International Journal of Innovative Research in Science and Engineering
Volume 08, Issue 02, 2022
www.ijirse.com
ISSN: 2454-9665

Study for the Development of Thermal Insulated Sustainable GreenMaterial for Roof Top

Mohammad Irshad Ansari[1], Dr. Ramakant Agrawal[2]

M.Tech Student[1], Professor[2], and Head of Department of Civil Engineering, Oriental Institute of Science & Technology Bhopal, (M.P) India.

Abstract

One of the essential objectives in building design is to offer thermal comfort to inhabitants while increasing energy efficiency by minimizing heat penetration through a structure's roof and walls. The current study aims to discover and develop cost-effective insulating materials made from locally accessible waste materials. To minimize heat flow into the space, several designs of over deck insulation were placed over each RCC roof structure. As a comparison, roof-1 (R1) was left naked with no insulation, while roof-2 (R2) was coated with a 3:1combination of broken burned bricks and lime mortar (Conventional Indian technique) to a thickness of 50 mm. The created novel thermal insulating material performed well in roof insulation-based performance study, with an overall heat load reduction of 96.80 percent. For plastering applications, novel insulating cement mortars were created with the inclusion of discarded waste materials such as a mixture of fly ash (F.A.), eggshell (E.S.), bamboo fiber, and expanded polystyrene (EPS). After ensuring that the developed mortars were workable, they were tested for required properties such as compressive strength and water absorption, and the thermal conductivity of the modified mortar was tested using standard procedures to adopt appropriate plastering mortar for indoor and outdoor applications. Similarly, low-weight thermal insulation bricks for non-load bearing wall constructions were created utilizing a mix of fly ash (F.A.), Red mud, and bamboo fiber in place of 25% clay. After determining the minimum necessary strength for non-load bearing bricks based on conventional building reference codes, they were submitted to a water absorption test, with a stated limit of 20%, following the completion of the required attributes. This offers comfort to non-air-conditioned building occupants while saving a considerable amount of energy and money for air-conditioned buildings. This has the potential to contribute to long-term growth substantially.

Keywords *– Expanded polystyrene, fly ash, non-load bearing bricks, Thermal insulation*

I. Introduction

A long time has passed since buildings were acknowledged as one of the most significant artificial structures, with a substantial effect on local and global environments. The primary function is to provide shelter and pleasant living space for its occupants. When used as a shelter, a building is a physical place designed to provide comfort and protection to human beings in the face of a hostile outside environment. The construction of a structure and its operation significantly affect the environment, both directly and indirectly. India is the non-OECD East Asia's second-biggest commercial energy user, using 19 percent of the region's total primary energy. India's economic development has been mainly attributed to increasing energy usage. Conventional energy sources provide 78 percent of India's overall energy requirements, while renewable energy sources meet the remaining 22 percent (Luthra et al., 2015).

Climate change has accelerated in recent years. One of the major issues driving energy policy has emerged. More than 150 nations, including India, have signed the United Nations Framework Convention on Climate Change, pledging todevelop and implement climate change mitigation and adaptation measures.

Building's total heat load is split into two categories: heat transmitted into the building envelope via exterior components such as walls, roofs, floors, windows, and doors, and heat produced within the structure by people, equipment, and lighting. The cooling load on externally loaded buildings is primarily due to heat transfer between thesurrounding environment and the interior conditioned area. The cooling load of an externally loaded structure changessignificantly depending on the surrounding circumstances on any particular day. Internal heat-producing sources suchas people, appliances, and processes account for most of the cooling load in internally loaded buildings. Because the heat transfer from the changing surroundings is considerably smaller than the heat transfer from internal heat sources, the heat production from internal heat sources may stay more or less constant. The system design approach for an externally loaded structure differs from an internally loaded building regarding energy efficiency and costs. Limited experimental research has been conducted to reduce heat penetration through roofs with cost-effective retrofits incorporated into Indian building structures. The literature on insulation in Indian roof constructions is limited. Similarly, mixing non-recyclable and non-decomposable solid waste materials for heatmitigation through roof structure is a very effective method when considering the economic and environmental aspects, which is rarely considered in the literature.

II. Review of literature

The history of thermal comfort can be traced back to the dawn of civilization. They lived in caves and gradually relocated to mud, stone, and wood buildings. Then they began to construct structures out of manufactured materials such as, Clay blocks which were used to defend humans from the hot and cold weather. Buildings, including the National Gallery of Art, bear testimony to this. Egypt's ancient pyramids were built out of stones and mud to protect the people from the scorching heat of the desert throughout the day and keep them warm. Cork was utilized by the ancient Greeks and Romans to minimize heat absorption. Asbestos was used to resist the spread of heat and fire. TheGreeks invented a cavity-filled double-wall structure known as the Cavity wall. The mid-1700s industrial revolution introduced a lot of insulating materials such as cardboard, straws, sawdust, cotton, etc. Because Asbestos is dangerous,cellulose and fiberglass insulation have been developed to replace it. Polyurethane foam, which can fill voids, is becoming increasingly popular. However, when considering sustainability and environmental degradation, it is preferable to look back and examine discarded items to discover a better option that provides superior thermal performance. (Davy et al.2015)

International Journal of Innovative Research in Science and Engineering
Volume 08, Issue 02, 2022
www.ijirse.com
ISSN: 2454-9665

Modern business and residential buildings adopt insulation technology to lower their energy costs. Using low-cost, locally available discarded waste material to provide thermal protection to a building could be a potential research topic. A detailed literature analysis was conducted to know the various tactics used to improve energy efficiency and to identify unique material development strategies for building thermal insulation. Recent literature has been used to frame the scope and purpose of this research, which included experimental studies to reduce heat infiltration throughthe roof, the development of an insulation mortar, and the estimation of overall heat load reduction in a building.

III. Methodology

Raw materials, eggshell powder, expanded polystyrene, fly ash, rice husk ash, and bamboo fiber processing stages. Eggshells are fibrous and contain 95-97% $CaCO_3$ crystal (limestone), used as a fertilizer and animal feed Thermoplastic polymer EPS (expanded polystyrene foam) has a closed cellular structure. It's a non-toxic, biologicallyinert hydrocarbon substance having a density of 11 to 32 kg/m^3. The components of F.A. might vary depending on the source and nature of coal. A significant quantity of silicon dioxide (SiO_2) (both amorphous and crystalline), aluminum oxide (Al_2O_3), and calcium oxide (CaO) is found in Fly ash. Rice husk is produced as a by-product of paddymilling and surrounds the paddy grain. Approximately 78 percent of the weight of paddy is received as rice, broken rice, and bran throughout the milling process. Rice husk is the remaining 22% of the weight. The rice mills use this rice husk as a fuel to generate steam for the parboiling process. While around 75% of the rice husk ash will be burned as volatile organic matter, the remaining 25% will be rice husk ash (RHA). The amorphous silica content of this RHAis between 85 and 90%.

Table 1 Chemical Properties of Fly ash and cement

Properties	Ordinary Portland cement (OPC)	Fly Ash (FA)
Physical properties		
Density (kg/m^3)	3150	2290
Specific Gravity	3.08	2.17
Blaine surface area (cm^2/g)	3996	2469
Chemical composition		
SiO_2 (%)	20.39	60
Al_2O_3 (%)	5.6	22.7
Fe_2O_3 (%)	3.43	4.6
CaO (%)	63.07	4.5
MgO (%)	2.91	1
Na_2O (%)	0.38	0.7
K_2O (%)	0.35	2
SO_3 (%)	0.7	0.5
Loss on ignition (%)	2.06	4

International Journal of Innovative Research in Science and Engineering
Volume 08, Issue 02, 2022
www.ijirse.com
ISSN: 2454-9665

1. Development of material

The development of over deck insulation materials and testing in prototype structures, development of greeninsulation mortars and characterization for plastering applications,

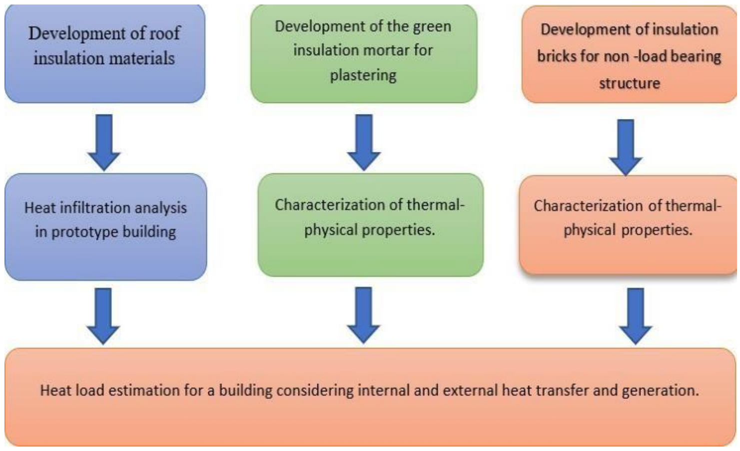

Figure 1 Flow chart of methodology

2. Experimental procedure

The amount of heat infiltration for any roofing system will be determined by weather conditions such as solar radiation and ambient temperature. All of the roofing systems'temperature sensors (J-type thermocouples or RTD) are connected to a data logger, where theyare gathered, processed, conditioned, andstored in a computer system. The investigation results were then utilized to make, test, and validate analyticaltechniques foreach roof configuration. Every 5 seconds, the weather station recorded ambient weather conditions like air temperature, relative humidity, wind speed and direction, solar radiation, and rainfall. The data was recorded every 5 seconds and averaged over 30 minutes. Figure 2. shows a sample of solar radiation and atmospheric temperature data collected during five days.

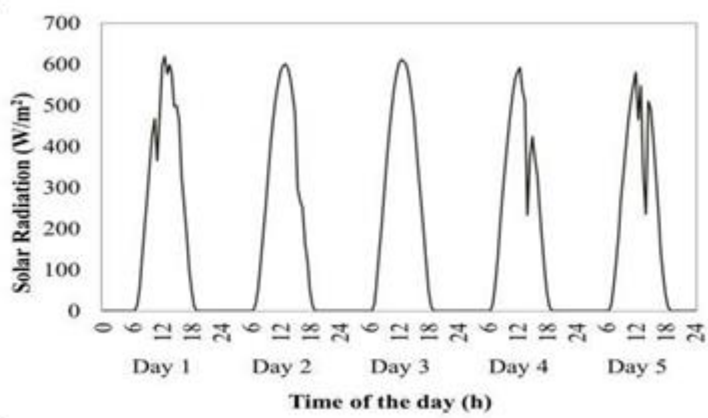

Figure 2 Five days half an hour atmospheric airtemperature profile.

IV. Result and discussion

1. X-ray diffraction spectrum of bamboo fiber.

The three peaks at 2θ = 16.15°(broad), 34.6°(general), and 21.95°(sharp), crystallographic planes are corresponding to the (101), (040), and (002) crystallographic plane reflections, respectively (El Oudiani et al. 2011). The peak, which is observed as one broad peak around 16–17°, was mainly due to many amorphous compounds like hemicelluloses and lignin in the fibers. The sharp and intense peak at about 22° is close to cellulose Iβ. The properties of bamboo fiber led to the difference in crystallinity in EBF and IBF. It is reported that the crystallinity of fiber is related to the fiber type and area. In the transverse direction of bamboo, the crystallinity index decreased from the outer layer to the inner layer of bamboo (Yang et al., 2010. Determination). Moreover, the better packing of the cellular chains in the EBF made the higher crystallinity than the inner's (Symington et al. 2008).

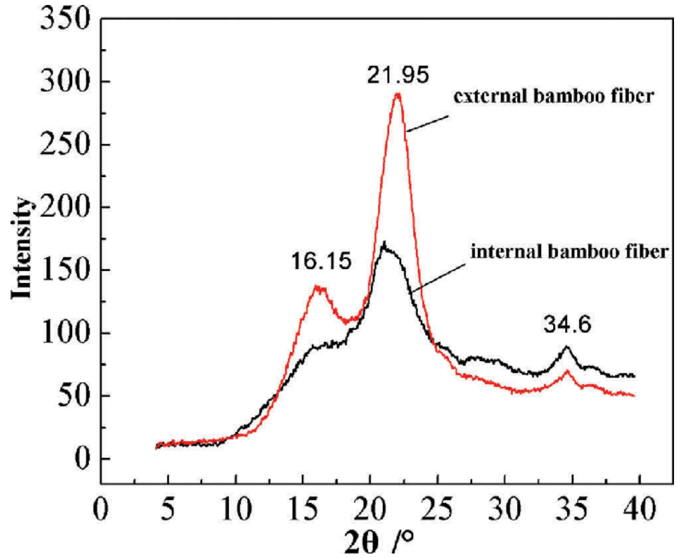

Figure 3. X-ray diffraction spectrum of bamboo fiber.

2. Water absorption

Figure 4.4 depicts the variation in compressive strength of various mortars at varying compositions. Becauseof its more substantial binding qualities with cement and sand, FAM has a higher compressive strength than other varieties, and it increases as the F.A. level increases. Because F.A. is more refined than sand, it can becompacted more effectively with fewer voids, resulting in a higher compressive strength for FAM. By replacing 25% of the sand with F.A., the compressive strength of FAM increases by 17%.

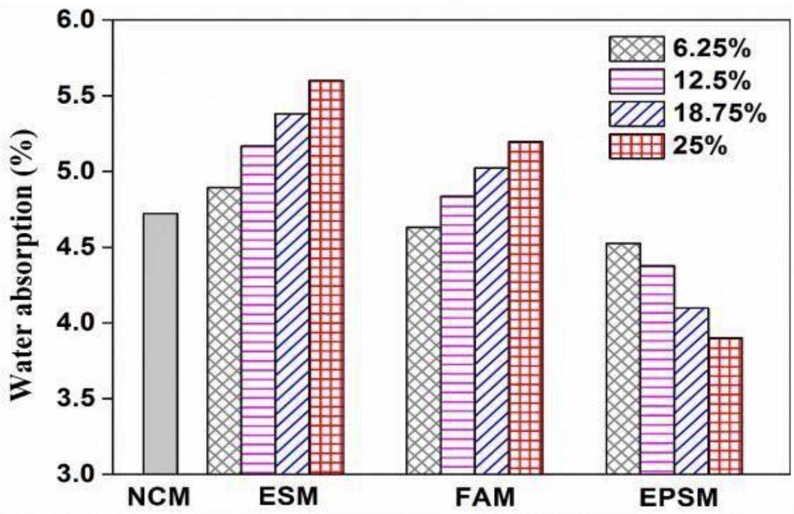

Figure 4. Water absorption analysis of the different mortar samples.

3. Compressive strength

The compressive strength of the brick determines the load-bearing capacity of a wall. The wall in a building serves two objectives. The wall was deemed a non-load-bearing wall in pillar beam constructions, but in tiny building constructions, the wall may operate as a weight-bearing structure. Figure 4.7 depicts the average compressive strength of the brick series. Insulation bricks are designed and manufactured for non-load bearing constructions and must have a minimum compression strength of 3.5 MPa according to IS1077specifications.

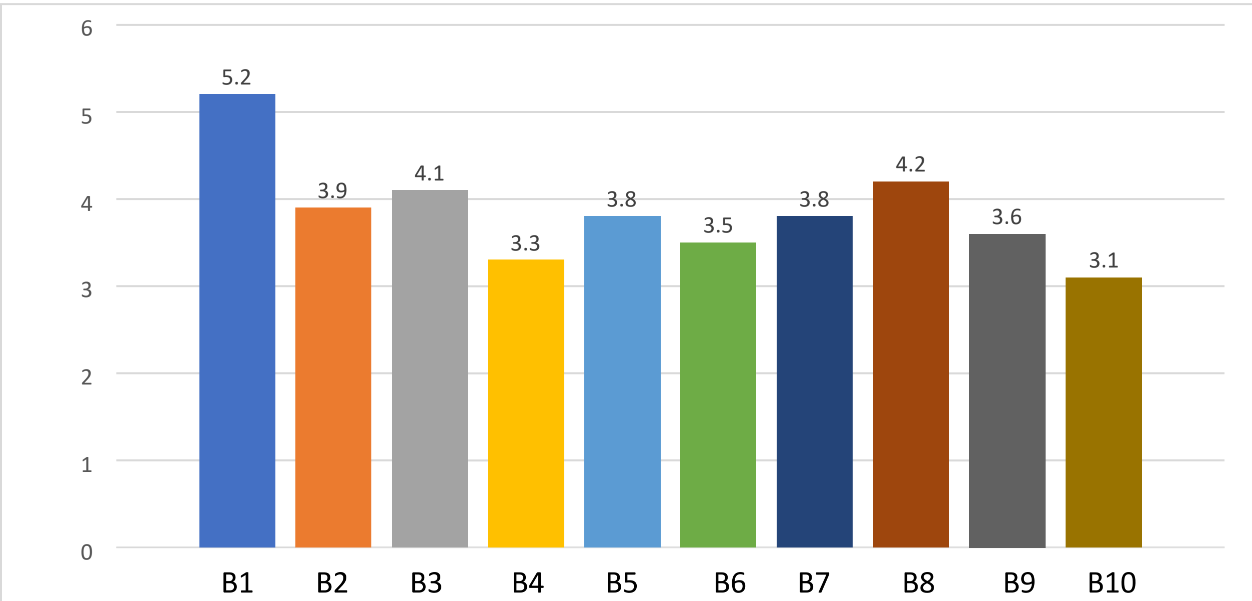

Figure 5. Compressive strength analysis of modified brick samples

V. Conclusion

The use of novel over-deck insulation to roof and wall components of a building resulted in a 59.20 percentreduction in external heat load for the top floor area. They will significantly lower the cooling load for an air- conditioned structure and provide suitableliving conditions for tropical countries like India. Because the building sector consumes a rising amount of energy, innovative building envelopsinsulation will help solve the energy crisisand slow the rate of environmental degradation.

The following are the most critical findings from this study:

- For typical Indian weather conditions, the thermal performance of three over-deck insulation profiles ofroof structures is compared to a simple RCC reference roof structure.
- When the traditional weathering coarse over-deck insulation of broken brick lime mortar mixture was laid over the RCC structure, heat infiltration was reduced by approximately 66.67% (R2).
- When compared to the reference roof structure, an internationally famous inorganic expanded polystyrene over-deck insulation with low thermal conductivity roof profile (R3) has provided an 85 percent reduction in heat infiltration (R1).
- The unique eco-friendly insulating brick developed for this work from discarded organic waste rice huskand bamboo fiber was installed over the RCC roof structure (R4) to achieve a heat infiltration reductionof 76.80% compared to the reference roof.This substantially contributed to comfortable living conditions by reducing the cooling burden. The addition of fly ash to a mortar series known as FAM results in a 17% improvement in compressive strength and a 10% reduction in thermal conductivity without compromising workability or water absorption qualities.
- The incorporation of bamboo fiber into brick material, coupled with fly ash, improvesthe insulating properties of bricks (B6) with compressive strengths over the threshold limitations established by building reference codes.

References

1) Davy, JL, Phillips, TJ & Pearse, JR 2015, 'The dumping of gypsum plasterboard wooden stud cavitywalls,' Applied Acoustics, vol. 88, pp. 52-56.

2) Lee, S & Chong, WO 2016, 'Causal relationships of energy consumption, price, and CO2 emissions in the U.S. building sector, Resources, Conservation and Recycling, vol.107, pp. 220-226.

3) Si, B, Tian, Z, Jin, X, Zhou, X, Tang, P & Shi, X 2016, 'Performance indices and evaluation of algorithms in building energy-efficient design optimization,' Energy, vol.114, pp. 100-112.

4) Kalbar, PP, Birkved, M, Hauschild, M, Kabins, S & Nygaard, SE 2018, 'Environmentalimpact of urban consumption patterns: drivers and focus points. Resources, Conservation and Recycling, vol. 137, pp.260-269.

5) Liu, S, Meng, X & Tam, C 2015, 'Building information modeling-based building design optimization for sustainability, Energy and Buildings, vol. 105, pp. 139-153.

6) Ramachandra, TV, Aithal, BH & Sreejith, K 2015, 'GHG footprint of significant cities in India. Renewable and Sustainable Energy Reviews, vol. 44, pp. 473-495

7) Berardi, U 2016, 'The outdoor microclimate benefits and energy saving is resulting fromgreen roofs

retrofits,’ Energy and Buildings, vol. 121, pp. 217-229.

8) Sha, A, Liu, Z, Tang, K & Li, P 2017, 'Solar heating reflective coating layer (SHRCL)to cool the asphalt pavement surface,' Construction and Building materials, vol. 139, pp. 355-364.

9) Xaman, J, Cisneros-Carreno, J, Hernandez-Perez, I, Hernández-Lopez, I, Aguilar- Castro, KM and Macias-Melo, EV 2017, 'Thermal performance of a hollow block with/without insulating and reflective materials for roofing in Mexico,’ Applied Thermal Engineering, vol. 123, pp.243-255.

10) Saleem, MA, Abbas, S & Nehdi, ML 2019, 'Assessment of reinforced concrete slabs using in-situ load testing: A case study, Journal of Building Engineering, p.100844.

11) Asadi, I, Shafigh, P, Hassan, ZFBA and Mahyuddin, NB, 2018, 'Thermal conductivityof concrete–A review,' Journal of Building Engineering, vol. 20, pp. 81-93.

12) Brunner, S & Simmler, H 2008, 'In situ performance assessment of vacuum insulationpanels in a flat roof construction,’ Vacuum, vol. 82, vol. 7, pp. 700-707.

13) Zhang, L, Pan, Z, Zhang, Y & Meng, Q 2018, 'Impact of climatic factors on evaporativecooling of porous building materials, Energy and Buildings, vol. 173, pp. 601-612.

14) Li, X & Malkawi, 2016, 'Multi-objective optimization for thermal mass model predictive control in small and medium-size commercial buildings under summer weather conditions,’ Energy, vol. 112, pp.1194-1206. And Zhang, L, Pan, Z, Zhang, Y& Meng, Q 2018, 'Impact of climatic factors on evaporative cooling of porous buildingmaterials, Energy and Buildings, vol. 173, pp. 601-612.