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# Theoretical and Modelling Analysis of Nano-Based Aerogel Bricks for Energy Optimization in Buildings of Hot Semi-Arid Climates: Advancing Towards Net-Zero Energy Solutions

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The increasing demand for sustainable construction technologies is crucial in addressing climate change and global energy crises. Integrating advanced materials into building designs plays a key role in tackling these challenges and paves the way toward net-zero and net-positive energy buildings. This research investigates the potential of Nano-based aerogel bricks to optimize energy consumption in buildings situated in hot semi-arid climates, where heat gain and cooling demands are significant. A detailed simulation analysis examines the im-pact of Nano-based aerogel bricks on thermal performance and heat gain reduction in the Frank & Debbie Management Complex at A.M.U., located in such a climate. Using Ecotect Analysis modeling software, the study compares the heat transfer characteristics of traditional brick walls with those enhanced by Nano-based aerogels. The research considers several variables, including climate conditions, building orientation, and occupancy patterns, to provide a holistic view of the building's thermal behavior. The findings demonstrate that Nano-based aerogel bricks reduce heat gain by 13.1%, resulting in a notable reduction in cooling energy demand. The building achieves a monthly load of 36.5 kW, compared to 42 kW with conventional bricks during peak summer months. This reduction highlights Nano-based aerogels' potential to enhance indoor comfort and significantly reduce energy consumption. Additionally, the research examines the environmental and economic benefits of using Nano-based aerogel bricks, which contribute to energy efficiency and the broader goal of reducing car-bon footprints. By lowering cooling energy loads, Nano-based aerogels align with the movement toward net-zero energy buildings, combining advanced materials with renewable energy principles. These insights are valuable for architects, engineers, and policymakers focused on improving energy performance in hot semi-arid climates.

**Keywords:** Nano-based Aerogel bricks, Energy optimization, Simulation modeling, Hot semi-arid climates, Net-zero energy buildings.

## 1. Introduction

### 1.1 Background

The global population has precipitated a profound energy crisis, with Indian buildings contributing a staggering 30% of annual global greenhouse gas emissions and consuming 40%

of all energy [1]. An intensifying concern is the escalating heat gain in buildings, leading to heightened energy consumption for heating and cooling, thereby increasing carbon emissions and diminishing energy efficiency [2;3].

Traditional brick walls, prevalent in construction, exhibit limited thermal insulation properties, facilitating substantial heat transfer [4;5]. The imperative for sustainable building design has necessitated the exploration of alternative construction materials capable of effectively reducing heat gain.

Nanotechnology, a pioneering research field, holds the potential to revolutionize building efficiency through the manipulation of nanoparticles to enhance material properties at the nanoscale. One such innovative alternative is Nano-based aerogel bricks, garnering attention for their potential to significantly enhance thermal performance in construction [6]. Aerogels, locally known as "frozen smoke," are highly porous materials acclaimed for their remarkable thermal insulation properties [6]. This research explores into the transformative potential of aerogel-infused bricks, aspiring to revolutionize in the construction industry.

This research uses a live building simulation model to examine the thermal behavior of the Frank & Debbie Management Complex at A.M.U. Aligarh. The simulation of the traditional bricks with Nano based aerogel bricks gives a detailed study on how it works in realistic case. This study would help in understanding the potential of Nano based aerogel brick materials in changing the shall of sustainable building and solving the heat gain problems.

### 1.2 Research Objectives

The main objective of this paper is to do a thorough simulation analysis in order to observe the reduction of heat gain due to presence of Nano-based aerogel bricks in the walls of a living educational building named Frank & Debbie Management Complex at A.M.U. which is situated in hot semi-arid climate zone.

This research involves following objectives:

1. To evaluate the thermal performance of Nano-based aerogel-based bricks and compare with conventional brick masonry walls.

2. To evaluate whether building materials for construction purpose with Nano aerogel bricks blocks are highly cost effective.

3. To assess the environmental impact and benefits of using Nano aerogel technology in sustainable construction Among all construction elements.

4. To meet these challenges, advanced modeling and simulation methodologies in heat transfer will be utilized for simulating in conventional and Nano enhanced aerogel walls. Different climates, different use profiles and orientations of the building will be analyzed in order to obtain a broad overview of the thermal behavior of the building.

## 2. Literature Review

### 2.1 Nano-based Aerogel Bricks and Its Application

Nano- based aerogel bricks are an innovation in building materials to provide a solution specifically for the heat gain problems in buildings. These bricks utilize nanotechnology to control the movement of particles, optimizing the properties of a material at the nanoscale [6]. The bulk of these bricks consist of silica aerogel, made up of silica gel which is well known for its extraordinary thermal insulation properties as well as low density and high porosity [7;9].

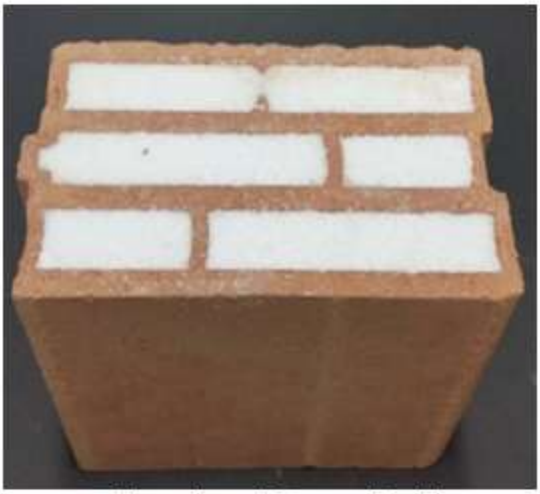


***Fig. 1.*** Nano-based Aerogel Bricks

To improve mechanical robustness and durability, fibrous reinforcements, such as glass fiber or carbon fibers, are often incorporated in the formulation, also supporting the structural integrity of aerogel-filled bricks [8;10].

Fillers of general fillers may be introduced to improve the mechanical properties and to reinforce the bricks [8;10] which indicates the flexibility of composition.

Chemical adjuvants are also important, which help to stimulate certain properties of the bricks in different applications. Such additives, fire retardants, water repellents and UV stabilizers, among others, play a key role in improving overall performance and preserving the service life of the innovative construction material [8;10]. Modifiers are added to shape the nanostructure of the aerogel and adjust the pore size distribution and im-prove the thermal insulation performance [11].

The bricks are designed to look like regular bricks, and can be used in regular construction methods. This block formulation allows easy integrated construction with traditional building systems in walls, roofs and other structural members of the building [11].

Nano-based aerogel bricks, having great applications on saving energy, can be flexibly used in various applications. The enhancement of the thermal performance of the walls of buildings is one of the most significant applications. The research examines the potential of Nano based aerogel bricks to mitigate heat gain and in-crease energy efficiency when used in place of conventional bricks.

The Frank & Debbie Management Complex of A.M.U. Aligarh is taken as a case where it has been applied as living building model to check this phenomenon. More specifically, for the walls of an educational building in this study we therefore aim to compare the thermal behavior of the Nano-aerogel bricks and the conventional bricks. This real-world implementation clearly demonstrates the feasibility and the practical efficiency of integrating Nano Mixed aerogel bricks in existing buildings.

In the context of this particular application, the research contributes to the wider knowledge base related to sustainable building practice, and thus provides a potential means of addressing heat gain and improving the energy performance of buildings. The centrality of Nano silicon-based aerogel bricks is highlighted as these bricks are beginning to motivate transformation in the construction industry to be a sustainable industry.

### 2.2 Thermal Conductivity and Insulation Properties of Nano-based Aerogel bricks

The low thermal conductivity of Nano Aerogel Bricks (typically < 0.015 W/m.K) is one of the most important properties. This characteristic makes them able to serve as effective insulators that will minimize the heat spreading through walls. Several researches have shown better insulation properties of these bricks that might allow for reduction of energy consumption in buildings.

**Table 1**. Properties of Nano based Aerogel bricks

| S.No. | Property | Description |
|---|---|---|
| **1.** | Materials Composition | Silica aerogel matrix infused with nanoparticles |
| **2.** | Density (Kg/m$^3$) | Typically, 150-300 kg/m$^3$ |
| **3.** | Specific Heat Capacity (J/Kg.K) | Approximately 1000-1400 J/Kg.K |
| **4.** | Thermal Conductivity (W/m.K) | Typically, below 0.015 W/m.K |
| **5.** | Thermal Resistance | (R-value, High R-value, providing excellent insulation m2.K/W) |

### 2.3 Thermal Conductivity and Insulation Properties of Traditional bricks

As traditional brick walls have been widely used in construction but exhibit limited thermal insulation properties. Traditional bricks, commonly used in construction, are primarily composed of natural clay or shale, mixed with water to create a malleable mixture. Depending on the specific requirements, additives like sand or grog may be included. After shaping, these bricks undergo a high temperature firing process in kilns to enhance their strength and durability. Brick walls allow significant heat transfer due to their high thermal conductivity, resulting in increased energy consumption for cooling and heating. Enhancing the thermal performance of brick walls is essential for reducing heat gain [9;10].
There are few types of wall elements (masonry units) commonly used in construction along with their thermal parameters as shown in Table 2:

**Table 2.** Properties of Traditional bricks

| S.No. | Property | Description |
|---|---|---|

| | | |
|---|---|---|
| **1.** | Materials Composition | Clay-based brick |
| **2.** | Density (Kg/$m^3$) | Typically,1600-1920 kg/$m^3$ |
| **3.** | Specific Heat Capacity (J/Kg. K) | Approximately, 840-1000 J/Kg. K |
| **4.** | Thermal Conductivity (W/m. K) | Typically, around 0.69 W/m. K |
| **5.** | Thermal Resistance, | (R-value, Moderate R-value, providing standard insulation m2. K/W) |

## 3. Live Case study: Frank & Debbie Islam Management Complex, A.M.U.

### 3.1 Introduction

The Department of Business Administration and Faculty of Management Studies and Research are housed at the Complex. This structure was built on a 3 Acre block of land in the Sir Syed House Complex.

### 3.2 General information

- Owner : Aligarh Muslim university
- Location : AMU Campus Aligarh
- Climate : Composite climate
- No. of floors : G+1
- Typology : Institutional

Aligarh Muslim University's Management Complex is an innovative project funded by alumni. This construction project seeks to give the Faculty of Management Studies and Re-search, a flagship institution of AMU, state-of-the-art physical infrastructure.

**Fig. 2. Image showing aerial view of the management complex**

### 3.3 Building Drawings Geometrical description

The complex consists of five rectangular, two-story buildings, four of which have been built and one of which is still under construction. There are connecting tunnels between each of the construction pieces.

As seen in Fig. 3, the blocks are organized along an Amphitheatre court. And detailed building drawing are shown in Fig. 4 & 5 respectively.

**Legend**

1. Reception Block
2. Administrative Block
3. Lecture Hall Block
4. Seminar & Research Division
5. Under construction Block

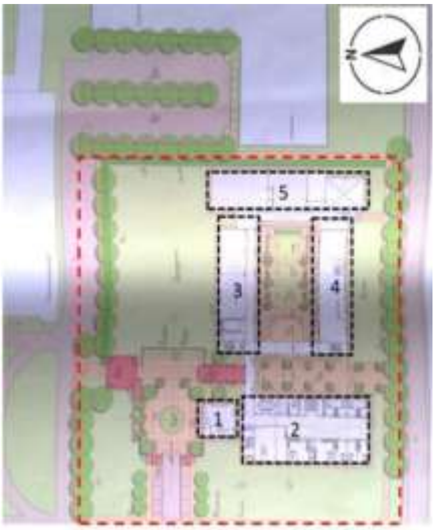



**Fig. 3. Site Plan of Frank & Debbie Islam management complex, A.M.U**

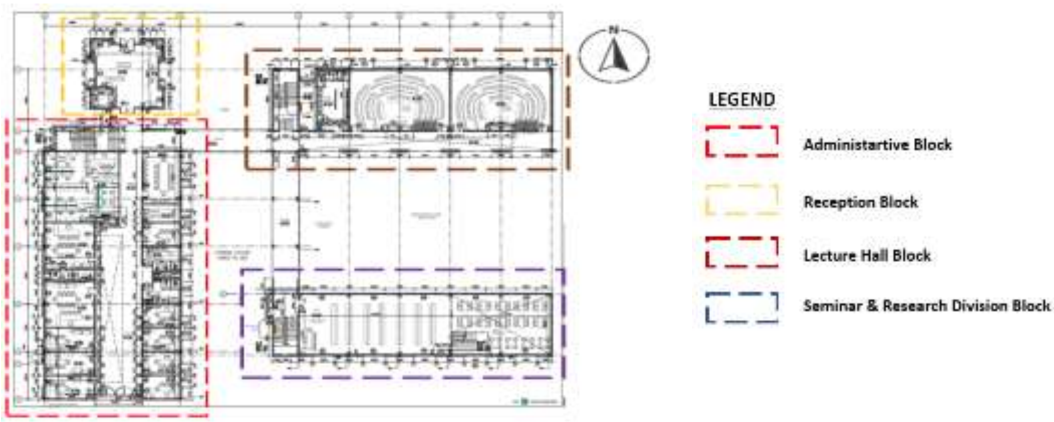



**Fig. 4. Ground floor Plan of Frank & Debbie Islam management complex, A.M.U.**

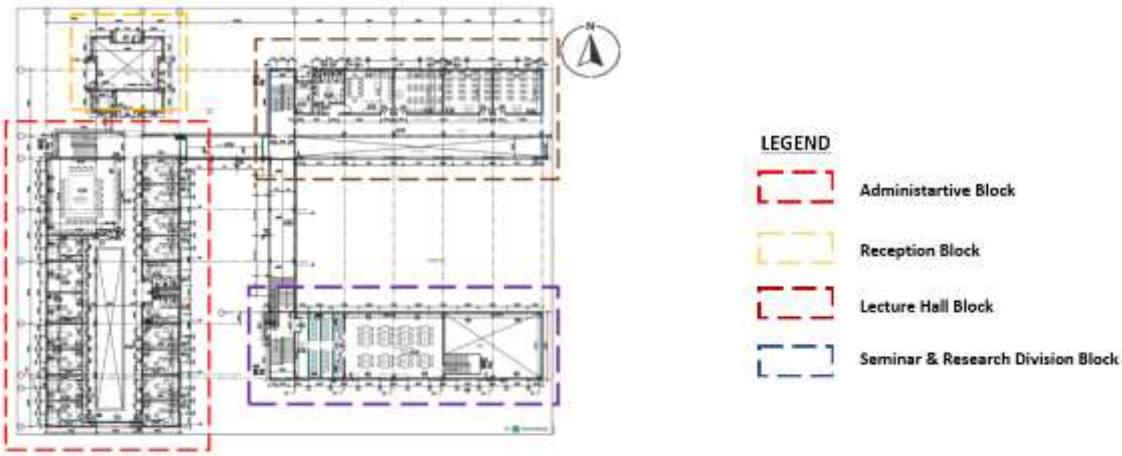



**Fig. 5. First floor Plan of Frank & Debbie Islam management complex, A.M.U.**

### 3.4 Material description

The Thermal properties of materials in the Table 3:

**Table 3.** Materials description of Frank & Debbie Islam management complex, A.M.U.

| Component | Layers (From outside) | Thickness (in mm) | Conductivity (W/m.K) | Density (kg/m$^3$) | Specific Heat (J/kg.K) |
|---|---|---|---|---|---|
| Roof | Brick Tiles | 20 | 0.720 | 1900 | 840 |
| | Cement Screed | 30 | 1.400 | 2100 | 650 |
| | Mud Phuska | 150 | 0.520 | 1620 | 880 |
| | Reinforced Concrete | 150 | 1.90 | 2300 | 840 |
| | Plaster | 10 | 0.431 | 1250 | 1088 |
| Wall | Sandstone tiles | 40 | 1.2 | 2000 | 840 |
| | Brick Masonry | 345 | 0.711 | 2000 | 836 |
| | Plaster | 12 | 0.431 | 1250 | 1088 |
| Floor | Vitrified Tiles | 10 | 0.309 | 1900 | 656.9 |
| | Cement screed | 40 | 1.40 | 2100 | 650 |
| | Sand Filling | 100 | 0.209 | 950 | 656.9 |
| | Rammed Earth | 150 | 0.335 | 1600 | 753.1 |
| | | 1500 | 1.280 | 1460 | 880 |
| Window | Clear glass | 6 | Solar Transmittance at normal incidence= 0.84 at | Visible Transmittanc e at normal incidence=0. 9 | |

| | | | |
|---|---|---|---|
| | | Solar Reflectance at normal incidence=0.8 | Visible reflectance at normal incidence=0.8 |

### 3.5 Building Modelling

**Model generated on the Autodesk Ecotect analysis 2011 software**

The Autodesk Ecotect software is a powerful simulation tool for buildings and their surroundings. Its main pur-pose is to improve energy efficiency in various climatic conditions, including sunlight exposure, daylight availa-bility, and thermal comfort.

To achieve this, the software relies on the thermal properties of different materials used in construction. By assigning these properties to each component of a building, such as walls, floors, and roofs, the software can conduct accurate simulations for each zone.

Over Ecotect, a basic model of the Management Complex's existing building is created as shown in Fig. 6.

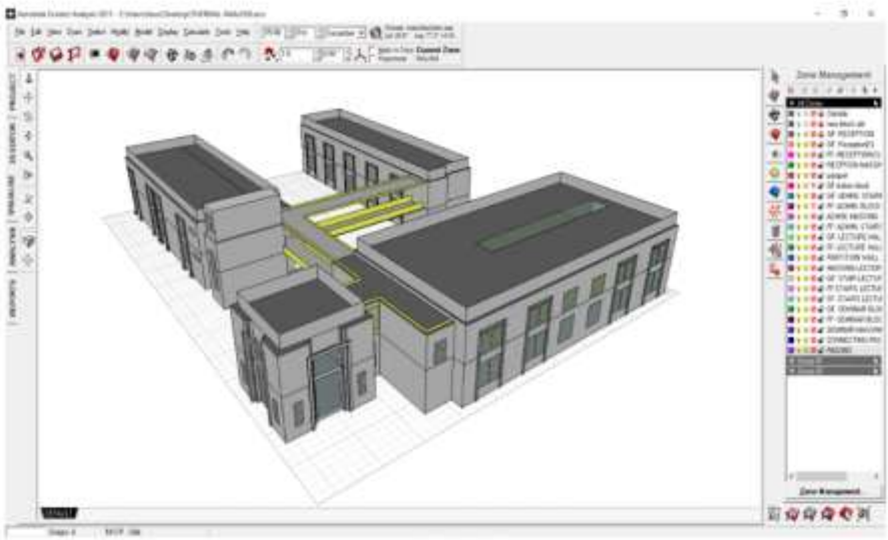


**Fig. 6. Frank & Debbie Islam management complex building model generated on Autodesk Ecotect software**

Then, each zone or model object was given the same materials, specifications, and properties. Following that, simula-tions are run with the correct inputs to learn the model's current pattern of operation. Site weather information is included in this data, which is essential for building energy, thermal comfort, and daylighting simulations since it provides the necessary climatic conditions for the calculations to run. Software needs the position and size of window apertures in addition to the geometry of the building to accurately display the solar incidence inside the structure. Additional datasets are required to calculate the building's thermal heat gains, including information about the building's construction and usage.

**The Fig. 7** shows the input data that was given to the Ecotect programme.

**Input Dataset**

**Fig. 7. Information of weather data file and building type Input in the Ecotect software**

## 4. Simulation Analysis

### 4.1 Simulation result of Existing Building model (Base Model)

**Internal heat gain**

These figures show the graphical results of fabric heat transfer in the existing administrative block of Frank & Debbie Islam management complex. In the given graph, the various color code depicts heat transfer values through building fabric to interior spaces.

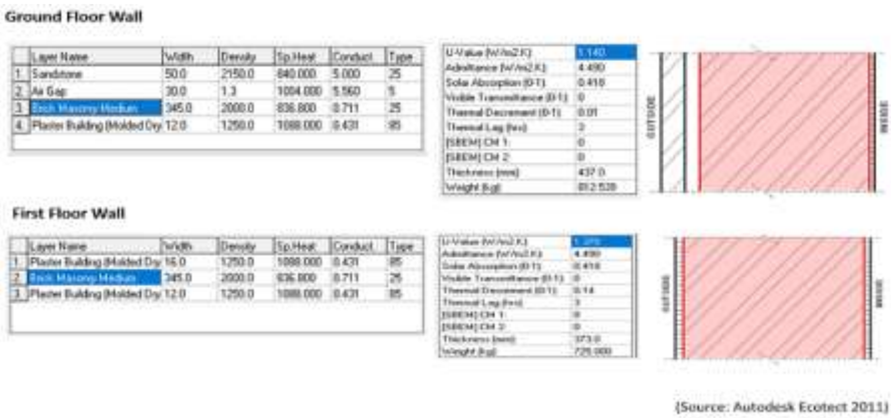
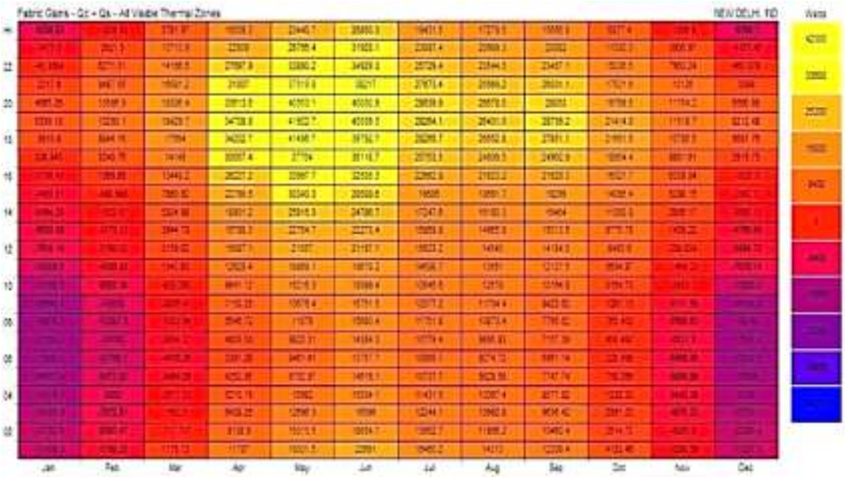



**Fig. 8. Wall material details of existing administrative block, Frank & Debbie Islam management complex, A.M.U**

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 00 | -11438 | -5198 | 1776 | 11787 | 19301 | 22691 | 16460 | 14313 | 12309 | 4103 | -3291 | -11327 |
| 01 | -12783 | -6993 | -718 | 8139 | 15014 | 18634 | 13663 | 11896 | 10460 | 2915 | -4204 | -12283 |
| 02 | -14106 | -7873 | -1592 | 6438 | 12696 | 16596 | 12244 | 10993 | 9636 | 2091 | -4876 | -13751 |
| 03 | -15515 | -9092 | -2674 | 5213 | 10992 | 15534 | 11432 | 10367 | 8578 | 1232 | -5441 | -15387 |
| 04 | -16528 | -9912 | -3484 | 4253 | 9703 | 14619 | 10738 | 9829 | 7748 | 739 | -5900 | -16504 |
| 05 | -17505 | -10769 | -4416 | 3391 | 8461 | 13758 | 10066 | 9275 | 6951 | 220 | -6469 | -17632 |
| 06 | -17358 | -10760 | -3934 | 4004 | 9820 | 14384 | 10779 | 9896 | 7157 | 450 | -6212 | -17504 |
| 07 | -16816 | -10281 | -3323 | 5547 | 11879 | 15680 | 11752 | 10873 | 7796 | 763 | -5569 | -16740 |
| 08 | -16940 | -10010 | -2836 | 7150 | 13676 | 16752 | 12577 | 11704 | 8424 | 1281 | -5122 | -16155 |
| 09 | -13707 | -6855 | -928 | 9641 | 16216 | 18099 | 13546 | 12578 | 10165 | 3165 | -2434 | -11503 |
| 10 | -10508 | -4507 | 1048 | 12629 | 18869 | 19678 | 14599 | 13561 | 12137 | 5655 | -1464 | -7579 |
| 11 | -7618 | -3160 | 3159 | 15687 | 21557 | 21197 | 15623 | 14545 | 14184 | 8494 | 238 | -5485 |
| 12 | -6630 | -2475 | 3945 | 16788 | 22765 | 22273 | 15870 | 14966 | 15014 | 9776 | 1439 | -4800 |
| 13 | -5494 | -1623 | 5305 | 18901 | 25815 | 24787 | 17248 | 16180 | 16464 | 11351 | 2956 | -3595 |
| 14 | -4404 | -481 | 7861 | 22800 | 30343 | 28509 | 19686 | 18692 | 19299 | 14095 | 5288 | -2342 |
| 15 | -3155 | 1370 | 10448 | 26227 | 33998 | 32535 | 22663 | 21623 | 21629 | 16022 | 6339 | -1021 |
| 16 | 327 | 5241 | 14149 | 30557 | 37764 | 36119 | 25754 | 24509 | 24963 | 18954 | 8882 | 2920 |
| 17 | 3916 | 8844 | 17564 | 34203 | 41497 | 39793 | 28266 | 26553 | 27851 | 21652 | 10786 | 6682 |
| 18 | 5339 | 10290 | 18430 | 34709 | 41923 | 40539 | 28264 | 26432 | 28739 | 21415 | 11519 | 8212 |
| 19 | 4665 | 10587 | 18306 | 33614 | 40553 | 40031 | 28640 | 26579 | 28053 | 19769 | 11754 | 6561 |
| 20 | 2218 | 8488 | 16581 | 31007 | 37520 | 38217 | 27673 | 25569 | 26031 | 17522 | 10126 | 3398 |
| 21 | -40 | 6271 | 14167 | 27698 | 33890 | 34929 | 25729 | 23544 | 23457 | 15037 | 7963 | 460 |
| 22 | -3478 | 2922 | 10711 | 22939 | 29766 | 31928 | 23087 | 20989 | 20082 | 11030 | 3901 | -4107 |
| 23 | -8207 | -1829 | 5782 | 16509 | 23441 | 26850 | 19432 | 17280 | 15567 | 6377 | -1310 | -9399 |

**Fig. 9. Heat transfer through the walls of existing administrative block, Frank & Debbie Islam management complex, A.M.U(Ecotect Analysis 2011**

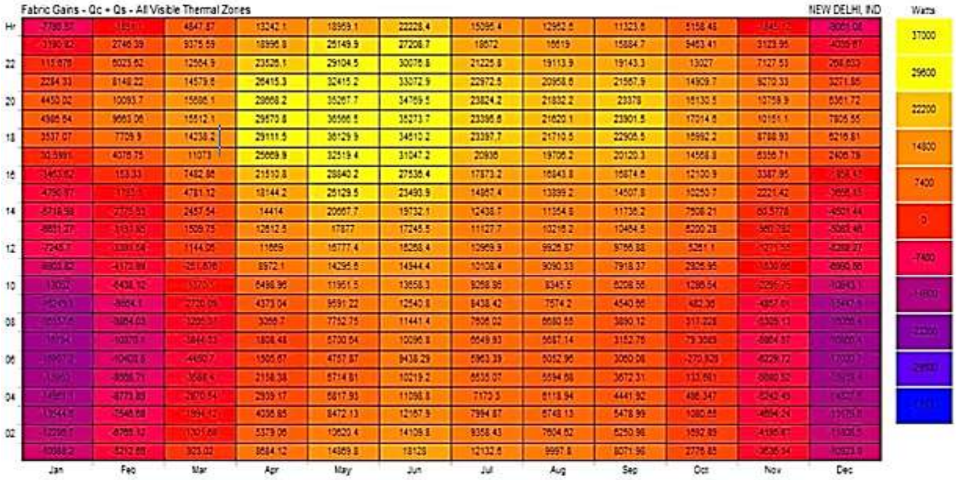
## Result of Fabric Heat Gain of Existing building Model

The graphs depict the heat gain distribution of the building's fabric. Fig. 9 shows the average monthly heat gain of the existing administrative block of management complex. The maximum overall heat gain through building fabric in existing building is comes out to be 41922.7 watts (i.e. 42 KW) during the month of May and can be reduced substantially by using alternate energy efficient materials which have better thermal performance than existing.

## 4.2 Simulation result of Building model using Nano based Aerogel filled bricks

**Internal heat gain**

These figures show the graphical results of fabric heat transfer in the administrative block using Nano based Aerogel bricks in place of traditional bricks of Frank & Debbie Islam management complex. In the given graph, the various color code depicts heat transfer values through building fabric to interior spaces.




| HOUR | JAN (Wh) | FEB (Wh) | MAR (Wh) | APR (Wh) | MAY (Wh) | JUN (Wh) | JUL (Wh) | AUG (Wh) | SEP (Wh) | OCT (Wh) | NOV (Wh) | DEC (Wh) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 00 | -10988 | -5213 | 923 | 8684 | 14870 | 18128 | 12133 | 9998 | 8072 | 2777 | -3636 | -10924 |
| 01 | -12287 | -6765 | -1302 | 5379 | 10620 | 14110 | 9358 | 7605 | 6251 | 1693 | -4196 | -11809 |
| 02 | -13545 | -7547 | -1994 | 4037 | 8472 | 12168 | 7995 | 6748 | 5479 | 1081 | -4694 | -13180 |
| 03 | -14961 | -8774 | -2871 | 2939 | 6818 | 11099 | 7170 | 6119 | 4442 | 486 | -5242 | -14828 |
| 04 | -15953 | -9569 | -3588 | 2158 | 5715 | 10219 | 6535 | 5595 | 3672 | 134 | -5681 | -15919 |
| 05 | -16907 | -10404 | -4451 | 1506 | 4758 | 9438 | 5963 | 5053 | 3060 | -271 | -6230 | -17021 |
| 06 | -16734 | -10370 | -3844 | 1808 | 5701 | 10097 | 6650 | 5687 | 3153 | 79 | -5965 | -16866 |
| 07 | -16158 | -9864 | -3205 | 3057 | 7753 | 11441 | 7606 | 6681 | 3890 | 317 | -5309 | -16066 |
| 08 | -16249 | -9564 | -2720 | 4373 | 9591 | 12541 | 8438 | 7574 | 4541 | 482 | -4857 | -15448 |
| 09 | -13052 | -6438 | -1370 | 6499 | 11952 | 13658 | 9269 | 8345 | 6209 | 1287 | -2296 | -10843 |
| 10 | -9904 | -4173 | -252 | 8972 | 14296 | 14944 | 10108 | 9090 | 7918 | 2927 | -1631 | -6991 |
| 11 | -7246 | -3392 | 1144 | 11669 | 16777 | 16268 | 10970 | 9927 | 9767 | 5261 | -1272 | -5289 |
| 12 | -6631 | -3192 | 1510 | 12613 | 17877 | 17246 | 11128 | 10216 | 10465 | 6200 | -961 | -5083 |
| 13 | -5719 | -2780 | 2458 | 14414 | 20668 | 19732 | 12439 | 11355 | 11736 | 7608 | 61 | -4501 |
| 14 | -4791 | -1793 | 4781 | 18144 | 25129 | 23494 | 14867 | 13899 | 14508 | 10251 | 2221 | -3656 |
| 15 | -3464 | 153 | 7483 | 21511 | 28840 | 27536 | 17873 | 16844 | 16875 | 12101 | 3388 | -1858 |
| 16 | 31 | 4077 | 11073 | 25670 | 32519 | 31047 | 20936 | 19706 | 20120 | 14569 | 6357 | 2407 |
| 17 | 3537 | 7710 | 14238 | 29112 | 36130 | 34610 | 23398 | 21710 | 22905 | 16992 | 8789 | 6217 |
| 18 | 4987 | 9663 | 15512 | 29571 | 36567 | 35274 | 23396 | 21620 | 23901 | 17015 | 10151 | 7806 |
| 19 | 4450 | 10094 | 15686 | 28668 | 35268 | 34769 | 23824 | 21832 | 23378 | 16130 | 10760 | 6362 |
| 20 | 2284 | 8148 | 14580 | 26415 | 32415 | 33073 | 22973 | 20959 | 21568 | 14910 | 9270 | 3272 |
| 21 | 116 | 6024 | 12565 | 23526 | 29104 | 30077 | 21226 | 19114 | 19143 | 13027 | 7128 | 269 |
| 22 | -3181 | 2746 | 9376 | 18997 | 25150 | 27209 | 18672 | 16619 | 15885 | 9463 | 3124 | -4040 |
| 23 | -7781 | -1891 | 4848 | 13242 | 18959 | 22228 | 15095 | 12953 | 11324 | 5158 | -1845 | -9061 |

**Fig. 10. Heat transfer through the walls of administrative block using Nano based Aerogel filled bricks, Frank & Debbie Islam management complex, A.M.U(Ecotect Analysis 2011)**

**Result of Fabric Heat Gain of building Model using Nano based Aerogel filled bricks**

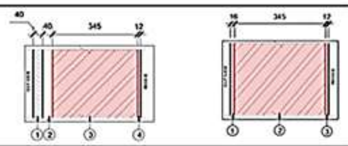
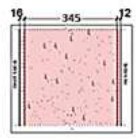
The graphs depict the heat gain distribution of the building's fabric. The figure 10 shows the average monthly heat gain of the administrative block of management complex by using Nano based Aerogel filled bricks in place of traditional brick. Then the maximum overall heat gain through building fabric building is reduced to be 36566.5 watts (i.e. 36.5 KW) which is shown in the figure.

## 5. Comparative Result of Fabric Heat Gain of building of Existing Model with the Nano based Aerogel filled bricks

The graphs depict the heat gain distribution of the building's fabric. The fig. 10 shows the average monthly fabric heat load of existing model (i.e. Base Model) with same specifications and materials of the administrative block of management complex. The maximum overall heat gain through building fabric in existing building is comes out to be **41922.7 watts (i.e. 42 KW)** during the month of May.
Similarly, the **Figures 11** shows the average monthly fabric heat load of Model with the Nano based Aerogel filled bricks is comes out to be **36566.5 watts (i.e. 36.5 KW).**

## 6. Calculation for Cost saving by Aerogel-filled bricks

**Table 3** Comparative Heat gain result of Exiting Frank& Debbie Islam management complex, A.M.U. with Traditional brick wall and with Nano based Aerogel filled bricks.

| S. No. | Models | Wall sections | Heat gain load |
|---|---|---|---|
| 1. | EXISTING BUILDING MODEL (BASE MODEL with Traditional brick wall) |  | 41922.7 watts (i.e. 42 KW) |
| 2. | EXISTING BUILDING MODEL (With Nano based Aerogel filled bricks) |  | 36566.5 watts (i.e. 36.5 KW) |

- Load reduction per hour due to aerogel-filled bricks: 5.5 KW (As per simulation result)
- Cost of each unit (1 KWh): Rs. 9 (Electric unit cost in Aligarh)
- Working hours of building per day: 10 hours
- Number of days in a year: 365

**Step 1:** Calculate the daily savings Daily savings = Load reduction per hour × Working hours per day
Daily savings = 5.5 KW × 10 hours = 55 KWh (55 units per day saving) {As 1KWh= 1 unit}
**Step 2:** Calculate the yearly savings Yearly savings = Daily savings × Number of days in a year
Yearly savings = 55 KWh/day × 365 days = 20,075 KWh
**Step 3:** Calculate the cost savings Cost savings = Yearly savings × Cost per unit
Cost savings = 20,075 KWh × Rs. 9/KWh = Rs. 180,675 (INR)

**So, if the working hours are 10 hours a day, the cost efficiency or savings per year due to the use of Aerogel-filled bricks is INR 180,675.**

## 7. Prospective Cost Analysis and Break-Even Projection for Aerogel Bricks in India

- Aerogel bricks are commercially not available in India but expected to come soon.
- Silica Aerogel Insulation sheets are commercially available @INR 3500 /square meter cost.
- As these bricks are in experimental stage, not commercially available so exact break even cost calculation is not possible.
- It is expected 5 years break even time for using Aerogel filled Bricks as an alternative of traditional bricks.

## 8. Conclusion

In summary, the in-depth analysis of fabric heat gain in our research illuminates the transformative impact of Nano-based Aerogel-filled bricks on energy efficiency in building design. The comparison between the existing model and the one fortified with Aerogel-filled bricks reveals substantial differences in heat gain reduction, particularly pronounced in critical periods such as May in hot semi-arid climates.

The administrative block of the management complex, represented by the existing model, experiences a nota-ble overall heat gain of 42 kW during May. In stark contrast, the model incorporating Nano-based Aerogel-filled bricks showcases a significant reduction, boasting an average monthly fabric heat load of 36.5 kW. This translates to a remarkable 13.1% reduction in fabric heat gain, surpassing the conventional model's 42 kW during the crucial month in hot semi-arid climates.

Beyond the quantitative metrics, the research underscores the economic feasibility of transitioning to Nano-based Aerogel-filled bricks. With a load reduction of 5.5 kW per hour, the cost savings amount to INR 180,675 annually, projecting a feasible break-even point in approximately 5 years. This economic viability positions Aerogel-filled bricks not just as an innovative construction material but as a financially sound alternative to traditional bricks.

Furthermore, the findings highlight the improved thermal insulation properties of Nano-based Aerogel-filled bricks compared to conventional brick walls. This dual benefit, combining enhanced energy efficiency and cost efficiency, positions Aerogel-filled bricks as a compelling choice for sustainable building practices.

In conclusion, the analysis of fabric heat gain convincingly demonstrates the effectiveness of Nano-based Aerogel-filled bricks in mitigating heat transfer through a building's fabric. The incorporation of these advanced bricks into building construction emerges as a strategic avenue to achieve significant energy savings, elevate thermal comfort, and promote sustainable design practices over all a kaleidoscopic move towards the pursuit of sustainable, net-zero building designs solutions. As we navigate the challenges of modern construction, this re-search sets the stage for a future where Nano-based Aerogel technology plays a pivotal role in shaping energy-efficient, cost-effective, and environmentally conscious building designs.

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