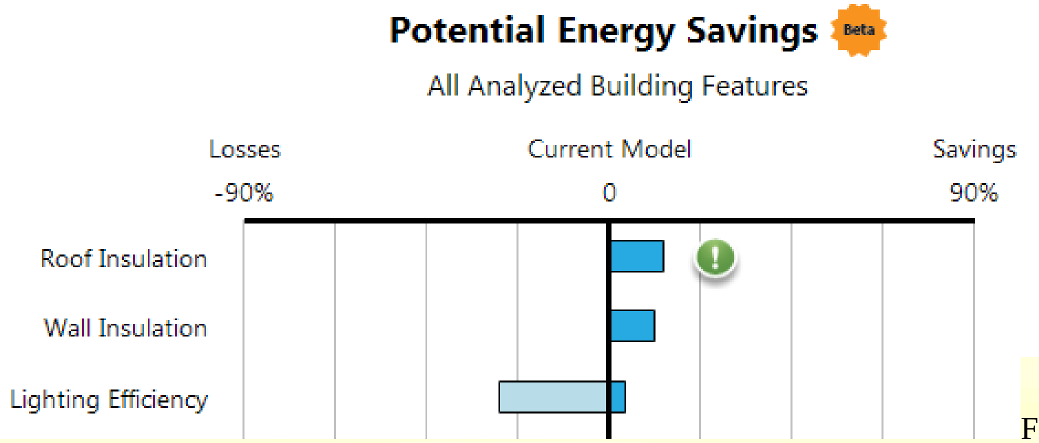


Fig.8.10

ENERGY SAVINGS GREEN MATERIALS

9.0 RESULTS:

1) *SOLAR STUDY*

The **cost incurred** for using **Aerocon Blocks** in construction is **25% more** than the cost incurred by **Burnt Clay Bricks**.

2) *HEAT LOAD CALCULATIONS*

There is **60% reduction of Peak Cooling Load** value when **Aerocon Blocks** were coupled with **Insulla Roofing Tiles** and used in replacement to **Bricks** with **Terracotta.**

3) *ENERGY ANALYSIS*

The building with **green materials record 24% reduction in overall energy costs**when compared to conventional materials.

10. CONCLUSIONS:

1) The use of Aerocon blocks throughout the building is found to be expensive so it is wiser to use green materials as such only on the sides of the building exposed to intense solar radiation and using conventional materials on the other sides.
2) The materials with the least Thermal Conductivity Values (U - Values) generated the lowest Peak Cooling Loads, meaning the indoor air temperature of a room depends upon the U – Value of the materials used in its construction.

3) The use of green materials in replacement to conventional materials in construction, reduce the cost incurred for HVAC systems every month. Thereby reducing the overall operational cost of the building.

REFERENCE

- Reducing Urban Heat Island Effects – Academic Journals
  www.academicjournals.org/ijps/pdf/.../Shahmohamadi%20et%20al.pdf
- Effects of Solar Absorption Coefficient on External Walls of Buildings
  www.waset.org/journals/waset/v52/v52-149.pdf
- The effect of Anthropogenic heat on formation of urban heat
  *www.hindawi.com/**journals**/usr/2011/497524/*
- Review of passive PCM latent heat thermal energy storage systems towards buildings' energy efficiency
  http://www.sciencedirect.com/science/article/pii/S0378778813000157
- A review on buildings energy consumption information
  http://www.sciencedirect.com/science/article/pii/S0378778807001016
- Green roofs; building energy savings and the potential for retrofit
  http://www.sciencedirect.com/science/article/pii/S0378778810001453
- Energy Impacts of Nonlinear Behavior of Phase Change Materials When Applied to Opaque Building envelopes
  http://solarenergyengineering.asmedigitalcollection.asme.org/article.aspx?articleid=1724724.