International Journal of Electrical Engineering & Emerging Technology, Vol. 04, No. 02, DEC 2021, pp 13-16

Investigation The Effect Of Bio Phase Change Material On The Thermal Comfort Of Building

Mohsin Ali Memon [a], Abdul Fatah Abbasi [b], Rizwan Ahmed Memon [b]
[a] Post Graduate student, Energy system engineering, Mehran university of engineering and Technology, jamshoro,76062,Pakistan
[b] Department of Mechanical Engineering, Mehran university of engineering and Technology Jamshoro, 76062, Pakistan

Corresponding author email: mohsinmuet543@gmail.com
[**Received on:** 08/10/2021 **Accepted on**: 21/10/2021 **Published on:** 04/12/2021]

Abstract—Office room building envelope get warmed in summer session due to rise in temperature and reached around almost 40^0C to 45^0C which causes overheating of buildings as a result thermal discomfort increase and cooling energy demand increases in building specially in Sindh. Also internationally energy demand rises in building sector, nearby 60% of the total energy used for cooling and heating purpose, Also on other hand unit price of electricity rise day by day in Pakistan. Therefore there is need to adopt some techniques which minimize these adverse effect, one of them is discussed in this research work which is passive cooling technique. Therefore this research work will focus on Bio Phase Change Material and their effect on the thermal comfort of the building. Hence, PCM method can be an effective technique for designing of energy-efficient buildings for this region of the country (Hyderabad, Pakistan) .Thus, the purpose of current investigation is to check the effectiveness of apply selective passive cooling strategy to a office building model located in Hyderabad for better thermal performance and to decrease energy use of building envelop in warm climate.

***Index Terms*— Bio Phase Change Material, Heat Gain, Operative Temperature, Office Building**

I.INTRODUCTION

Globally energy demand has been increased in the building sector during last four decades because of rise in the population, urbanization and living standard of the people[1],[24],[25].[2],[3] Buildings have added outstandingly to world energy utilization,[4],[5],[6]consequently greenhouse gases emissions are increased. [7] Therefore, it is essential to design energy efficient and sustainable buildings. [8],[9],[10],[11] Around 60% of the total energy used in building is utilized by Heating ventilation and air conditioning system. [12] Because of this higher energy consumption in the building it is required to adopt some new techniques to minimize the higher energy consumption in the buildings for the heating and cooling purpose.[13] The passive cooling method is one of the techniques which minimized energy utilization in the buildings and greenhouse gases emissions. [14]Active and passive are two types of cooling techniques, Active technique adopted the conventional HVAC systems on other hand; the passive cooling technique utilizes the energy present in the nature instead of the conventional energy sources.[15] Overheating of building cause thermal discomfort, [16] in order to avoid this adverse effect passive cooling technique can be utilized, [17] another technique such as increase the thermal mass of the building envelope as a result reduction in the installation of air conditioning unit. [18]Heat dissipation, heat prevention, and heat modulation are the three types of passive cooling strategies.[19] Heat dissipation is the discharge of internal heat. Heat prevention is the controlled heat absorption process. Thermal modulation is modifying heat gains. In the thermal modulation system the thermal energy storage materials are commonly used which are known as the phase change materials (PCM). [23] These materials are store and release the thermal energy in the form of latent heat during the phase change process.[19] PCM changes phase from solid-state to liquid state depending upon its temperature difference.[20] PCM materials are beneficial for effective energy utilization and indoor thermal comfort of a building. These benefits are increasing the scope of research in this area. Therefore, this research work will focus on the phase change materials and their effect on the thermal comfort of the building. Sindh is a hot weather province of the country where temperature reaches to the 45^{o}C and almost eight months of the year remains hot weather. Hence, PCM method can be an effective technique for designing of energy-efficient buildings for this region of the country. Thus, the purpose of current investigation is to check the effectiveness of apply selective passive cooling strategy to get better thermal performance and to decrease energy use of building envelop in warm climate. [21] Bio Phase change materials (PCM) when applied in the building envelope it will absorb heat in day time and releases it outdoor in the night time. Results of that peak indoor temperature of building decrease in the day time. [26] For cooling application phase change material have good potential,[22] because they are thermal stability for millions of charging and discharging, huge latent heat of fusion and low melting point. [26] Selection of Phase Change Material depends upon its melting point, in warmer region set point of phase change Material temperature should be lower than the upper range of comfort level, because of that in day time it can be melt easily and absorb extra thermal energy to maintain inside temperature near to the comfort.

II.OBJECTIVES

This research work is about to build an office room of a building with and without integrate Bio Phase Change Material in building envelope in order to analyse the heat conduction rate, also due to excessive amount of heat conduction rate by the building envelope in day time cause thermal discomfort for the occupant and increases operative temperature, therefore cooling load demand increases in day time. In this study the main focus on to achieve thermal comfort and reduce operative temperature and cooling load demand in day time by incorporating bio phase change material in building envelope.

III.METHODOLOGY

- A single room of a building is sketched in a design software having volume of 91 m^3 and simulated in energy plus software. Furthermore all necessary details of a single room considering Bio PCM properties are added in energy plus software such as construction, material properties as shown in tables below. After that, in order analyse the heat transfer rate a conduction finite difference solution algorithm that incorporated in energy plus software is used.
- In energy plus software a single room is categorized in a zone having different surfaces such as walls, roof etc, having same construction but with different materials detail. In energy plus software from surface construction elements option a Bio-PCM is selected in order to analyse the difference in heat transfer rate by using conduction finite difference solution algorithm.
- In energy plus software, from out variable option "Operative temperature" variable and heat conduction rate are selected as a study parameters that help us to evaluate the cooling energy consumption and saving for hot season in Hyderabad Pakistan.

A. Room Model of An Office

Using a CAD software a single room of a building is modeled having one window and Door facing south and north directions respectively as shown in fig.1.For office room dimensions refer the Table-I and Table-II.

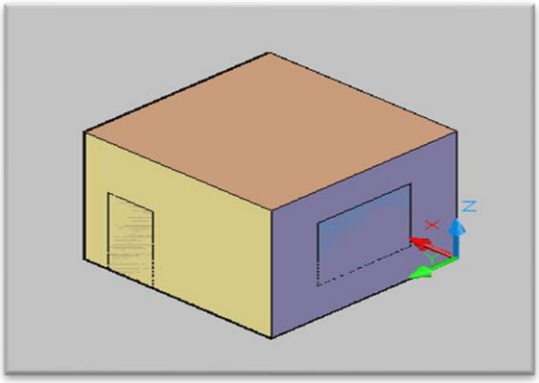

Figure. 1. Single office room of a building

TABLE I :Dimensions of Office Room of a Building

Sr.No	Length	Width	Height	Volume
1	4.5m	4.5m	4.5m	91 m^3

TABLE II :Door and window Dimension of a Office room

Name	height	width	Area
Door	1.98m	0.762m	1.51m^2
Window	1m	1m	1m^2

B. Material Properties and Construction Details

In Energy plus software need to input all necessary material properties like, thickness, conductivity, density and specific heat, the details of these properties are mentioned in Table-III. Also in energy plus software every building envelope layer have same construction detail but with different material as mentioned in Table-IV.

TABLE III :Physical Properties of The Material

Name	Thickness (m)	Conductivity (W/m^2 K)	Density (Kg/m^3)	Specific Heat (j/Kg.K)
F 16 Acoustic tile	.0.0191	0.06	368	590
M01 100mm Brick	0.1016	0.89	1920	790
lightweight Concrete	0.1524	0.53	1280	840
heavyweight Concrete	0.2032	1.95	2240	900
Mortor/stucco (cement	0.051	0.97	1600	900
Bio PCM Q23	.0.01	0.2	1125	3350

TABLE IV :Material and Construction Detail

Sr.No	1	2	3	4	5	6
Material	Mortor/ stucco (cement)	M01 100mm Brick	Heavy weight Concrete	F 16 Acoustic tile	Light weight Concrete	Bio PCM
Window	6mm Clear	-	-	-	-	-
Door	wood	-	-	-	-	-
Wall construction	Mortor/ stucco (cement)	M01 100mm Brick	Mortor/ stucco (cement)	Bio PCM	-	-
Roof construction	Light weight Concrete	Mortor/ stucco (cement)	Bio PCM	-	-	-
Floor construction	Heavy weight Concrete	F 16 Acoustic tile	-	-	-	-

IV.RESULTS AND DISCUSSION

A. Building Office Room Heat Conduction Analysis

From fig. 2,3,4,5, it is observe that Bio Phase change material function properly for the current office room building location (Hyderabad pakisatan), the amount of heat energy transferred through conduction in the office room building walls almost stored in bio phase change material, basically bio phase change material are well know as energy storage device in our research work we obseved that between march and october months amount of heat transfer rate through the wall by conduction increased due to the hot weather condition in hyderabad, pakistan.during these months people used of air conditioner for their comfort, therefore in this research work Bio Phase change material is used to minized the use of air

conditioner in these months.Bio Phase change materials (PCM) when applied in the building envelope it will absorb heat in day time and releases it outdoor in the night time. Results of that peak indoor temperature of building decrease in the day time as discussed below.

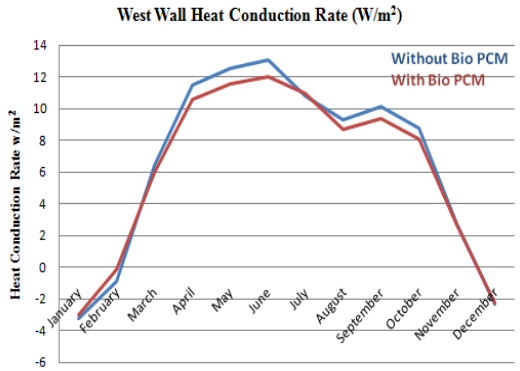

Figure. 2. West Wall Heat Conduction Rate

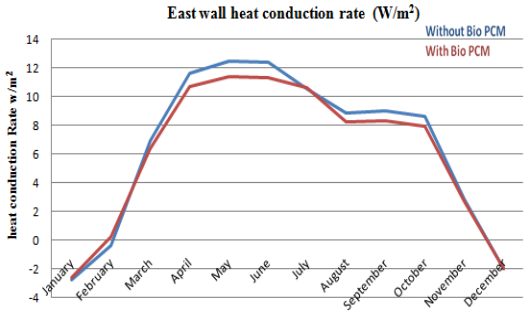

Figure.3. East wall Heat Conduction Rate

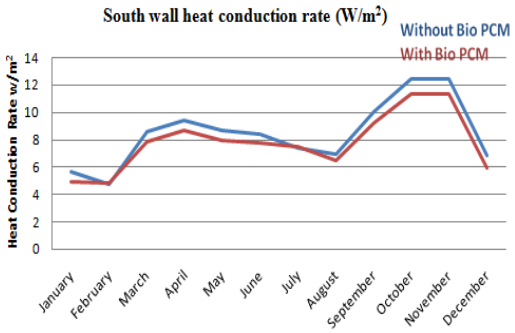

Figure. 4. South Wall Heat Conduction Rate

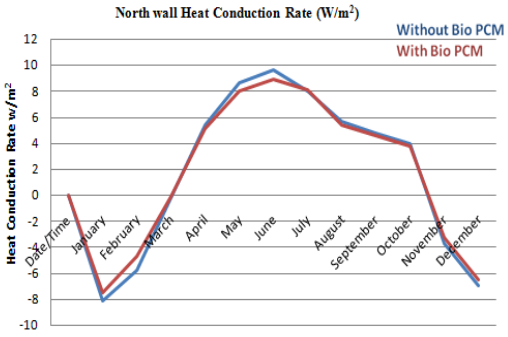

Figure. 5. North Wall Heat Conduction Rate

B. Building Office Room Operative Temperature

From fig.6,it is observed that when building envelope is incorporated with Bio Phase Change material operative temperature decreases. According to the ASHRAE standard 55-1992 uses the operative temperature as the environmental variable for the evaluate thermal comfort at different movement and clothing insulation, In our study regarding the office room building concluded that during the month between march and October operative temperature remain high in case of office room considered without Bio PCM, the value of operative temperature between 30°C to 33°C. But when we incorporate Bio Phase Change Material with building envelop the values of operative temperature decreases from 30°C to 27°C between march and October, which satisfy the thermal comfort conditions. Although thermal comfort can be acceptable from the point of view of human act, given that it tends to be top when people are comfortable with the surroundings.

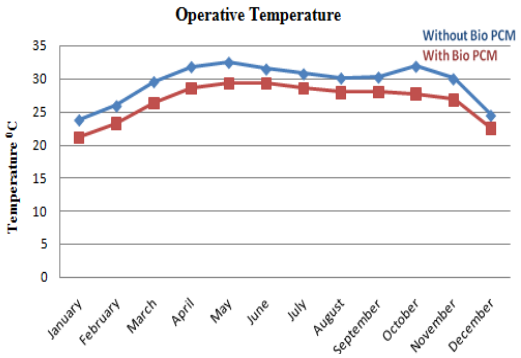

Figure. 6. Operative Temperature

C. Cooling Energy Saving and Unit Cost saving Analysis

It is observed from above results that utilization of Bio PCM is beneficial because of it reduce heat conduction rate of building office room envelope but also provide a satisfactory operative temperature along this as shown in fig. 7, each month there is a saving of cooling energy, if we take it in digits almost 72 Kwh/year saving is achieved, almost 6 Kwh/month cooling energy is saved. According to the unit cost of electricity for domestic consumer, up to 100 unit the cost (Rs/Kwh) is around 2.64.According to this statistic in our case we can saved 16 Rs in Each month.

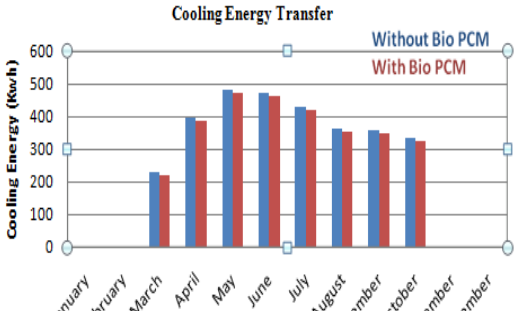

Figure. 7. Cooling Energy Consumption (Kwh)

V. CONCLUSIONS

In Hyderabad Pakistan almost eight months of the year remain hot weather with higher temperature value which make people uncomfortable and they rely on HVAC system, Therefore as discussed in this research work thermal heat storage material

are beneficial for that climate, like Bio PCM they can not only reduce operative temperature between the rang around 1ºC to 3ºC but also reduce cooling load demand almost 72Kwh/year saving is achieved, as a result some cooling load cost reduction which is around 16 Rs/month is achieved. Also Bio PCM material are thermally stable and there payback period should be around 15 to 20 years. Thus PCM technique is effective for designing of energy efficient building for current region of the country. Therefore current investigation purpose is achieved to check the effectiveness of apply selective passive cooling strategy to get better thermal performance and to decrease energy use of building envelop in warm climate.

REFERENCES

[1] Abuelnuor AA, Omara AA, Saqr KM, Elhag IH. Improving indoor thermal comfort by using phase change materials: A review. International Journal of Energy Research.;42(6):2084-103• May 2018.
[2] Akeiber H, Nejat P, Majid MZ, Wahid MA, Jomehzadeh F, Famileh IZ, Calautit JK, Hughes BR, Zaki SA. A review on phase change material (PCM) for sustainable passive cooling in building envelopes. Renewable and Sustainable Energy Reviews.1;60:1470-97• Jul 2016.
[3] Osobajo OA, Otitoju A, Otitoju MA, Oke A. The impact of energy consumption and economic growth on carbon dioxide emissions. Sustainability.;12(19):7965• Jan 2020.
[4] Wang T, Foliente G, Song X, Xue J, Fang D. Implications and future direction of greenhouse gas emission mitigation policies in the building sector of China. Renewable and Sustainable Energy Reviews. 1;31:520-30. Mar 2014.
[5] Calautit JK, Chaudhry HN, Hughes BR, Ghani SA. Comparison between evaporative cooling and a heat pipe assisted thermal loop for a commercial wind tower in hot and dry climatic conditions. Applied Energy. 1;101:740-55. Jan 2013.
[6] Hughes BR, Chaudhry HN, Ghani SA. A review of sustainable cooling technologies in buildings. Renewable and Sustainable Energy Reviews. 1;15(6):3112-20. Aug 2011
[7] Iwaro J, Mwasha A. The impact of sustainable building envelope design on building sustainability using Integrated Performance Model. International Journal of Sustainable Built Environment. 1;2(2):153-71. Dec 2013
[8] Ali SB, Hasanuzzaman M, Rahim NA, Mamun MA, Obaidellah UH. Analysis of energy consumption and potential energy savings of an institutional building in Malaysia. Alexandria Engineering Journal. 1;60(1):805-20.Feb 2021
[9] Ihara T, Gustavsen A, Jelle BP. Effect of facade components on energy efficiency in office buildings. Applied Energy. 15;158:422-32.Nov 2015.
[10] Pérez-Lombard L, Ortiz J, Pout C. A review on buildings energy consumption information. Energy and buildings. 1;40(3):394-8. Jan 2008.
[11] Habib MA, Hasanuzzaman M, Hosenuzzaman M, Salman A, Mehadi MR. Energy consumption, energy saving and emission reduction of a garment industrial building in Bangladesh. Energy. 1;112:91-100.Oct 2016.
[12] Couret DG. Minimum Energy Housing in Cuba. Sustainability, Energy and Architecture: Case Studies in Realizing Green Buildings. 25:195.Sep 2013.
[13] Song YL, Darani KS, Khdair AI, Abu-Rumman G, Kalbasi R. A review on conventional passive cooling methods applicable to arid and warm climates considering economic cost and efficiency analysis in resource-based cities. Energy Reports. 1;7:2784-820. Nov 2021.
[14] Rajapaksha U. Environmental Heat Stress on Indoor Environments in Shallow, Deep and Covered Atrium Plan Form Office Buildings in Tropics. Climate.;8(2):36.Feb 2020.
[15] Delavar H, Sahebi H. A sustainable mathematical model for design of net zero energy buildings. Heliyon.1;6(1):e03190. Jan 2020.
[16] Al-Yasiri Q, Szabó M. Incorporation of phase change materials into building envelope for thermal comfort and energy saving: A comprehensive analysis. Journal of Building engineering. 28:102122. Dec 2020.
[17] Santamouris M, Kolokotsa D. Passive cooling dissipation techniques for buildings and other structures: The state of the art. Energy and Buildings. 1;57:74-94.Feb 2013.
[18] Saeed RM. Advancement in thermal energy storage using phase change materials. Missouri University of Science and Technology; 2018.
[19] Alam M, Jamil H, Sanjayan J, Wilson J. Energy saving potential of phase change materials in major Australian cities. Energy and Buildings.1;78:192-201. Aug 2014.
[20] Barzin R, Chen JJ, Young BR, Farid M. Application of PCM Energy Storage in Combination with Night Ventilation for Space Cooling. InThermal Energy Storage with Phase Change Materials 25 (pp. 259-276). CRC Press.Jul 2021.
[21] Fiorito F. Phase-change materials for indoor comfort improvement in lightweight buildings. A parametric analysis for Australian climates. Energy Procedia. 1;57. Jan 2014.
[22] Haggag M, Hassan A, Abdelbaqi S. Phase Change Material to Reduce Cooling Load of Buildings in Hot Climate. InKey Engineering Materials. Trans Tech Publications Ltd. (Vol. 801, pp. 416-423). 2019.
[23] Hui SC. Low energy building design in high density urban cities. Renewable energy.1;24(3-4):627-40. Nov 2001.
[24] Olivieri L, Tenorio JA, Revuelta D, Navarro L, Cabeza LF. Developing a PCM-enhanced mortar for thermally active precast walls. Construction and Building Materials 30;181:638-49. Aug 2018.
[25] Nižetić S, Arıcı M, Bilgin F, Grubišić-Čabo F. Investigation of pork fat as potential novel phase change material for passive cooling applications in photovoltaics. Journal of Cleaner Production. 1;170:1006-16. Jan 2018 .
[26] Lagou A, Kylili A, Šadauskienė J, Fokaides PA. Numerical investigation of phase change materials (PCM) optimal melting properties and position in building elements under diverse conditions. Construction and Building Materials.20;225:452-64. Nov 2019.