Techno-Economic Analysis of Insulating Bricks Used in Educational Building Made by Local Available Agricultural Waste

Sharma, Divyanshi
Department of Civil Engineering, Kautilya Institute of Technology and Engineering

Vinod Kumar Modi
Department of Civil Engineering, Kautilya Institute of Technology and Engineering

Kumar, Chandan
Department of Mechanical Engineering, Swami Keshvanand Institute of Technology, Management & Gramothan

https://doi.org/10.5109/7160914

出版情報：Evergreen. 10 (4), pp.2590-2598, 2023-12. 九州大学グリーンテクノロジー研究教育センター
バージョン：

Techno-Economic Analysis of Insulating Bricks Used in Educational Building Made by Local Available Agricultural Waste

Divyanshi Sharma[1*], Vinod Kumar Modi[2], Chandan Kumar[3]
[1]Department of Civil Engineering, Kautilya Institute of Technology and Engineering, Jaipur, India
[2]Department of Civil Engineering, Kautilya Institute of Technology and Engineering, Jaipur, India
[3]Department of Mechanical Engineering, Swami Keshvanand Institute of Technology, Management & Gramothan, Jaipur, India

*Author to whom correspondence should be addressed:
E-mail: architectdivyanshi@gmail.com

(Received March 20, 2023; Revised December 19, 2023; accepted December 19, 2023).

Abstract: Due to low-income workers' strong need for low-cost housing and India's mixed environment, new-built housing stock must be cost-, durability-, and efficiency-conscious. Walls make for a large amount of building costs, thus choosing a wall system is crucial. This option depends on how durable, pleasant, eco-friendly, and affordable a system is to fulfil quality and cost criteria. Energy efficient building offers for robust, economical, and sustainable housing, but it's not well-known. So, the building sector has ignored its sustainable qualities. This article compares the thermal characteristics and overall Life Cycle Costs (LCC) of building walls with local developed insulated walls in one of Rajasthan's hottest locations. In-situ temperature and heat flux measurements were taken following ISO 9869 to determine yearly energy needs. Total LCC was based on initial construction costs and yearly energy expenditures for building wall systems. sustainable housing has a lower U-value than brick walls, resulting in reduced yearly energy consumption and a 70% annual energy cost savings. This savings, along with low initial building costs, rendered the optimal sustainable walls cheaper over 30 years than the burnt brick unit.

Keywords: CFD simulation, Energy Simulation, Bricks, agricultural waste, Sustainable building

1. Introduction

The amount of energy required to heat and cool buildings accounts for as much as forty percent of the world's total energy usage. Emissions of greenhouse gases are becoming an increasingly significant problem on a worldwide scale, in addition to being a local environmental concern. Natural gas and electricity, both of which are often utilized to a large extent in building construction, have a sizeable bearing on the overall pollution emissions. As a result, lowering the amount of energy that is used for electrical and other purposes within the construction industry is a common piece of advice[1-3]. Incorporating insulation into the exterior walls of a building is a key component of an effective passive strategy for making buildings resistant to the passage of unwanted heat between interior and exterior spaces. Because of this activity, the total heat conductivity of walls is decreased, and the time scale over which heat is transferred is increased.

A number of university research teams collaborated to develop an improved plan for the building's outside wall. Enhanced thermal performance achieved through the utilization of novel insulating materials tailored to the environmental conditions of Morocco. Expanded polystyrene (EPS) and rock wool (RW) have two distinct thicknesses, according to the findings: the thickness of popular insulating materials) is 0.060 m, and the thickness of 0.085 m. The ideal insulation comprises of expanded polystyrene (EPS) and rock wool (RW). Researchers[4] from many institutions in Iran took into account the weather patterns of Ardabil, Tehran, and Khuzestan in order to determine the ideal thickness of the layers of insulation that are located on the exterior of the building. According to the findings of the thermal and thermo-economic research, the ideal thicknesses of the insulation layers for Ardabil are 10.6 centimeters, while the optimal thicknesses for Tehran are 11.95 centimeters, and the optimal thicknesses for Khuzestan are 16.35 centimeters[5].

Axaopoulos et al.[6] determined the best insulation thickness of several materials for a variety of cooling and heating loads, wind speeds, and wind directions for each material. The optimal insulation thickness was determined for each material. The ideal insulating thickness for the many different circumstances ranged anywhere from 4.25 centimeters to 15.5 centimeters, while the payback period ranged anywhere from 5.47 years to 12.11 years. The life cycle cost (LCC) method was utilized by Dombayci and colleagues[7] in order to investigate what the appropriate insulating thickness of a structure should be. As a consequence of their research, they determined the bare minimum and utmost acceptable levels of insulation thickness for environments with warm and cold temperatures respectively. Evin et al.[8] evaluated the heating and cooling loads of a number of different structures using the appropriate thermal insulation thicknesses for Turkey. The method was used to the construction of a residential building, and the results were studied by comparing and evaluating the performance of four distinct insulating materials under a range of climatic conditions. It has been determined that increasing the thickness of the insulation leads to a greater rise in the number of heating degree-days.

Pourghorban et al.[9] made use of a numerical simulation to figure out the optimal configuration for the reflective insulation system and the air gap that is contained inside the walls of the construction. They found that reflective insulation systems should have a 20 mm air gap next to the reflecting surfaces for the best feasible configuration to accomplish the required results. This was the most effective way to obtain the desired outcomes.

The researchers Jie et al.[10] included factors such as energy consumption, worldwide cost, and environmental emissions to calculate the optimal overall insulation thickness for a pre-defined index. Because of this, they were able to establish the ideal overall thickness of the insulation. Their findings were presented in the form of a mathematical equation when they were written up and presented. They obtained the curve-fitted function of cooling and heating building needs in connection to insulation thickness by using the method of least squares, and they asserted that there is an essential value of insulation thickness in relation to reductions in worldwide cost. They came to the conclusion that, despite the many financial factors that were taken into account, the critical value that was estimated for the insulation should not be exceeded in terms of the thickness of the insulation that is used. This decision was reached after they discussed and debated the issue.

In the majority of the study referred to in the preceding paragraph, single-objective optimization was used. This was done in order to lower the number of economic-based factors. The bulk of the works that came before have concentrated, as their primary purpose, on maximizing economic parameters such as the payback period or the overall cost. This has been the case for the majority of those works. However, the use of insulating layers in building envelopes can be justified for a variety of reasons, and not simply because of the effect that these layers have on the surrounding environment. Even while only a small number of prior studies have examined a variety of insulation configurations[11], the number of these configurations is extremely modest and does not encompass all of the possible envelope layers' combinations that are significant. Torres-Rivas et al.[11] used the same method and goal functions, but in addition to that, they took into account the possibility of condensation and mass transfer into the insulating layers. They arrived to the conclusion that using insulating materials that are derived from bio-based materials not only results in a large decrease in the overall installation costs, but it also results in a reduction in the environmental consequences of the project.

Equest (Version 3.65)[12-13], since it is capable of accounting for the required level of detail, is utilized to carry out dynamic simulations for full year building energy simulation. Equest software use the energy plus simulation software. This software is freely available for any type of simulation of the buildings. Optimization fo the energy requirement of the building can also have performed in Equest software. Major of the researchers done research using equest software were change the wall insulation properties to control the heat loss from the building or cooling energy loss from the building. Economical analysis of the building can also have done in this software using utility information of the place where the building was planned to built.

The goal of this research was to develop a method to manufacture insulating bricks out of agricultural waste and other locally sourced construction materials. The best possible insulating bricks were then evaluated with a CFD simulation to find the relation among the experiment data for the bio bricks made by the researcher using Agro waste materials. In the current study, a techno-economic analysis[14-16] of the bricks used in educational building (KITE, Jaipur) was carried out. The simulations were carried out using Equest software.

2. Research methodology

The purpose of this research is to establish which kind of agro-waste-based insulating bricks are the most effective for use in the local region of Rajasthan (India). In order to do this, initially a single-objective optimization will be carried out to produce the best possible insulated brick using cow dung powder, Agro waste powder, lime stone, and any other necessary construction components. After that, a computational fluid dynamics (CFD) simulation was run to validate the results of the experiment concerning the insulating bricks. This was done by constructing a rectangular chamber for the purpose of conducting a heat transfer study. In the most recent study, a techno-economic analysis was carried out utilizing Equest software to determine the best and most optimal insulated brick. The research methodology flow diagram was shown in figure 1.

Fig. 1: Research Flow diagram of the present study

3. Energy simulation method

The EQUEST program is used to calculate the energy needs of a typical structure, as well as the influence that insulating the building envelop will have on the amount of energy and water that will be used, as well as the payback period. The Equest toolbox was chosen in large part due to the advantages it offers in whole-building energy modeling in comparison to the basic approaches that were discussed before. The following are some of the functionalities offered by Equest software:

Made a full scale building simulation model in building energy simulation software in which all envelope components of the building were made for year round simulation using the bio bricks.

In building energy simulation software, real weather files were user to make the real type data generation, so detailed information regarding the BES simulation was most crucial part of the Equest simulation software like internal partition of the building, wall and other building materials properties, time duration of the buildings all these are required information for the BES simulation software.

4. Materials and methods

The following is a list of ecologically friendly resources that are used in the production of masonry bricks, in the order in which they are listed: clay, shale, sand, and limestone

Agro Waste (AW)
Cow Dung Ash (CDA)
Fly Ash (FA)
Slaked Lime
Water

Cow dung is easily accessible in India and works as a water-resistant and moisture-buffering plaster in mud homes. Cow manure is plentiful. This makes it an intriguing stabilizer for unfired mud bricks. Mostly undigested fibers and bacterial biomass make up excrement. Despite the fact that fibers are beneficial for increasing moisture absorption, his latest research on bacterial biomass found it to be water resistant. When dung is combined with mud, a homogenous brick with mediocre water resistance and good moisture capacities is created. Researchers have discovered how to make a non-uniform brick with exceptional water-resistance and moisture-absorbing/releasing qualities and maintain the insulation capabilities of the bricks. The chemical properties of the cow dung powder was present in table 1.

Table 1: Cow Dung Ash Chemical Properties[17)]

Element (mg/kg)	Na	K	Ca	Mg	P	N	ZN
%	0.08	0.3	1.0	0.48	0.84	1.37	286

Table 2 included the entire needed combination for this investigation and show all of the information of the various combination proportions that were produced for this investigation are listed. Raw ingredients were initially combined in the dry state for each percentage of the combination, and then water was added to continue the mixing process in the wet state.

To produce the needed plasticity for molding purposes, water was added to each clay-waste mix in a proportion that ranged from 18–25% of the weight of the raw materials. This was done in a manner that was similar to the previous work[18)]. After the mixture was thoroughly combined, brick samples with dimensions of 200 millimeters by 100 millimeters by 75 millimeters were formed by hand utilizing molds and applying no pressure. First, the brick samples were exposed to the sun for three days, and then they were quenched in water for two weeks.

Because it was important to keep the insulation properties of the bricks, certain design considerations were chosen, and bricks both with and without hollow structures in the shape were taken into account. As a result, each sample contains hollow structures as well, which were predetermined for each sample and do not exceed 20% of the total volume of the brick shape. Figure 2 depicts the brick's overall layout and composition. The fabrication of the brick was done at college laboratory

(KITE, Civil Department, Jaipur). Rectangular box was made fr making the bricks and no pressure was applied to any sample used for present study.

Table 2: Composition of the mixture of the brick made for present study

Insulation Brick Sample	AW (%)	CDA (%)	FA (%)	Remaining (%)
Simple	-	-	50	50
IB-I	10	-	50	40
IB-II	-	10	50	40
IB-III	5	5	50	40

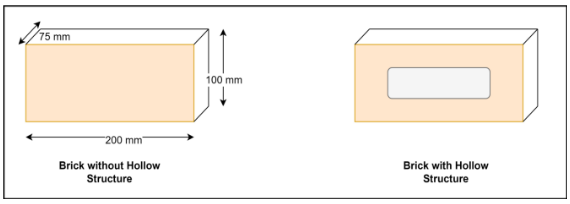


Fig. 2: Dimension of brick used in present study

5. CFD simulation and validation

Insulation bricks manage a building's energy usage, promoting sustainable development. In the current study, bricks were insulated by using agricultural waste and leaving air holes in the end product (Hollow bricks). In this study, a CFD simulation was performed to assess an experiment on newly produced insulating bricks. After validating the building with insulating blocks, a year-round energy simulation was performed to calculate the structure's energy savings. Figure 3 shows the CFD simulation's rectangular chamber.

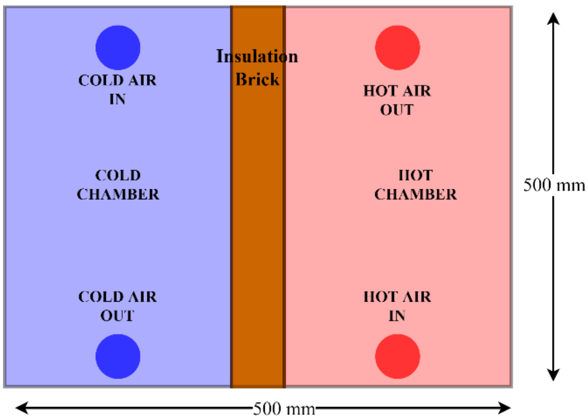
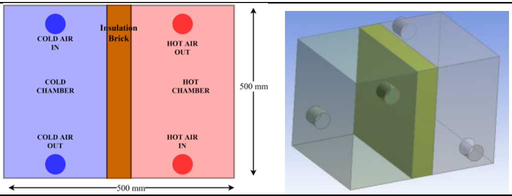


Fig. 2: Dimension of CFD domain used for present investigation

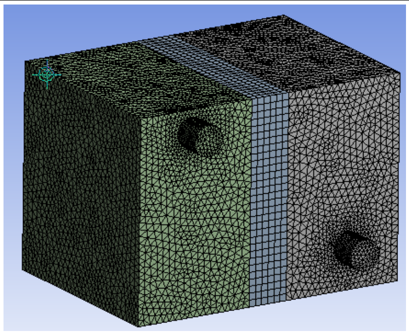
CFD simulation was utilized to test the insulating ability of bricks made from Argo waste and other local resources. Simulation software was Ansys Fluent 18.2. This section details the simulation's modeling techniques. Table 3 contains all modeling stages.

Table 3: cfd modeling steps required for the battery cooling system

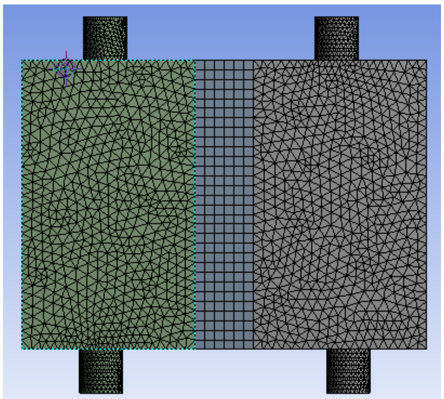
Step-I: Geometry making (Design Modeler)



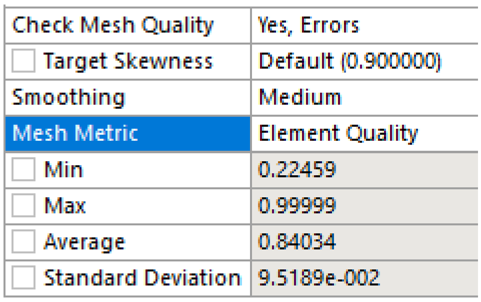
Step-II: Meshing of the Domain



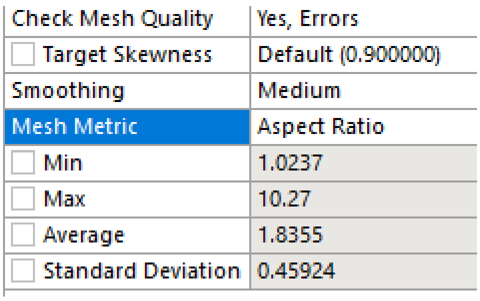
Front View of the Meshing



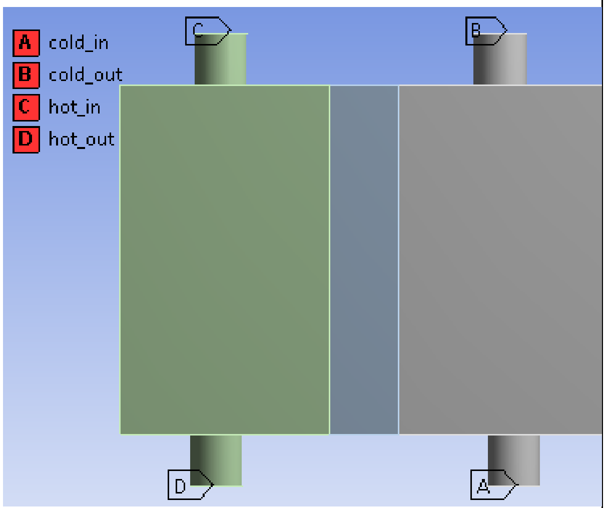
Mesh Quality



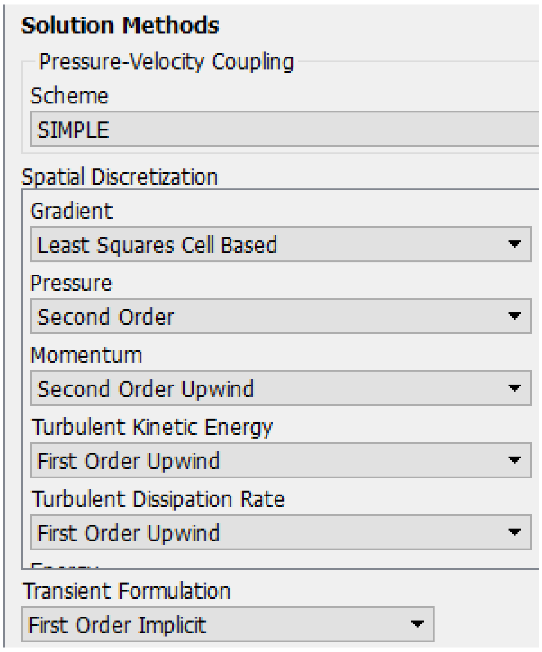
Check Mesh Quality	Yes, Errors
Target Skewness	Default (0.900000)
Smoothing	Medium
Mesh Metric	Element Quality
Min	0.22459
Max	0.99999
Average	0.84034
Standard Deviation	9.5189e-002

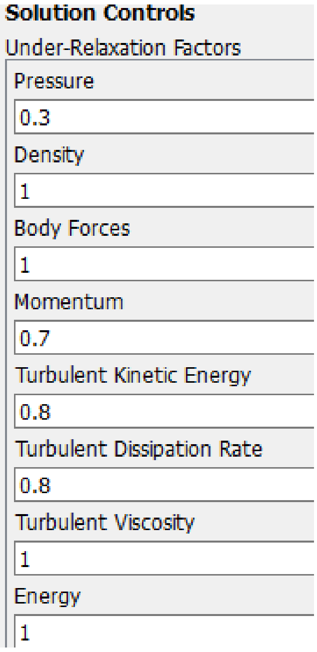


Step-III: Named Boundary Conditions

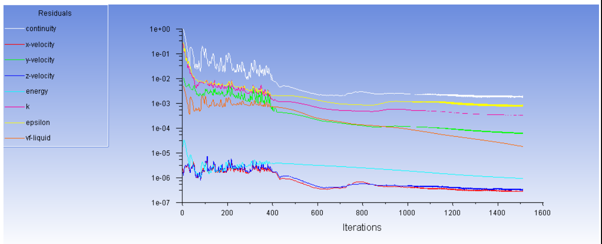


Step-IV: Solution methods and Controls

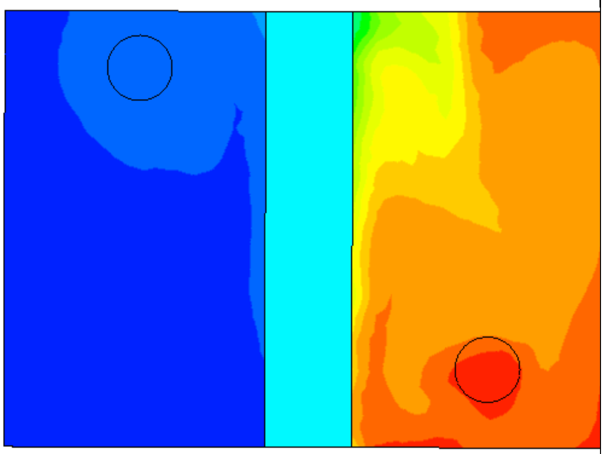




Step-V: Solution Run



Step-VI: Results



The CFD simulation was carried out to validate the fabricated bricks using Agro waste. In present study temperature was measured within the chamber to validate the results. The boundary conditions set for the heat transfer analysis of the chamber was shown in table 4.

The complete simulation was run for a time interval of ten minutes, as specified by the experiment that was carried out. At the chamber's equidistant midpoint, the temperature was measured for both the warm and the cool chamber. The outcome was quite productive, and it was demonstrated that the CFD validation had a fair degree of congruence with the results of the experiment. table 5 depicts the validation that was carried out on the insulating bricks.

Table 4: Boundary Conditions required for present study

Boundary Name	Type	Values	Unit
Cold Inlet	Velocity Inlet/ Temp	1 and 26	m/sec and C
Hot inlet	Velocity Inlet/ Temp	1 and 45	m/sec and C
Cold and Hot Outlet	Pressure Outlet	1	Bar
Brick Wall	Wall	-	-

Table 5: CFD Validation of the Insulation Brick (IB-3) Experiment study

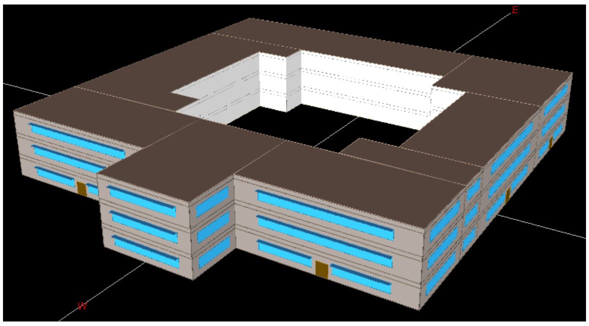
Time (min)	Cold Chamber		Error (%)	Hot Chamber		Error (%)
	Ex Temp ^{0}C	CFD Temp ^{0}C		Ex Temp ^{0}C	CFD Temp ^{0}C	
0	26.0	26.0	0.0	45.0	45.0	0.0
2.5	26.3	26.8	1.9	44.3	44.1	0.45
5.0	26.8	27.2	3.8	43.8	43.1	1.6
7.5	27.1	27.5	1.5	42.6	41.8	1.9
10.0	27.4	28.4	3.6	41.2	40.6	1.5

As can be seen in table 5, the error that was reported throughout the CFD simulation was within the acceptable range of below 5%, indicating that there was a very decent level of agreement throughout the research. After the CFD validation was finished, the next part of the current study was addressed, which was to now carry out the techno economic analysis of the structure that uses the insulating brick manufactured by researchers utilizing Agro waste.

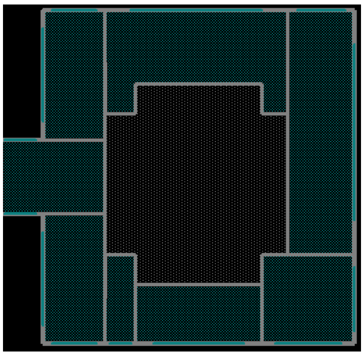
6. Building energy simulation

The structure that served as a case study in the simulations is seen in Figure 4. It is a residential structure with a total of five stories and two apartments on each floor. Insulation retrofitting is only performed on the building's exterior; the building's interior walls, as well as the ceilings and floors of the individual apartments, do not have insulation installed. The structure as a whole is modeled and evaluated in EQUEST, and the zone on the bottom level as well as the staircases are both considered to be unconditioned zones. For both the conditioned and unconditioned zones, the internal loads that are connected to inhabitants (4 people in each partition of building), lighting arrangement in internal part of building, and gas operated instruments are planned to occur during the entirety of the simulation time. All of the individual units, as well as the sub-zones that each unit contains, are conditioned using the identical HVAC systems and controls. The weather that ISHARE reported for the Jaipur region was the one that was used for this.

The development of the building in Equest software was accomplished by making use of satellite photographs of the structure together with a CAD diagram that was supplied by the management. It was assumed that attention should be used in the creation of the software building. The researcher was responsible for providing the properties of the construction materials in accordance with the studies that he conducted on all of the necessary insulation bricks.



(a.)



(b.)

(c.)

Fig. 4: KITE Main Educational Building Model made in EQUEST (a) Isometric View (b) Top View of KITE (c.) Satellite View of Kite

7. Result and discussion

The current research project was divided into three sections, the first of which involved the production of an insulating brick manufactured from agricultural waste that was readily available in the area. In the second portion, CFD validation was done with the experimental data. In the third and final section, building energy simulation was performed for the optimum insulating brick, which was generated by the manufacture of the bricks. Insulation brick produced using both cow dung powder (five percent) and agricultural waste (five percent), with the other ninety percent being regular remaining construction materials. The results of the experiments conducted on the insulating bricks may be seen in table 6.

Table 6. Experiment results for insulation bricks sample fabricated in present study

Brick Sample	Compressive Strength (MPa)	Modulus of Rupture (MPa)	Water Absorption (%)	Thermal Conductivity (W/mK)
Simple	9.8	0.97	18.3	0.547
IB-I	7.9	0.81	21.2	0.524
IB-II	9.2	0.94	19.5	0.517
IB-III	**9.1**	**0.88**	**20.4**	**0.506**

According to table 6, the sample with the greatest possible mechanical qualities and the lowest possible thermal conductivity to utilize for a techno economic analysis is the sample IB-III. This sample also has the lowest possible thermal conductivity. After that, the CFD validation was performed on this sample in order to check the accuracy of the experiment results before carrying out the techno economic analysis. The baseline simulation was compared with insulation bricks in EQUEST software and the effect of insulation thickness over the payback period was present in table 7.

Because of the significance of the instability of simulations and the fact that the amount of time it takes for temperatures in a zone to adjust to changes in the temperature outside as well as the resulting load transfer, a time step analysis is carried out to assure outcome correctness. Comparisons of the answers are made using a number of different time steps, ranging from 5 to 25 per hour. On the basis of the answers that were obtained, it was discovered that establishing the time steps to be equal to 10 minutes (6-time steps per hour) produces precision that is satisfactory.

Table 7. Electrical Consumption of Building for different Brick Smaples (1000*kWh)

Brick Sample	Simple	IB-I	IB-II	IB-III
Jan	53.3	52.8	52	50
Feb	67.7	67.6	66.4	64.5
Mar	67.2	67.1	65.9	64
Apr	77.3	77.3	76.3	74.4
May	110.1	110.1	109.2	107.3
Jun	57.9	57.9	56.8	54.9
Jul	61	61	59.8	57.9
Aug	115.1	115.1	113.9	112
Sep	70.1	70.1	69	67.1
Oct	78	78.1	77	75.1
Nov	82.7	82.8	81.6	79.7
Dec	37.9	38	36.7	34.8

8. Conclusion

The incorporation of insulating materials into the outside walls of a building leads to an increase in the heat transfer resistance of the structure, which in turn leads to a decrease in the consumption of resources (such as gas, water, and electricity). The ideal insulating scenario for moderately dry regions has been determined over the course of this research by applying the economic criterion of total cost. The outcomes are presented down below. The best assumption is based on the industrial rank insulation configuration that is utilized in educational buildings, which consists of several layers of insulation having bio bricks in between each layer of insulation. The only thing that is determined throughout the process of optimization is the thickness of the layers, and this is done while taking into consideration the limits that are imposed on construction. This is done in order to achieve maximum efficiency. In the current investigation, three distinct types of insulating bricks were manufactured, and further experiments were carried out on a range of different variables. For the most effective insulating bricks, an overall hybrid mix of cow dung powder and agricultural waste proved to be the most effective combination. In addition, CFD validation was carried out for the ideal brick, and the inaccuracy was within a range of 5 percent. Using the Equest program designed for educational buildings, a simulation of the building's energy use was carried out.

References

1) D'Agostino, Diana, Filippo de'Rossi, Marcello Marigliano, Concetta Marino, and Francesco Minichiello. "Evaluation of the optimal thermal insulation thickness for an office building in different climates by means of the basic and modified "cost-optimal" methodology." Journal of Building Engineering 24 (2019): 100743.
2) Lo, Kevin. "The "warm houses" program: Insulating existing buildings through compulsory retrofits." Sustainable Energy Technologies and Assessments 9 (2015): 63-67.
3) Satrio, Pujo, Teuku Meurah Indra Mahlia, Niccolo Giannetti, and Kiyoshi Saito. "Optimization of HVAC system energy consumption in a building using artificial neural network and multi-objective genetic algorithm." Sustainable Energy Technologies and Assessments 35 (2019): 48-57.
4) Gounni, Ayoub, Mohamed Tahar Mabrouk, Mohamed El Wazna, Abdelhamid Kheiri, Mustapha El Alami, Abdeslam El Bouari, and Omar Cherkaoui. "Thermal and economic evaluation of new insulation materials for building envelope based on textile waste." Applied Thermal Engineering 149 (2019): 475-483.
5) Ziapour, Behrooz M., Mohsen Rahimi, and Mohammad Yousefi Gendeshmin. "Thermoeconomic analysis for determining optimal insulation thickness for new composite prefabricated wall block as an external wall member in buildings." Journal of Building Engineering 31 (2020): 101354.
6) Axaopoulos, Ioannis, Petros Axaopoulos, Gregoris Panayiotou, Soteris Kalogirou, and John Gelegenis. "Optimal economic thickness of various insulation materials for different orientations of external walls considering the wind characteristics." Energy 90 (2015): 939-952.
7) Dombayci A, Atalay O, Güven Acar S¸, Yilmaz Ulu E, Kemal OH. "Thermoeconomic method for determination of optimum insulation thickness of external walls for the houses: case study for Turkey" Sustain Energy Technol Assessments (2017); 22:1–8. https://doi.org/10.1016/j.seta.2017.05.005.
8) Evin D, Ucar A. "Energy impact and eco-efficiency of the envelope insulation in residential buildings in Turkey" Appl Therm Eng (2019);154:573–84. https://doi. org/10.1016/j.applthermaleng.2019.03.102.
9) Pourghorban A, Kari BM, Solgi E. "Assessment of reflective insulation systems in wall application in hot-arid climates" Sustain Cities Soc 2020;52:101734. https:// doi.org/10.1016/j.scs.2019.101734.
10) Jie P, Zhang F, Fang Z, Wang H, Zhao Y. "Optimizing the insulation thickness of walls and roofs of existing buildings based on primary energy consumption, global cost and pollutant emissions" Energy (2018);159:1132–47. https://doi.org/10.1016/ j.energy.2018.06.179.
11) Torres-Rivas, Alba, Mariana Palumbo, Assed Haddad, Luisa F. Cabeza, Laureano Jiménez, and Dieter Boer. "Multi-objective optimisation of bio-based thermal insulation materials in building envelopes considering condensation risk." Applied Energy 224 (2018): 602-614.
12) J. Xing, P. Ren and J. Ling, "Analysis of energy efficiency retrofit scheme for hotel buildings using eQuest software: A case study from Tianjin,China," Energy and Buildings, vol. 87, pp. 14-24, (2015).
13) M. T. Ke, C. H. Yeh and J. T. Jian, "Analysis of Building Energy Consumption Parameters and Energy Savings Measurement and Verification by Applying eQuest Software," Energy and Buildings, vol. 61, pp. 100-107, (2013).
14) Al-Sanea, Sami A., and M. F. Zedan. "Improving thermal performance of building walls by optimizing insulation layer distribution and thickness for same thermal mass." Applied Energy 88, no. 9 (2011): 3113-3124.
15) Kurekci, Nuri Alpay. "Determination of optimum insulation thickness for building walls by using heating and cooling degree-day values of all Turkey's provincial centers." Energy and buildings 118 (2016): 197-213.
16) Ren, Haoshan, Zhenjun Ma, Wenye Lin, Shugang Wang, and Weihua Li. "Optimal design and size of a desiccant cooling system with onsite energy generation and thermal storage using a multilayer perceptron neural network and a genetic algorithm." Energy Conversion and Management 180 (2019): 598-608.
17) AS, Hilal, and P. Magudeaswaran. "Development of Eco Brick and Concrete with the partially replacement of Cow dung-A Review."International Journal of Science and Engineering Research (IJ0SER), 5, Issue-11 (2017)
18) Goel, Gaurav, and Ajay S. Kalamdhad. "An investigation on use of paper mill sludge in brick manufacturing." Construction and building

materials 148 (2017): 334-343.

19) Anil, A.K. Chanda, and S. Angra, “Optimization of Stiffness Properties of Composite Sandwich using Hybrid Taguchi-GRA-PCA”, EVERGREEN Joint Journal of Novel Carbon Resource Sciences & Green Asia Strategy, 8(2), 310-317 (2021). doi.org/10.5109/4480708
20) S. S. M. Fadzullah, M. M. Nasaruddin, Z. Mustafa, W. A. W. A. Rahman, G. Omar, M. A. Salim, and M. R. Mansor, “The effect of chemical surface treatment on mechanical performance of electrically conductive adhesives”, EVERGREEN Joint Journal of Novel Carbon Resource Sciences & Green Asia Strategy,7(3), 444-451 (2020). doi.org/10.5109/4068625
21) M. Ayadi, S. Ahou, S. Awad, M. Abderrabba and Y. Andres, "Production of Biogas from Olive Pomace," EVERGREEN Joint Journal of Novel Carbon Resource Sciences & Green Asia Strategy 7 (2), 228-233 (2020). doi.org/10.5109/4055224
22) Zingre, Kishor T., Xingguo Yang, and Man Pun Wan. "Performance analysis of cool roof, green roof and thermal insulation on a concrete flat roof in tropical climate." EVERGREEN Joint Journal of Novel Carbon Resource Sciences & Green Asia Strategy 2(2), 34-43 (2015). doi.org/10.5109/1544078
23) Singh, Saurabh, Suraj Kumar Singh, Rahul Kumar, Abhishek Shrama, and Shruti Kanga. "Finding Alternative to River Sand in Building Construction." EVERGREEN Joint Journal of Novel Carbon Resource Sciences & Green Asia Strategy 9(4), 973-992 (2022). doi.org/10.5109/6625713
24) Kalsia, Mohit, Ankit Sharma, Rajneesh Kaushik, and Raja Sekhar Dondapati. "Evaporative Cooling Technologies: Conceptual Review Study."EVERGREEN Joint Journal of Novel Carbon Resource Sciences & Green Asia Strategy, 10(1), 421-429 (2023). doi.org/10.5109/6781102
25) P. Byrne, N. Putra, T. Mare, N. Abdallah, P. Lalanne, I. Alhamid, P. Estelle, A. Yatim, and A.L. Tiffonnet, “Design of a solar ac system including a pcm storage for sustainable resorts in tropical region,” Evergreen, 6 143–148 (2019). doi:10.5109/2321009
26) U. Agrobusiness, “Development of sustainable hydroponics technique for urban agrobusiness,” Evergreen, 9 (3), 629–635 (2022). doi.org/10.5109/4842519
27) M. Sultan, I.I. El-Sharkawl, T. Miyazaki, B.B. Saha, and S. Koyama, “Experimental study on carbon based adsorbents for greenhouse dehumidification,” Evergreen, 1 (2), 5–11 (2014). doi:10.5109/1495157.