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The Effect of Nano Insulating Materials on the Thermal Performance of Residential Apartments

Shaymaa Younus

Faculty of Power Mechanic Techniques Engineering Department, Mosul Technical Institute, Northern Technical University, Mosul 41000, Iraq

Corresponding Author Email: Shaima.salem@ntu.edu.iq

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ABSTRACT

The environmental sustainability of residential units is related to various design principles, among which nanotechnology has emerged as a significant contributor to enhancing thermal performance. Despite their high initial cost, these materials promise to elevate the quality of residential performance and thermal comfort over time. There were numerous studies that addressed this subject, but the vast majority of them approached research and evaluation with an investigative and analytical mindset. There aren't many studies that look at the precise computer evaluation of the usage of insulating nanotechnologies in architecture, which shows that there is still a research deficit in the field. The objective of the research was to focus on computational capabilities to estimate the percentage of improvement in the thermal performance of a residential apartment in Mosul using local materials as a baseline case and compare it to expanded polystyrene second, followed by Nano insulation materials third and fourth, respectively. The results obtained show that, in each sample in the prior situations, the required thermal load decreased by rates of 45.8%, 22.8%, and 28.9% respectively, when compared to the base case. This demonstrates how crucial the nanomaterial's insulating properties are to raising thermal efficiency. Further, our findings demonstrated that the application of nanotechnology, particularly nano-vacuum insulation panels, can increase the number of days of thermal comfort in a residential apartment while concurrently reducing the peak heating and cooling requirements.

1. INTRODUCTION

Nanotechnology, defined as the manipulation of substances at the atomic and molecular level, is a frontier in the application of molecular manufacturing, processing, and design. This potent technology is leveraged to augment sustainable structures with diverse elements that enhance energy efficiency, building performance, and environmental consciousness, thereby promoting sustainability. Nanomaterials have found utility in an assortment of applications, such as self-cleaning coatings, air purifying coatings, heat-absorbing windows, insulation, and smart nanotechnology for light and heat control, along with temperature regulation [1].

The building industry, one of the major sectors contributing to environmental degradation, is heavily reliant on energy, natural resources, and manufactured goods. This industry accounts for an alarming 32% of the world's total energy usage [2]. Accordingly, the principles of sustainability efficiency, recycling, and environmental preservation are of paramount importance. However, the methods currently employed to actualize these principles remain suboptimal, underscoring the necessity for a long-term energy reduction strategy, an integral part of which includes the design of the building envelope [3].

In order to find new uses for these materials that lessen their drawbacks in the field of construction and achieving sustainability, it is crucial to revisit their qualities using contemporary technologies like nanotechnology [4]. In metric terms, it denotes one in a billion [5]. Nanotechnology is characterized as a method for manipulating a substance at the atomic and molecular level as well as the development of novel materials and devices that make the best use of the features of nanoscale materials [6]. Nanotechnology is another example of the knowledge-based approach to creating new classes of construction technologies, which is frequently used in place of conventional technology [7].

The new modern architectural style of the twenty-first century, known as nano-architecture, will revolutionize the field of architecture in all ways, including how architects think and get ideas, the materials used in construction and finishing, and how we present our work to the public and building occupants. Nonetheless, while having a minor impact on our daily lives, architecture has a significant influence on the world we live in. Engineering with nanotechnology: (*nanotechnology* + *architecture* = *nanoengineering*) [8].

Vacuum compression, which can be employed to lower thermal conductivity as well as gaseous conduction, which both reduce heat transfer, is the fundamental mechanism that distinguishes VIPs and enables remarkable performance [9, 10]. In the experiment described in this article, silica nanoparticles were investigated in a glass window prototype with an aluminum frame. The outcomes show the material's strong acoustic characteristics and exceptional thermal performance [11]. In this research project, the insulating material Nanogel Aerogel was integrated with the building envelope to examine the energy efficiency of a historic educational structure in Egypt. Software called Design Builder was used to run energy simulations. In a climate with high temperatures, like Egypt, the results show that adding VIP and air gel to the building envelope improves the structure's thermal performance. A large reduction in annual energy usage, which results in a savings of about 36.5% vs the baseline, is another outcome.

2. RELATED STUDIES

Several recent research have concentrated on the applications of nanotechnology in architecture, how it may be utilized to overcome limitations and unleash creativity, and how it might elevate building materials' energy-related performance to new heights [12].

According to research, it is one of the most recent sciences that has sparked a new growth in this industry and has the potential to generate new materials or add to the features of existing ones as shown in Figure 1 [13].

Through two main sections the first is a theoretical study to identify nanotechnology and its applications, and the second is an analytical study of three global future projects currently being implemented and within the sustainable orientation, which were analyzed in accordance with sustainability criteria and its three levels—the study examined the possibility of using nanotechnology in improving the performance of buildings to achieve the principles of sustainability (structure Structural, building envelope, and internal environment) The analysis of these examples' findings revealed that the development of energy-saving, productive, and export projects utilizing nanotechnology was made possible by the use of nano-insulation materials that lower internal loads and prevent thermal leakage to the interior. The study concluded that nanotechnology succeeded practically or theoretically in achieving the principles of Sustainability in buildings in varying proportions, especially in the field of energy efficiency [4]. Which dealt with the study of the extent of the impact of materials and nanotechnology on the outer covering of buildings in terms of quality and characteristics of materials, formulation and architectural formation as well as considerations of cost and extending the life span through research in the foundations and determinants of the application of materials of nanotechnology to obtain criteria and evaluation points, the most important of which are (economic criteria, aesthetic, provision energy, maintenance, and many others) and then using those criteria to evaluate international buildings with Nano scale uses, and the study concluded that the application of nanotechnology led to the emergence of smart architecture in building performance, operation, and maintenance, and that its use led to achieving a main goal, which is to raise the efficiency of buildings and help in saving energy [13]. Which mentioned that the great potential of nanotechnology and materials can change the image of architecture through the development of the performance of the materials and raw materials used through the study in two phases, the first is inductive to the subject of nanotechnology in general, focusing on nanomaterial and their effects on energy, efficiency and sustainability, and the second is an analytical comparison between the application of nanotechnology on buildings The list and the Nano house, which focuses in most of its steps on raising the efficiency of the building and reducing its energy gain. The result was that nanotechnology can become a leader in building methods for the new millennium, in addition to contributing to overcoming environmental problems, in addition to that it can give materials new properties that help them to Withstanding different climatic conditions. The study dealt with clarifying the complementary relationship between Nano applications and the sustainability of buildings and the importance of these applications in being one of the most important contemporary tools for the sustainability of buildings and focusing on the innovative solutions provided by these applications with regard to building facades by adopting a descriptive approach and explaining the integration of nanotechnologies in architecture in addition to the case study approach to research in Applying its results in support of the interrelationship between architecture, nanotechnology, and sustainability [14]. The study concluded that nanotechnology applications would provide innovative solutions in order to support sustainability to reach a better urban environment, in addition to its ability to produce environmentally friendly building materials, and a study [15]. That dealt with testing thermal performance, rate of heat transfer, amount of heat gain and loss through the envelope using highly efficient techniques in energy use compared to traditional building materials in Egypt, then the study concluded that the nanomaterials integrated with the building envelope will achieve the lowest scientifically and experimentally recorded value of heat transfer in the field of construction, which can reach 72% Compared to the performance of the thermal Nano model with the traditional model.

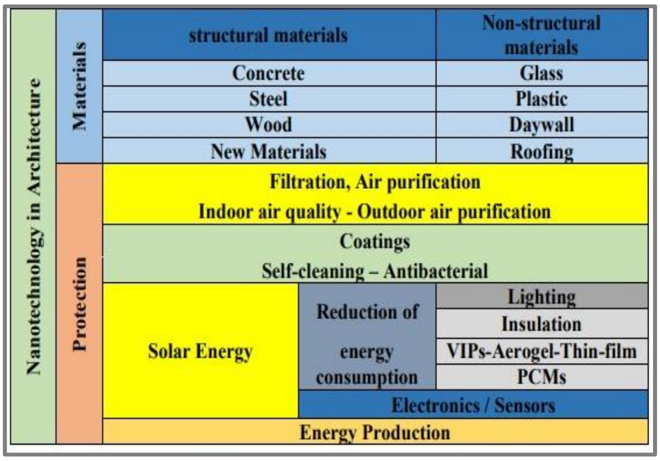


Figure 1. Impact area of nanotechnology in buildings [9]

Additionally, the study [5] examined the use of insulation materials based on nanotechnology in a variety of architectural applications due to their unusual heat transfer method, which causes the heat flow to collide with numerous internal obstacles and produce a higher heat transfer resistance than insulation materials made of more conventional materials.

Nano-insulating materials' physical and thermal characteristics as well as the applications for each one in floors, ceilings, and other building components were discussed.

It is evident from the aforementioned recent studies and many others that the use of nanotechnology to architecture has had a significant impact on it on a number of levels. Whereas the studies [3, 16] provided access to new architectural patterns while also assisting architects in overcoming design and implementation limitations.

It offers the architectural form leeway for creative design [14]. The second level is structural and offers the potential for creating new materials or enhancing the qualities of already-existing ones [4]. The third stage is environmental, and it involves enhancing the qualities of insulating materials to help increase building efficiency and lower energy use [13].

When focusing on nanomaterial, the researcher can classify their uses in architecture, as in Figure 2, into the following:

(1) Structural Nano materials: contribute to improving the properties of construction materials such as concrete admixtures and glass admixtures.

(2) Complementary Nano materials: contribute to improving the properties of complementary materials such as external coatings.

(3) Nano-insulating materials: contribute to improving the thermal insulation properties of buildings.

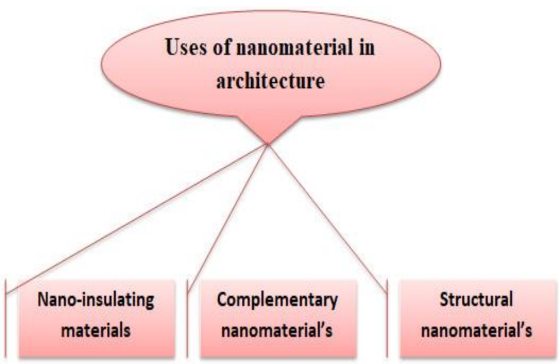


Figure 2. The uses of nanotechnology in architecture / prepared by the researcher

When considering the thermal performance of buildings as an important necessity in our day and age, it may help reduce energy consumption and improve building performance, which is reflected on the financial side and is thought of as a general indicator of its environmental friendliness [17]. The study will concentrate on insulating nanomaterial, which are relatively new and have not attracted the necessary interest in environmental studies. The majority of these studies were analytical and survey-based, ignoring their practical application and accurate measurement, which can provide them with an adequate response to a number of questions about the significance of insulating nanomaterial in comparison to conventional insulating materials, such as the following:

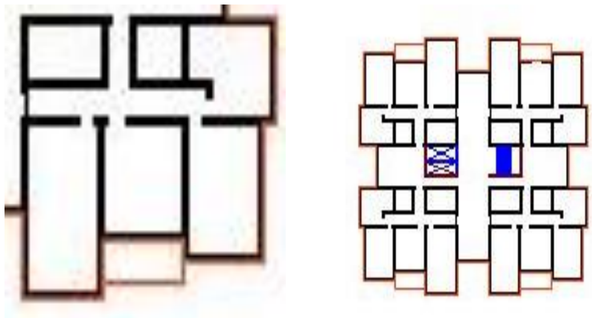
First, vacuum insulation sheets (VIP): It comprises of a porous material, such as foam, powder, or fiberglass, that fills the area, enclosed by a cover made of plastic foil (typically covered with aluminum) or stainless steel. Its distinctive feature is that it offers superior insulation than conventional insulation materials, enhancing building efficiency and cutting down on carbon emissions. Its tiny thickness allows its use in floors, ceilings, and walls [18] and as depicted in Figure 3. It does not require routine maintenance and has an expected lifespan of between 30 and 50 years [4]. They can reduce energy consumption compared to standard insulation when used in walls and ceilings.

Second, it is called frozen smoke, and it consists of 5% solid material and (95%) air. It is the lightest solid material ever, and a unique material that is characterized by high light transmission, low heat conductivity, and is anti-ultraviolet, and therefore resistant to color change, as in Figure 3 [18], and reduces heat gain, energy consumption, and carbon emissions, and it is used to protect the house from fires, and it has very light weight [19].

Third, thin films: These sheets of stainless-steel nanofibers are used to insulate glass from heat by absorbing infrared radiation and blocking sunlight. This reduces the temperature of the interior space by two to three degrees in comparison to conventional materials. This, as depicted in Figures 3 and 4, aids in the rationalization of energy consumption in buildings.

A-Vacuum Insulation Panels (VIP)	B-Air gel	C-thin films

Figure 3. The main types of insulating nanomaterial [4]



(a) A corner residential apartment with two external exposure facades

(b) The location of the apartment within the floor

Figure 4. The selected sample, Diwan residential project / researcher

Moreover, the percentage of the outer surface area that is exposed increases and the size of the material is decreased as it is shrunk to the Nano scale [20]. This can lower the heat transfer coefficient in building structures by increasing heat transfer (thermal conductivity, heat radiation, and heat flow) [5]. The highest performance is attained as a result of the insulation materials' high porosity and solid structures with nanopores, which result in a high air scarcity inside of them [1].

Some people might think that employing insulating nanomaterials is not economically feasible since they are expensive, yet their lifespan and thermal insulation effectiveness can last up to 30 to 50 years [12]. We face a significant issue in that the introduction of nanotechnology is constrained due to the absence of specialized scientific programs in the universities of construction and applied arts, which can have a positive impact on the user in the future by reducing operational costs in buildings using this technology. Technical hubs are required to standardize "Nanotechnology and Nanomaterial [21].

3. RESEARCH PROBLEM

The majority of studies on nanomaterials in general, insulating nanomaterials specifically, and their applications in architecture used an inductive analytical method for groups of global projects to estimate the impact of using nanomaterials without turning to a more precise computer measurement process to determine the impact of these materials on the thermal performance of residential apartments, which are the most energy-intensive buildings.

4. RESEARCH OBJECTIVE

The effect of nano-insulating materials on the thermal performance of residential apartments will be calculated using the computer measurement method specified by (Ecotect 2011 program).

In addition to a comparison of the effect of nano-insulating materials specified as (vacuum insulation panels and air gel) separately on the thermal performance of residential apartments using a conventional material (concrete) or a specific traditional insulation material (expanded polystyrene panels).

Finally, the thermal load ratio for each of the cases relative to the first basic case and the efficiency of thermal performance for each of them will be calculated, which is greatly reflected in reducing energy consumption.

5. RESEARCH HYPOTHESIS

(1) The possibility of calculating the effect of dielectric nanomaterials more accurately using computer programs.

(2) The effect of nano-insulating materials on the thermal performance of residential apartments is greater than when using traditional materials or normal insulation materials.

6. RESEARCH METHODOLOGY

ECOTECT2011, an integrated environmental design tool that many designers employ in the early stages of the design process to quantify environmental consequences in projects before they came into force, is utilized in the research to determine the heat load per square meter of the residential area. The most significant usage restrictions associated with the program are its treatment of the constituent spaces of any residential apartment as thermal zones in addition to evaluating the implemented projects in reality to make any necessary adjustments. This program was chosen for its ability to measure thermal loads first and the compatibility of its climatic data with the city of Mosul under test. The fundamental unit for thermal analysis and measurement of all types of thermal loads (heating and cooling) for all durations (daily, monthly, and yearly) is the separate (THERMAL ZONE).

In four different cases, the first uses a conventional local building wall and is the basic case for measurement, the second uses conventional thermal insulation, the third uses nano insulation materials represented by vacuum insulation panels, and the fourth case is represented by using nano-air gels. The comparison between the aforementioned cases and the ratio of the difference of each case to the first basic case are then calculated.

7. STUDY CASE

The Diwan residential project is one of the local residential projects that is now under development. The research selects a corner apartment inside the (Point system), one of the most prevalent patterns throughout the world, as a sample for the study. It is situated in Mosul, which was chosen for investigation. The method of work and measurement is however possible for corner and non-corner flats, for point system and other system, each according to its characteristics, as shown in Figure 4, in order to test the research's hypothesis, achieve its goals in a neutral manner, and arrive at realistic and accurate results. It must exhibit particular traits or prerequisites, including the following:

7.1 Climatic requirements

Since the measurement process will be carried out using a computer program that requires specific climatic data for a specific area, and because the study is conducted in the city of Mosul, we will resort to choosing the climatic data for the city of Mosul, assuming that the sample chosen for the apartment is a proposed model for a residential apartment in the city of Mosul, and the thermal comfort limit for users has also been determined. Within the program B (22-28) as in Figure 5, In addition to neutralizing the effect of wind and internal loads in the program as in Figure 6, The measurement was limited to the thermal transfer of materials without radiation in an effort to identify the real and accurate thermal behavior of materials.

All of the determinants mentioned were intended to avoid any additional factors or influences that could cause confusion or error in the results and calculations.

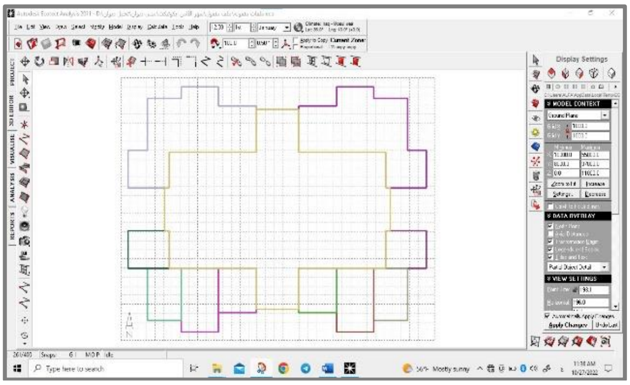


Figure 5. Apartment plan drawing within the program / researcher

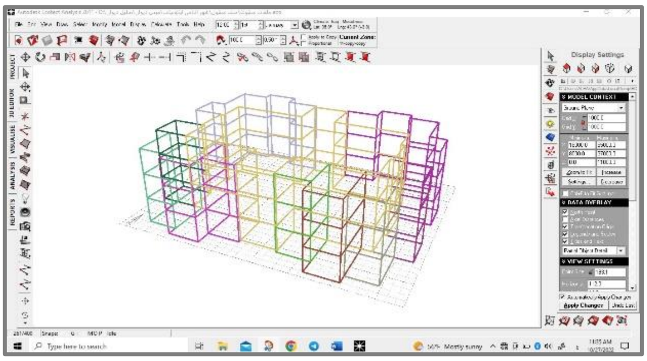


Figure 6. Apartment model drawing within the program / researcher

7.2 Practical test

The applied tests to evaluate the thermal performance of the selected residential apartment begin by exporting the plan using the program (AUTOCADE, 2018). From there, a ZONE is drawn for the apartment spaces as a whole, and a fixed height is given for the floor, and as a result, we obtain a three-dimensional model as shown in Figures 7 and 8. Then, after determining the building materials for the exterior walls and calculating the (u-value) in each case, we turn to calculating the thermal load per square meter of the apartment's area by selecting SPACE LOAD from the list of (CALCULATE), and the program then runs the analysis. We select the side menu option (MONTHIY LOAD), which displays the results of the thermal loads for each month and the total, loads per square meter of the apartment, and a thermal load calculator. Table 1 shows some thermal properties of traditional, insulating and nano insulating materials specified in the research as follows:

Table 1. The thermal properties of some traditional materials, insulating, and Nano-insulating materials / researcher from the Iraqi Insulation Code 2011 and 2016 [5]

No.	Material	Thermal Conductivity w/(m.k)	Density kg/m^3
1	Concrete	1.49	2300
2	Expanded polystyrene panels	0.03-0.037	15-40
3	Vacuum insulation panels	0.005-0.010	150-300
4	Aerobic gels	0.013-0.021	60-80

The first basic case is the walls of the residential apartment using traditional building materials:

These materials were chosen because they are the most prevalent in the city of Mosul, which was chosen for the study, and they include: Determining the walls of the outer shell of the residential apartment question with the regional traditional building materials depicted in Figures 7 and 8, and with the thermal properties proven in the Iraqi thermal insulation code.

- A 15 cm thick block wall.
- External finishing with cement plaster 10 mm thick.
- Interior finish with plaster board 20 mm thick.

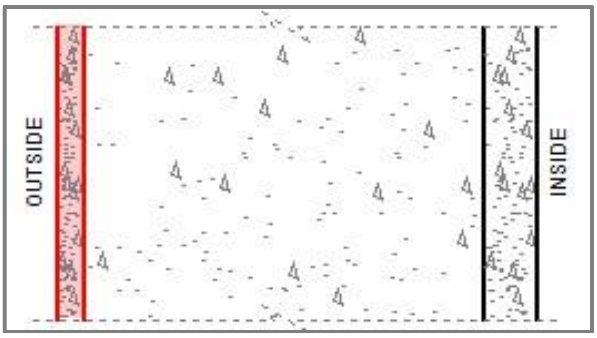


Figure 7. The wall layers on first case

	Layer Name	Width	Density	Sp.Heat	Conduct.	Type
1.	Cement Plaster, Sand Aggre	10.0	2050.0	840.000	1.080	35
2.	Block, Mediumweight, 150 N	150.0	2300.0	840.000	1.490	35
3.	Gypsum Plasterboard	20.0	980.0	840.000	0.360	35

Figure 8. The wall layers characteristics on first case

The second case is the walls of the residential apartment using traditional building materials and adding an insulation material Specifically (Expanded polystyrene panels).

Determining the external walls of the apartment with the traditional building materials specified in the first case above and adding insulation material (Expanded polystyrene panels). It was chosen because it is available and used locally, and its thermal specifications are determined according to the Iraqi Thermal Insulation Code, as shown in Figures 9 and 10.

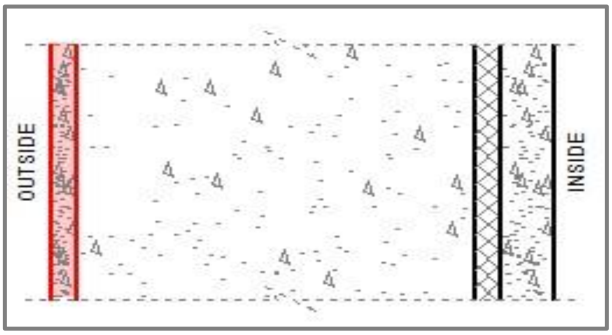


Figure 9. The wall layers for second case

	Layer Name	Width	Density	Sp.Heat	Conduct.	Type
1.	Cement Plaster, Sand Aggre	10.0	2050.0	840.000	1.080	35
2.	Block, Mediumweight, 150 N	150.0	2300.0	840.000	1.490	35
3.	Polystyrene, Expanded (EPS	10.0	23.0	840.000	0.035	95
4.	Gypsum Plasterboard	20.0	980.0	840.000	0.360	35

Figure 10. The wall layers characteristics on second case

The third case is the walls of the residential apartment using traditional building materials and by adding a nano-insulating material (vacuum insulation panels).

Determine the outer walls of the apartment with the traditional building materials specified in the first case, and add a nano-insulating material, especially the vacuum insulation panels, as they are available locally in a less costly and more efficient way compared to other nano-materials and with the characteristics shown (p. 3), and as shown in Figures 11 and 12.

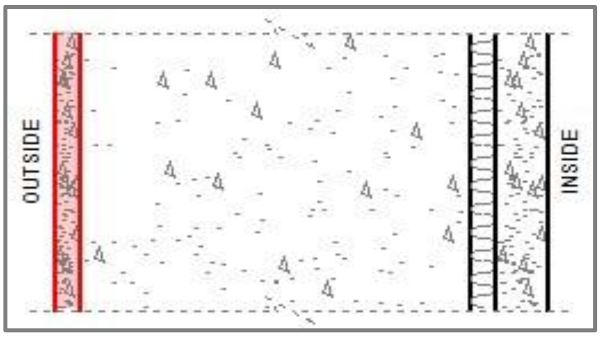


Figure 11. The wall layers on third case

	Layer Name	Width	Density	Sp.Heat	Conduct.	Type
1.	Cement Plaster, Sand Aggre	10.0	2050.0	840.000	1.080	35
2.	Block, Mediumweight, 150 N	150.0	2300.0	840.000	1.490	35
3.	الالواح الفراغية	10.0	150.0	800.000	0.005	45
4.	Gypsum Plasterboard	20.0	980.0	840.000	0.360	35

Figure 12. The wall layers characteristics on third case

The fourth case is the walls of the residential apartment using traditional building materials and adding nano-insulating material (air gels).

Defining the outer walls of the apartment with the traditional building materials specified in the first case and by adding a nano-insulating material. The air gels were chosen with the characteristics shown (p. 3), because it is available and more efficient compared to other nano-materials, as shown in Figures 13 and 14.

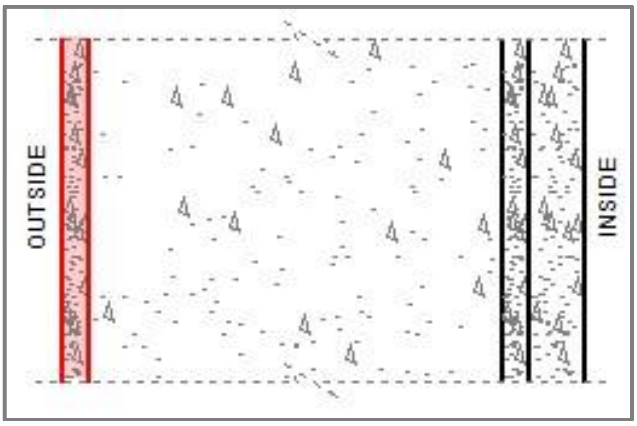


Figure 13. The wall layers on fourth case

	Layer Name	Width	Density	Sp.Heat	Conduct.	Type
1.	Cement Plaster, Sand Aggre	10.0	2050.0	840.000	1.080	35
2.	Block, Mediumweight, 150 N	150.0	2300.0	840.000	1.490	35
3.	Aergel	10.0	70.0	840.000	0.017	35
4.	Gypsum Plasterboard	20.0	980.0	840.000	0.360	35

Figure 14. The wall layers characteristics on fourth case

8. RESULTS

The results of the practical study can be presented, which include the following:

1. The results of the summer, winter and Total thermal load for the apartment chosen in the research and the load ratios as follows:

A- The results of summer, winter and total thermal load for the residential apartment as a whole using walls with building materials according to the four cases specified in the research methodology and as shown in Table 2 and Figures 15, 16, 17, as follows. By discussing the results of the thermal performance of the residential apartment chosen in the research according to the summer, winter and total thermal load, it is clear that the heat load in the first case using concrete was 19734336, 1911847 and 21646184 respectively, which is the highest the highest among the four measured cases, meaning that the thermal performance of the apartment was the least, efficient among them, followed by the second case using expanded polystyrene material, then followed by the fourth case using Nano air gels material, and finally the heat load value of the third case came using Nano vacuum insulation panels, so it was the best and most efficient case among the four measured cases.

Table 2. Heating, cooling, and total thermal load of the apartment in the four cases / researcher

No.	Case Name	Heating Loads of Apartment	Cool Loads of Apartment	Total Load of Apartment
1	wall using traditional building materials	19734336	1911847	21646184
2	wall using traditional insulating building materials	9076752	877025	9953777
3	wall using Nano-vacuum insulation panels	4595808	436557	5032366
4	wall using nanoparticle gels	5725383	550028	6275411

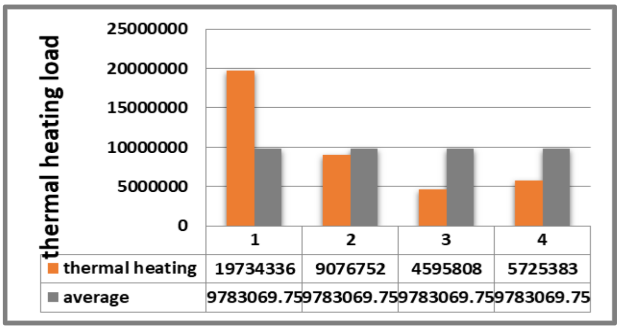


Figure 15. Variation of heating load of the selected apartment in the four cases and the average

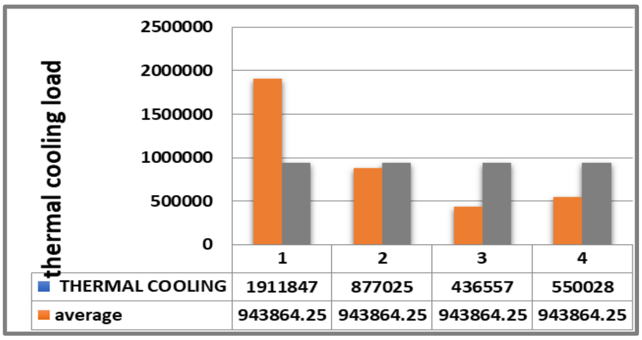


Figure 16. Variation of cooling load of the selected apartment in the four cases and the average

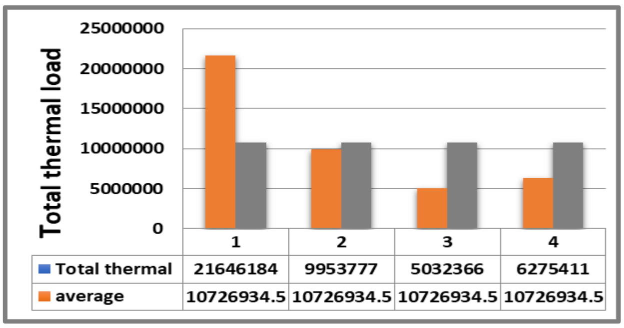


Figure 17. Total thermal load of the selected apartment in the four cases / researcher

B- The results of calculating the percentage of heat load required for the selected residential apartment by adding the traditional insulation material (the second case) or Nano (the third or fourth case) relative to the first case (considering the first case is the basic case).

Thus, for any case whose thermal performance is to be calculated compared to the basic case specified in the research, and for any load, whether heating or cooling load, or the total annual heat load, as shown in Table 3 and Figures 18 and 19 as follows. And using the following relationship:

The percentage of thermal load required in the second case is equal to $\dfrac{\textbf{thermal load in the second case}}{\textbf{thermal load in the basic case (the first)}} * \mathbf{100\%}$

Table 3. Total thermal load required for the apartment as a whole for the cases specified relative to the basic case

No.	The Ratio of the Required Heating Load to the Base Case	The Ratio of the Required Cooling Load to the Base Case	The Ratio of the Required Total Load to the Base Case
1	Basic Case No (1)	Basic Case No (1)	Basic Case No (1)
2	45.9% from case (1)	45.8% from case (1)	45.9% from case (1)
3	23.2% from case (1)	22.8% from case (1)	23.2% from case (1)
4	29% from case (1)	28.7% from case (1)	28.9% from case (1)

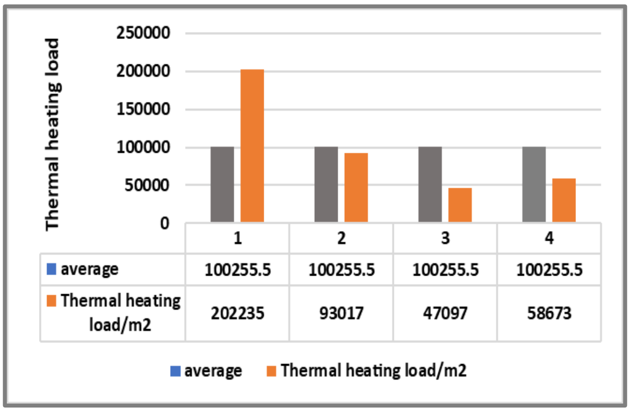


Figure 18. Thermal heating load /m^2 of the selected apartment area / researcher

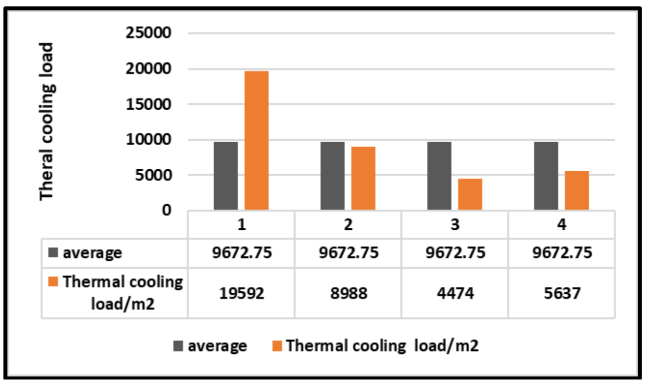


Figure 19. Thermal cooling load /m^2 of the selected apartment area / researcher

The results show that the percentage of thermal load required in the second case using expanded polystyrene was approximately (45.9%), compared to the first case using traditional concrete and in its three summer, winter and total cases, while the fourth case, which included the use of Nano air gels, was approximately 28.9%. The third case, which included the use of Nano vacuum insulation panels, the required thermal load percentage reached approximately 23.2% compared to the required load in the first case, as it is the most efficient and the best thermally among the four specific cases under study.

2. The results of the summer, winter and total thermal load per / m^2 of the apartment area and the percentage of loads and thermal efficiency thereof as follows:

A- The results of thermal load / m^2 of the apartment area, with walls using building materials according to the four cases specified in the research methodology and as shown in Table 4 and Figures 20 and 21. And as follows:

When comparing the thermal performance of the residential apartment in the four cases in question, it is evident that the basic case had the highest heating, cooling, and total load consumption per square meter of the apartment area, while the third case's use of Nano-vacuum insulation panels had the lowest value. This result confirms the earlier finding that the basic case has the highest efficiency and thermal performance when compared to other cases of walls.

Table 4. The summer, winter, and total heat load per square meter of the area of the selected residential apartment

Case Name	Summer Heat Load/m^2	Winter Heat Load/m^2	Total Heat Load/ m^2
1-wall using traditional building materials	202235	19592	221827
2-wall using insulating materials	93017	8988	102005
3- wall using Nano-vacuum insulation panels	47097	4474	51571
4- wall using nano air gels	58673	5637	64309

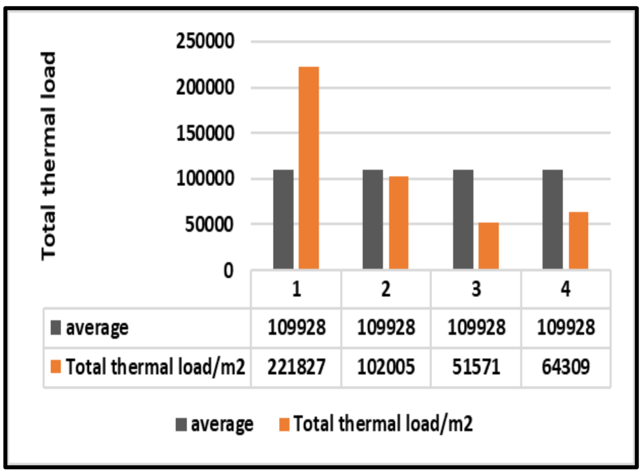


Figure 20. Total thermal load /m^2 of the selected apartment area / researcher

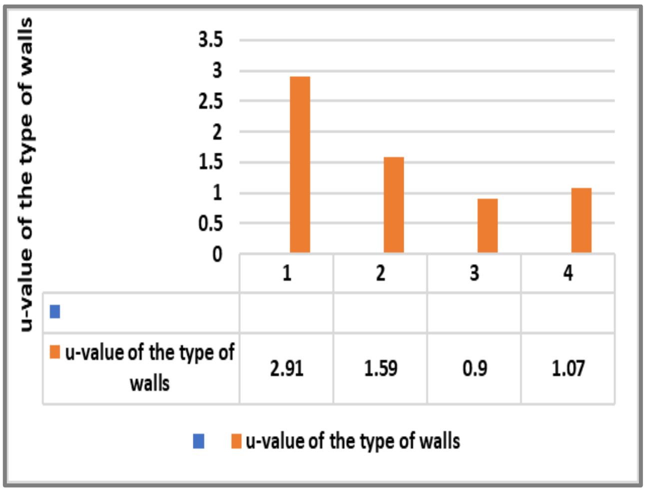


Figure 21. The values of the heat transfer coefficient of the wall in the four cases of the walls / researcher

B- The results of calculating the percentage of heat load required per square meter of the apartment area for the cases of the walls compared to the first basic case based on the following relationship and as shown in Table 5, as follows:

$$\textbf{The percentage of thermal load/m}^2 \textbf{ of the apartment's area required in the second case is equal to } \frac{\text{thermal load/m}^2 \text{ in the second case}}{\text{thermal load/m}^2 \text{ in the basic case (the first)}} * 100\%$$

Table 5. The percentage of pregnancy required /m^2 of the apartment area for cases to the basic case / researcher

No.	Required Heating Load Ratio	Required Cooling Load Ratio	Required Total Load Ratio
1	Basic Case No (1)	Basic Case No (1)	Basic Case No (1)
2	45.9% from case (1)	45.8% from case (1)	45.9% from case (1)
3	23.2% from case (1)	22.8% from case (1)	23.2% from case (1)
4	29% from case (1)	28.7% from case (1)	28.9% from case (1)

C- The results of calculating the efficiency of thermal performance per square meter of the area of the residential apartment chosen in the research, according to the following Formula:

Thermal efficiency /m^2 of the apartment area = 100% - the percentage of thermal load in Table 5

-The thermal efficiency /m^2 of the apartment area in the second case using expanded polystyrene is approximately (54.1%), better than the basic case.

-The thermal efficiency /m^2 of the apartment area in the third case using nano-vacuum insulation panels is approximately (76.8%) better than the basic case.

-The thermal efficiency /m^2 of the apartment area in the fourth case using pneumatic gel is approximately (71.1%) better than the basic case.

The results above show the preference of the third case by using nano-vacuum insulation panels with an efficiency of about (76.8%) better than the basic case, followed by the fourth case with an efficiency of (71.1%) better than the basic case and then the second case with an efficiency of (54.1%) better than the basic case.

3. The results of calculating the thermal load per square meter of the external exposure area, the percentage of loads, and the thermal efficiency of the residential apartment specified in the research, as follows:

A- The results of the summer, winter and total thermal load per square meter of the external exposure area of the apartment can be obtained by dividing the total thermal load of the apartment to the external apartment exposure area, using the following Formula, as shown in Table 6 As follows:

Total Surface Area: 378.837 m^2 (388.2% flr area).

Total Exposed Area: 165.520 m^2 (169.6% flr area).

$$\textbf{Thermal load per square meter of external exposure area} = \frac{\textbf{total thermal load}}{\textbf{external exposure area of the apartment}}$$

Table 6. Heating, cooling and total loads /m^2 of the external exposure area of the apartment / researcher

No. CASE	Heating Load/m^2 of exposure area	Cooling Load/m^2 of Exposure Area	Total Load/m^2 of Exposure Area
1	119226.29	11550.55	130776.85
2	54837.80	5298.60	60136.40
3	27765.88	2637.49	30403.37
4	34590.28	3323.03	37913.31

B- The results of calculating the ratio of the summer, winter and total load per square meter of the external exposure area for each case, and considering the first case of walls using traditional materials is the basic case for measurement and by dividing the load for each of the second, third and fourth cases to Thermal load of the first basic case and as shown in Table 7 as follows:

Table 7. The percentage of heating, cooling and total load /m^2 of the external exposure area for cases to the base case / researcher

No.	Required Heating Load Ratio	Required Cooling Load Ratio	Required Total Load Ratio
1	Basic Case No (1)	Basic Case No (1)	Basic Case No (1)
2	45.984% from case (1)	% 45.873 from case (1)	45.984% from case (1)
3	23.248% from case (1)	% 22.834 from case (1)	23.248% from case (1)
4	28.990% from case (1)	% 28.769 from case (1)	28.990% from case (1)

By discussing the results above, it is clear that the percentage of thermal load required in the third case represented by the use of nanotechnology, especially vacuum insulation panels, was the lowest, reaching (23.248%) from the basic case, followed by the flat load in the fourth case, which included the use of air gels, by (28.990%) and then the second case, represented by polystyrene material, with a ratio of (45.984%) from the load of the first basic case, thus for the rest of the heating and cooling load tests for the residential apartment shown in Table 7, confirming the hypothesis of the research that the use of nanotechnology, especially nano-insulating materials, increases the efficiency of the thermal performance of the residential apartment in specific proportions and a minute.

C- The results of calculating the efficiency of thermal performance per square meter of the exposure area for the residential apartment specified in the research, according to the following Formula:

Thermal efficiency/ m^2 of the external exposure area = 100% - the percentage of thermal load in Table 6

-Thermal efficiency / m^2 of exposure area in the second case using expanded polystyrene = 54.016% better than the base case.

-The thermal efficiency / m^2 of the exposure area in the third case using nano vacuum insulation panels = 76.752% better than the basic case.

-Thermal efficiency / m^2 of exposure area in the fourth case using aerated gel = 71.01% better than the basic case.

The above results showed that the highest ratio of efficiency improvement was by using nano-vacuum insulation panels 76.752% better than the original case, followed by the use of air gel technology with an efficiency of 71.01% better than the original case and finally using expanded polystyrene with an efficiency of 54.016% better than the basic case, and these results indicate the possibility of determining an accurate and specific measurement to raise the efficiency of the apartment compared to the basic case, which makes it easier for the designer and the user to decide the feasibility of using such materials in the apartments, as their operational costs will witness a significant decrease during use.

4. The additional results and measurements that enhance the search result are as follows:

A- The results of the thermal transfer coefficient values of the total wall in the four cases specified in the research, which show that its value using expanded polystyrene reached (1.59) and in the fourth case using air gel it reached (1.07), and finally (0.9) in the third case using vacuum insulation panels and as shown in Table 8, and Figure 21 as follows:

Table 8. The values of the heat transfer coefficient of the wall in the four cases of the walls / researcher

No.	Case Name	u-value
1	The wall using traditional materials	2.91
2	The wall using insulating materials	1.59
3	The wall using Nano-vacuum insulation panels	0.9
4	The wall using nano air gels	1.07

Table 9. The highest value of the heating and cooling load in four cases / researcher

Case No.	Max Heating(W)	Max Cooling(W)
1	8346	2965
2	3840	1364
3	1947	692
4	2423	861

B- The results of the highest value of the heating load were in the four cases on (15th November), and the highest value for cooling load were in the four cases on (12th July), with values that were highest in the first case and lowest in the third case, as shown in Table 9 and Figure 22.

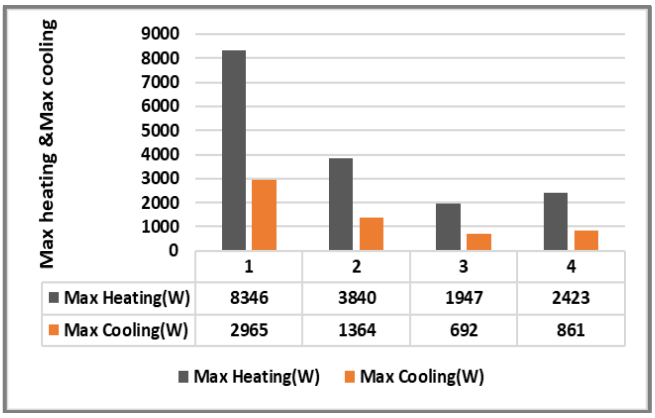


Figure 22. Highest values of the heating and cooling load for the selected residential apartment

The results show that the highest heating load and cooling load were 8346 and 2965 respectively in the first basic case, and the lowest was in the third case with values 1947 and 692 respectively, which confirms the preference of the third case for walls that include the use of vacuum insulation panels over other cases of research.

C- The results of calculating the number of days of thermal comfort (where the thermal loads are zero) in the residential apartment chosen in the research within the four cases of walls as shown in Table10 and Figure 23 and as follows:

Table 10. The number of thermal comfort days in the apartment in four cases / researcher

Case No.	N. of Days June	N. of Days Sept	Total N. of Days
1	14	19	**33**
2	15	21	**36**
3	19	24	**43**
4	16	24	**40**

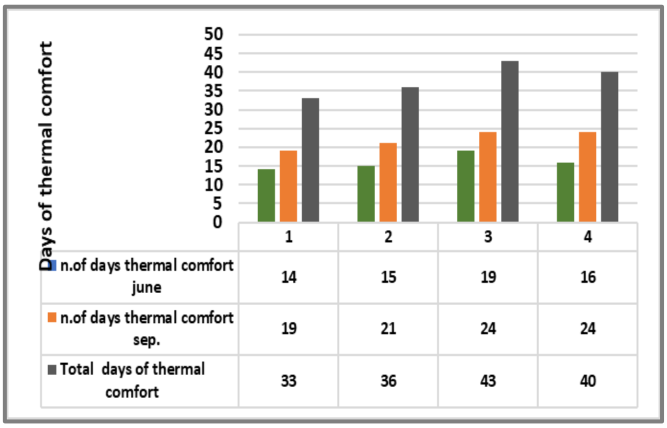


Figure 23. Number of thermal comfort days in summer, winter, and total / researcher

The results in Figure 23 and Table 10 show what was concluded from the previous tests that the total number of days of thermal comfort was the highest then the third case, reaching (43 days), followed by the fourth case, with (40 days), and then the second case, with (36 days) and finally the first case with (33 days), which enhances the result of the research with the advantage of using Nano-vacuum insulation panels in the walls, as it is the best and highest in its thermal performance.

9. DISCUSSION

1. Considering the thermal comfort of residential apartments as an urgent need that must be considered when designing and trying to harness all modern means to achieve it.
2. Considering the operating costs of residential apartments from huge thermal loads as losses that must be avoided in the future by using modern technologies for design and construction.

10. CONCLUSIONS

1. The computer program, particularly the Ecotect 2011 program, helped calculate and measure the effect of nano-insulating materials on thermal performance and provide approximate values, numbers, and ratios for that effect after most architectural studies were restricted to the analytical and survey method, which reflects the importance of focusing on employing computer programs in all stages of the design process, starting from Design, implementation.
2. Stressing the crucial part that the architectural and environmental designer must play, particularly in the realistic and numerical assessment of the thermal performance and thermal efficiency of any structure or apartment, in order to serve as a controlling role for any future design process. The environmental engineer is the process' overall leader for environmental sustainability, and he is worried about how these materials will be used going forward.
3. The primary resources and energy sources belong to everyone, and their unrestrained use has negative long-term effects on the environment for the individual and society, in addition to the negative short-term effects on the economy. These effects result in climatic negatives, which have negative long-term effects on the individual and society's health.
4. By reducing the summer and winter and total loads of both types of loads per meter square of the apartment's area and thermal loads per meter square of the apartment's exposure area, nanotechnology particularly the materials of vacuum insulation Panel and air gels helped to achieve the designers' goals in achieving a better residential environment thermally. Due to the importance of this aspect being the most energy-consuming in general, residential and in very good proportions positively reflect on raising the efficiency of the thermal performance of the residential apartment, leading to the user experiencing both greater thermal comfort and a lower cost.
5. The technology of nano-vacuum insulation panels was the first among the selected technologies compared to the nano-air gel material and the traditional expanded polyresin material, which gives preference to it in the future use for the purpose of achieving the best thermal efficiency in residential apartments.
6. Nanotechnology, especially nano-vacuum insulation panels, contributed to reducing the heat transfer coefficient through the wall (u-value) compared to other cases specified in the research, and that this value of the transfer coefficient can become a future indicator to identify the thermal behavior of other materials outside the research and evaluate their efficiency Thermal materials, whether these are nanomaterials, ordinary insulators, or any building material, through comparison and evaluation.
7. The use of these technologies and many others can contribute to the relative reduction of the operational costs of residential projects, no matter how high their initial sponsorship is, which reflects the architect’s desire to direct users to future thinking and a serious comparison between the operational and operational costs of any project, whether it is residential or commercial, and so on.
8. The use of nanotechnology in general and nano vacuum insulation panels in particular contributed to increasing the number of thermal comfort days for the residential apartment, and also contributed to decreasing the value of (maximum heating and (maximum cooling) for the residential apartment that uses this technology.

11. IMPLICATIONS AND FUTURE RESEARCH

Among the most important implications and future research are the following:

1. Investigating the application of nanoparticles in building design to ascertain the degree to which energy consumption is lowered in a healthy and environmentally sound way.
2. A study that increases the sustainability of nanomaterials in order to decrease the consumption of raw materials, which in turn results in a decrease in the energy consumed in the manufacture of materials, to see the extent to which the life cycle of some materials improves, in addition to knowing the percentage of reducing carbon emissions and greenhouse gases.

Researching the impact of nanomaterials on the quality of the building's interior environment, specifically the degree to which thermal performance is enhanced and the degree to which noise is decreased.

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