Study of Thermal Load Variation on Various Construction Materials & to Reduce Consumption of Conventional Energy

Abhishek Singh[1] and Rajneesh Gedam[2]
[1](Research Scholar, Department of Mechanical Engineering, R K D F College of Tech. Bhopal, M.P., India)
[2](Asst. Prof., Department of Mechanical Engineering, R K D F College of Tech. Bhopal, M.P., India)

Abstract: *Buildings are large consumers of energy in all countries, especially in regions with extreme climatic conditions. Half of the total energy produced in the developed world is used to heat, cool, ventilate and control humidity in buildings. We made three scenarios based on the additional effect (green roof and lime coating on the roof) we added into it. It has been found that the maximum reduction in heat gain is 0.255 kW-hr/m^2 in the Model II with additional green roofing. With lime coated roof in comparison to the base model is found to be 0.141 kW-hr/m^2*

Keywords: *Thermal observation, Casting, Aluminium alloy, Molding sand*

I. INTRODUCTION

Energy is a basic requirement for the existence and development of human life. Primarily, the commercial sources such as fossil fuels (coal, oil and natural gas), hydroelectric power and nuclear power provide the energy needs of a country. The demand for energy is growing at an alarming rate year after year. On the other hand, the fossil fuels are rapidly depleting and the era of fossil fuel is gradually coming to an end. With the increase in standards of living, the consumption of energy in buildings is progressively rising. A number of passive solar techniques were adopted in vernacular architecture in the various climatic zones. Energy conscious building involves the use of eco-friendly and less energy intensive materials, incorporation of passive solar techniques (including day lighting features) and integration of renewable energy technologies. Even in conditioned buildings, where mechanical devices are used to create a comfortable environment, the use of passive methods would help reduce the energy consumption.

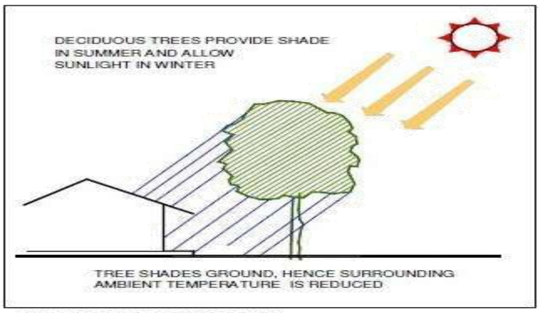
Climate and Building

Climate is dependent on various climate parameters such as temperature, humidity, and precipitation. Climate should be considered as one of the most important factors in building and system design, as it has considerable impact on energy use. globalized building typologies and envelope types tend to ignore or fight against regional climate characteristics, not least in the popularity of 'all-glass' envelopes. Building design should 'adapt' to known and historic climatic characteristics to achieve local and regional comfort expectations to minimize energy use, rather than be sealed to exclude climate

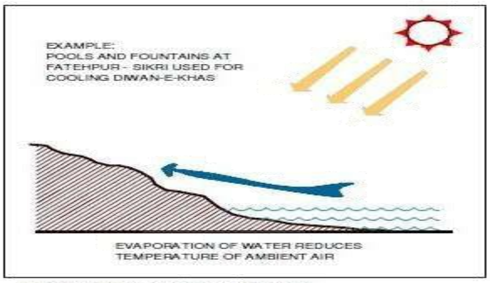
Factors Affecting Climate

a) Solar radiation
b) Ambient temperature
c) Air humidity
d) Precipitation
e) Wind
f) Sky condition

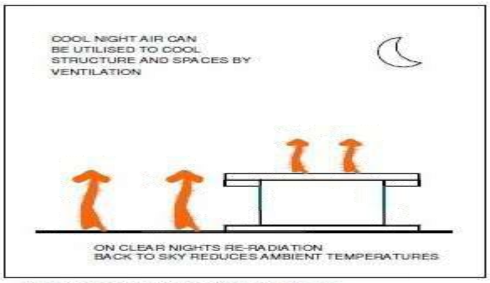
Ambient Temperature



EFFECT OF SHADING

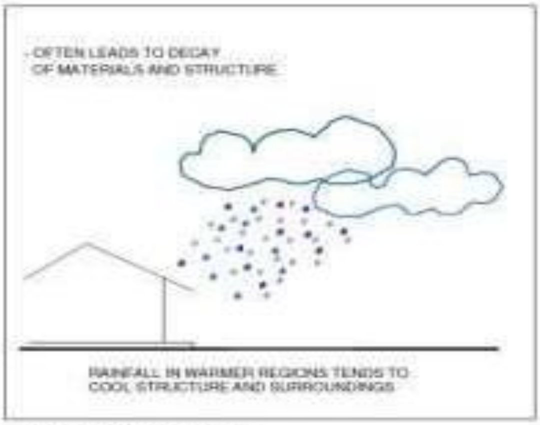


EFFECT OF WATER BODY



EFFECT OF SKY CONDITION

Precipitation



EFFECT OF RAINFALL

EFFECT OF SNOW

Climatic Zones and their Characteristics

Regions having similar characteristic features of climate are grouped under one climatic zone. Based on the climatic factors discussed in the previous section, the country can be divided into a number of climatic zones. India can be divided into six climatic zones, namely, hot and dry, warm and humid, moderate, cold and cloudy, cold and sunny, and composite.

Implications of Climate on Building Design

According to, thermal comfort is, “that condition of mind which expresses satisfaction with the thermal environment”. It is also, “the range of climatic conditions within which a majority of the people would not feel discomfort either of heat or cold”. Such a zone in still air corresponds to a range of 20 – 30 ºC dry bulb temperature with 30 – 60 % relative humidity. Besides, various climatic elements such as wind speed, vapour pressure and radiation also affect the comfort conditions.

II. LITERATURE REVIEW

G. Kirankumar et al. in their research paper carried out a simulation to find out best wall material in combination with the different window material to study the thermal performance of a building in four different climatic zone in India

P.K. Latha et al. in his review paper discussed about the different building materials for providing thermal comfort in a building. He has divided these material as natural and synthetic building materials

Matthieu Labat et al. have determined the basic hygro-thermal properties of straw clay sample provided by two French companies. In this paper they have determined that the mixes with densities lower than 450 kg m^3 would be suitable for use as self-insulating material in current construction

Jaehun Sim et al. , as one possible approach to improving the energy performance of the eco-friendly Korean traditional building, this study develops an energy simulation model to investigate the influence of five types of alternative walls

Juan M. Lirola et al. has given a review paper on the scale model use based on the results of other different research works. He has defined different models type based on different principles.

Alaa Alaidroos and Moncef Krarti have presented the initial findings of a current research study focusing on improving the ventilated wall cavity with spray evaporative cooling system that produce fine water droplets.

Salmaan Craig and Jonathan Grinham in their study demonstrated how to design pores in building materials so that incoming fresh air can be efficiently tempered with low-grade heat while conduction losses are kept to a minimum.

Stefano Fantucci et al.have published a paper on dynamic insulation system. In this paper they showed the results of an extensive experimental campaign on a ventilated opaque double skin façade based on hollow clay bricks.

A.V. Androutsopoulos et al. have showed the effect of cool roof on a school building. This study presents the results of a thorough investigation of a cool-roof application on a public school building (pilot building) located in Athens, Greece.

Objectives

- In this project we did Thermal analysis & Heat variation by construct a distorted scale model and evaluation of thermal comfort inside the living space by changing wall construction material, insertion of wall cavity and putting portable green roof or lime coating on the roof of the building.
- These distorted scale model will be constructed at Allahabad. In this project we will be collected data based on three scenarios.
- The data will be analysed based on the average of that month's reading for a particular scenario.

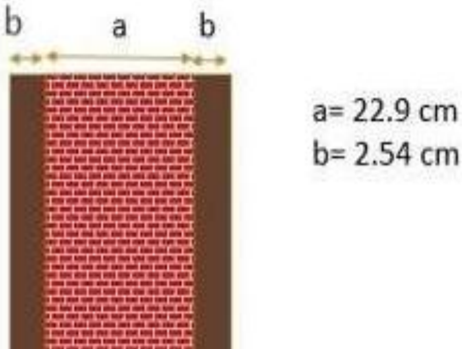
III. METHODOLOGY

In this project we have collected data based on three scenarios.

Description of Models

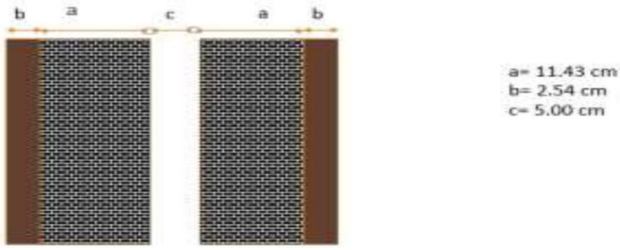
Model I

This Model I is made of conventional building material with conventional design. In this the walls are made of burnt clay brick.We have used thermocol or expanded polystyrene to fill the door and windows spacing. We have used K type thermocouple to measure the temperature of the outside and inside surface temperature of the wall.



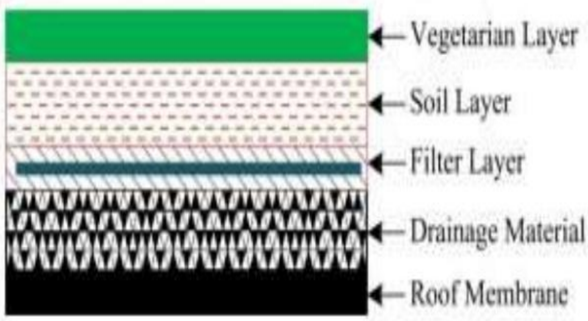
Model II

In this model we have used Fly Ash Brick (FAB) as the wall material. A wall cavity of 5 cm has been left between the two walls of the 0.127 m thickness. It is a composite walls of FAB with an air cavity of 5 cm. The fly ash bricks are made of fly ash, lime and gypsum. This is provided to cool the inner walls through the natural flow of cold air from the North side vent to the South top vent where the hot air will come out. This will provide a nearly uniform temperature of the inner room wall surfaces.The thermocol or expanded polystyrene sheet has been used to fill the door and windows spacing.



Portable Green Roof

A green roof (or eco-roof) is a roof that contains a soil (growing media) and vegetation layer as its outermost surface.A protection layer directly above the roof construction serves to protect the roof from moisture.This layer includes some combination of waterproof membranes and root barriers.We have put the thickness of growing medium (i.e. in our case is soil) to 10 cm and used cotton cloth for the filter layer



Data Collection

The desired data which have been measured are the temperature of all wall and roof surfaces, insolation and the ambient temperature. These measurements have been done in three different scenarios. In all scenarios the base Model I will be the same only Model II will be aided with different conditions.

Scenario I

In this case both models were used to measure the temperature without any other external use.In this case the room temperature difference between both these models would be because of the different wall material.

Scenario III

The roof of Model II is whitewashed .This is used to reflect the sun insolation because of its white surface so that the temperature of roof surface would decreases.This effect is known as the albedo effect

IV. RESULT & DISCUSSION

- **Scenario I**

February

For this month the percentage reduction of heat transfer per unit envelop area in Model II is 20.85% for the 12 hour period from 08:00 AM to 08:00 PM.The total thermal load saved for this period of time is 33.21 W-hr/m^2 (0.033 kW-hr/m^2). The maximum temperature difference between the inner and outer surface of the Model II east wall, also appear at 11:00 AM and numerated as 4.3^{o}C. The maximum temperature difference between the inner and outer surface of the Model II east wall, also appear at 11:00 AM and numerated as 4.3^{o}C.

March

For this month the percentage reduction of heat transfer per unit envelop area in Model II is 25.97% for the 12 hour period from 08:00 AM to 08:00 PM.The total thermal load saved for this period of time is 86.87 W-hr/m^2 (0.087 kW-hr/m^2). In this month the maximum temperature difference between the internal surfaces of south walls (Si) of both models are 3.9^{o}C at 17:00. The maximum temperature difference between the inner and outer surface of the Model II south wall, also appear at 14:00 and numerated as 16.8^{o}C.

April

For this month the percentage reduction of heat transfer per unit envelop area in Model II is 27.23% for the 12 hour period from 08:00 AM to 08:00 PM. The total thermal load saved for this period of time is 102.53 W-hr/m^2 (0.103 kW-hr/m^2).The maximum temperature difference between the inner and outer surface of the Model II south wall, appear at 14:00 and numerated as 11.4^{o}C.

May

For this month the percentage reduction of heat transfer per unit envelop area in Model II is 63.48% for the 12 hour period from 08:00 AM to 08:00 PM. The total thermal load saved for this period of time is 123.28 W-hr/m^2 (0.123 kW-hr/m^2).The maximum difference between the rooms of Model I and Model II is 2.5^{o}C .which is in the morning at 14:00 which is because the thermal mass and air cavity insulation in Model II.

- **Scenario II**

The green roof is applied on the model II. The month-wise results have been shown below

February

For this month the percentage reduction of heat transfer per unit envelop area in Model II is 74.37% for the 12 hour period from 08:00 AM to 08:00 PM. The total thermal load saved for this period of time is 129.97 W-hr/m^2 (0.033 kW-hr/m^2). The maximum temperature difference between the internal surfaces of South walls (Si) of both models are 4.4^{o}C at 14:00 as the solar beam radiation on the wall is maximum at this time.The maximum difference between the rooms of Model I and Model II is 1.4^{o}C

March

For this month the percentage reduction of heat transfer per unit envelop area in Model II is 79.34% for the 12 hour period from 08:00 AM to 08:00 PM. The total thermal load saved for this period of time is 149.24 W-hr/m^2 (0.149 kW-hr/m^2).For this month the maximum temperature difference between the internal surfaces of South walls (Si) of both models are 5.6^{o}C at 17:00 as the solar beam radiation on the wall is maximum at this time.

April

For this month the percentage reduction of heat transfer per unit envelop area in Model II is 67.04% for the 12 hour period from 08:00 AM to 08:00 PM. The total thermal load saved for this period of time is 168.02 W-hr/m^2 (0.168 kW-hr/m^2). For this month the maximum temperature difference between the internal surfaces of South walls (Si) of both models are 4.1^{o}C at 15:00 as the solar beam radiation on the wall is maximum at this time. The temperature difference between inner and outer surface of south wall in Model II is maximum at 13:00 and numerated as 14.1^{o}C.

May

For this month the percentage reduction of heat transfer per unit envelop area in Model II is 67.41% for the 12 hour period from 08:00 AM to 08:00 PM. The total thermal load saved for this period of time is 254.63 W-hr/m^2 (0.255 kW-hr/m^2). The maximum temperature difference between the internal surfaces of South walls (Si) of both models are 5.1^{o}C at 20:00 as the solar beam radiation on the wall is maximum at this time. The temperature difference between inner and outer surface of south wall in Model II is maximum at 13:00 and numerated as 9.2^{o}C.The maximum difference between the rooms of Model I and Model II is 6.2^{o}C which is in the morning at 15:00 AM which is because of the combined effect of green roof, wall material and wall cavity in model II.

- **Scenario III**

In this scenario the lime coating has been done on the roof of the Model II.

February

For this month the percentage reduction of heat transfer per unit envelop area in Model II is 26.18% for the 12 hour period from 08:00 AM to 08:00 PM. The total thermal load saved for this period of time is 42.14 W-hr/m^2 (0.042 kW-hr/m^2). The maximum temperature difference between the internal surfaces of South walls (Si) of both models are 3.4°C at 13:00 as the solar beam radiation on the wall is maximum at this time. The temperature difference between inner and outer surface of south wall in Model II is maximum at 12:00 and numerated as 14.2°C.The maximum difference between the rooms of Model I and Model II is 1.9°C which is in the morning at 08:00 PM which is because the thermal mass and air cavity insulation in Model II.

March

For this month the percentage reduction of heat transfer per unit envelop area in Model II is 28.76% for the 12 hour period from 08:00 AM to 08:00 PM .The total thermal load saved for this period of time is 102.76 W-hr/m^2 (0.103 kW-hr/m^2). The maximum temperature difference between the internal surfaces of South walls (Si) of both models are 3.4°C at 16:00 as the solar beam radiation on the wall is maximum at this time.The temperature difference between inner and outer surface of south wall in Model II is maximum at 14:00 and numerated as 15.6°C.The maximum difference between the rooms of Model I and Model II is 1.7°C which is in the morning at 08:00 AM which is because the thermal mass and air cavity insulation in Model II.

April

For this month the percentage reduction of heat transfer per unit envelop area in Model II is 32.02% for the 12 hour period from 08:00 AM to 08:00 PM.The total thermal load saved for this period of time is 130.75 W-hr/m^2 (0.131 kW-hr/m^2). The maximum temperature difference between the internal surfaces of South walls (Si) of both models are 5.2°C at 18:00 as the solar beam radiation on the wall is maximum at this time. The temperature difference between inner and outer surface of south wall in Model II is maximum at 12:00 and numerated as 13.1°C.The maximum difference between the room temperatures of Model I and Model II is 3°C which is in the morning at 11:00 AM and 12:00 noon which is because the thermal mass, whitewashed roof outer surface and air cavity insulation in Model II.

May

For this month the percentage reduction of heat transfer per unit envelop area in Model II is 43.38% for the 12 hour period from 08:00 AM to 08:00 PM. The total thermal load saved for this period of time is 140.46 W-hr/m^2 (0.141 kW-hr/m^2). The maximum temperature difference between the internal surfaces of South wall (Si) of both models are 1.8°C at 18:00 as the solar beam radiation on the wall is maximum at this time. The temperature difference between inner and outer surface of south wall in Model II is maximum at 13:00 and numerated as 9.8°C.The maximum difference between the room temperatures of Model I and Model II is 2.7°C which is in the morning at 13:00 which is because of the combined effect of the thermal mass, whitewashed roof surface air cavity insulation in Model II

V. CONCLUSION

From measurement procedures the following conclusion have been drawn. The maximum temperature difference is 2.5 in May for scenario I. This effect is because of the wall cavity and wall material The average reduction in heat gain of the room because of fly ash wall and wall air cavity is 10.27 W/m^2.When the external green roof is applied on Model II, the maximum room temperature difference between the models is 6.2°C in May. The maximum reduction in the heat gain in Model II with green roof has been found to be 0.255 kW-hr/m^2. The average reduction in heat gain through green roof in May is 38.94 W/m^2.In scenario III we have used lime coating over the roof. Maximum room temperature difference between both models is 3°C in the month of April. In this scenario the maximum reduction in heat gain to the room is found to be 0.141 kW-hr/m2.This difference is because of the reflection of the incident solar radiation on the roof surface. It can be seen from the results that the temperature of inner surface of the walls of Model II is approximately very close to among one another. Following the above finding it can be concluded that all of these solar passive cooling techniques can reduce the heat gain to the room in a significant amount during summer days at Allahabad. In all of these techniques the impact of green roof on the thermal load of a building is comparatively high to that of the other methods.

Future Work

- Study with some other material can be done.
- At the place of green roof some cooling nanofluid can be utilize.
- To increase reflection of sun radiation some technique can be applied.

VI. REFERENCES

[1] *[1] G. Kirankumar, S. Saboor, T. P. Ashok Babu, Investigation of different window and wall materials for solar passive building design, Procedia Technology 24 (2016) 523 – 530*

[2] *[2] P.K. Latha, Y. Darshana, Vidhya Venugopal, Role of building material in thermal comfort in tropical climates–A review, Journal of Building Engineering 3 (2015) 104–113*

[3] *[3] Matthieu Labat, Camille Magniont, Nicolaas Oudhof, Jean-Emmanuel Aubert, From the experimental characterization of the hygro-thermal properties of straw-clay mixtures to the numerical assessment of their buffering potential, Building and Environment 97 (2016) 69-81*

[4] *[4] Jaehun Sim, Jehean Sim, The effect of external walls on energy performance of a Korean traditional building, Sustainable Cities and Society 24 (2016) 10–19*

[5] *[5] Juan M. Lirola, Estéfana Casta˜neda, Benito Lauret, Mohamed Khayet, A review on experimental research using scale models for buildings: Application and methodologies, Energy and Buildings 142 (2017) 72–110.*

[6] *[6] Alaa Alaidroos, Moncef Krarti, Numerical modeling of ventilated wall cavities with spray evaporative cooling system, Energy and Buildings 130 (2016) 350–365.*

[7] *[7] Salmaan Craig, Jonathan Grinham, Breathing Walls: The Design of Porous Materials for Heat Exchange and Decentralized Ventilation, Energy and Buildings, 2017*

[8] *[8] Karam M. Al-Obaidin , Mazran Ismail, Abdul Malek Abdul Rahman, Passive cooling techniques through reflective and radiative roofs in tropical houses in Southeast Asia: A literature review, Frontiers of Architectural Research (2014) 3, 283–297*

[9] *[9] A.V. Androutsopoulos, G.M. Stavrakakis , M. Damasiotis, Cool Roof Impacts on a School-Building Thermal and Energy Performance in Athens, Greece, Procedia Environmental Sciences 38 (2017) 178 – 186*

[10] *[10] Hanna Jędrzejuk, Olaf Dybiński, The influence of a heating system control program and thermal mass of external walls on the internal comfort in the Polish climate, Energy Procedia 78 (2015) 1087 – 1092*

[11] *[11] Sabrina Barbosa, Kenneth Ip, Ryan Southall, Thermal comfort in naturally ventilated buildings with double skin facade under tropical climate conditions: The influence of key design parameters, Energy and Buildings 109 (2015) 397–406*

[12] *[12] Stefano Fantucci, Valentina Serra, Marco Perino, Dynamic insulation systems: experimental analysis on a parietodynamic wall, Energy Procedia 78 (2015) 549 – 554.*