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Adaptive Technologies of Nano-Architecture for the Next Generation of Sustainable Building Applications

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KEYWORDS:
Nanotechnology, Nano-Architecture, Nanomaterials, Nanomaterials Techniques, Vacuum insulation panels, Aerogel, Phase change material.

Abstract— **The present research casts light on the recent development in discovering a novelty in the field of technology which needs staying up with the latest updates with this innovation which has prompted nanotechnology. This has become the most important technology connected with our daily life and many activities and fields. The manufacture of many of the products on the market depends on nanotechnology, whereas the control of materials in the ultra-small-scale nanometer is a revolution in contemporary technology in all areas of life, especially in materials design, construction methods, and architectural perceptions. The research addresses the definition of nanotechnologies and their applications through the use of nanomaterials and applies them in the construction field, which led to a high evaluation of sustainable buildings that are compatible with the environment. The Specific Programs Building attached to the Faculty of Engineering at Mansoura University is selected as the case study where nano-insulation materials are applied to help improve the performance of the building and reduce the energy consumed, especially in building cooling operations.**

I. INTRODUCTION

THE expression "nanotechnology" has developed throughout the years by means of conceptual drift to the term "anything smaller than microtechnology," for example, nanopowders, and different things that are nanoscale in size, but not alluding to mechanisms that have been deliberately constructed from nanoscale components. This development version of the term is more properly called "Nanoscale Bulk Technology," whereas the original meaning is presently more relevant to "Molecular Nanotechnology" (MNT), or "Nanoscale Engineering," or "Molecular Mechanics," or "Molecular Machine Systems," or "Molecular Manufacturing"[1].

Nanotechnology is an energizing zone of logical improvement which guarantees more for less. It provides approaches to make smaller, less expensive, lighter and faster devices that can accomplish smarter and cleverer things, use less raw materials, and consume less energy. There are numerous models of nanotechnology application from simple to complex. For instance, nano-coatings are capable of repelling dirt, reducing the need for harmful cleaning agents, or preventing the spread of hospital-borne infections. Proceeding onward to more complicated products, a great example of the use of nanotechnology application is a cell phone, which has changed significantly within a few years getting to be smaller and smaller, while paradoxically, developing smarter and faster and less expensive [2].

The uses of nanotechnology are in all fields of our life, it can relate in medicine, industry, communications, transportation, and more important, architecture. The utilization of nanotechnology in architecture is wide and varies from the early

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stages of sketching up to the final touches of finishing, particularly in picking the correct material which won't only reflect the design but also has a significant affects the method of architecture thinking according to the new colossal options that offered by nanotechnology [3].

Nano-Architecture is the integration of nanotechnology into architecture, using nanoproducts, nanomaterials, nano-telecommunication, or even nanoshapes. When you insert new technology into a field such as the construction industry, one should in every case initially look at the advantages and benefits it can bring. In the case of using nanotechnology, we are talking about the added worth and extra functions according to the market requirements regarding product development. Great design on a fundamental level constantly depends on demand, and thusly contributes to the advancement of both nanomaterials and resulting nanoproduct, on the long haul the materials and products which required by demand will be established while others will vanish from the market [4]. Regardless of any factor, nanotechnology can make a concrete contribution to the following areas: [4]

- Optimization of existing products.
- Reduction in weight and/or volume.
- Reduction in the number of production stages.
- A more efficient use of materials.
- Reduced need for maintenance. And as a direct result:
- Reduction in the consumption of raw materials and energy and reduced CO2 emissions.
- Conservation of resources, greater economy, comfort.

II. NANOMATERIALS TECHNIQUES

Nanomaterials are a field which adopts a materials science-based strategy to nanotechnology. It studies materials with morphological highlights on the nanoscale, and particularly those which have unique properties coming from their nanoscale dimensions. Nanoscale is typically defined as smaller than a one-tenth of a micrometer in one dimension at least, however, this term is likewise utilized for materials smaller than one micrometer [5]. Table 1 shows nanomaterials in different dimensions.

TABLE 1
NANOMATERIALS CATEGORIZED BASED ON THEIR DIMENSIONS.
Source: Nano material science, Nanotechnology, (2010) [6].

Nanomaterial Dimension	Nanomaterial type	Scale
One Dimensional (1-D)	Thin Films. Coatings. Layers.	< 100 nm
Two Dimensional (2-D)	Nanotubes. Nanowires. Fibers.	< 100 nm
Three Dimensional (3-D)	Nanoparticles. Nanorings. Quantum Dots. Microcapsules. Nanoshells.	< 100 nm

A. Coating (Finishing Materials)

1) Self-Cleaning (Lotus Effect)

This is one of the best-known means of designing surfaces with nanomaterials. The name "Lotus-Effect" is often confused with "Easy-to-clean" surfaces or with Photocatalysis, which is also self-cleaning [8]. Fig. 1 shows natural self-cleaning for Lotus leave.

TABLE 2:
COATINGS TYPES [7].

Product	Self-Cleaning (Lotus Effect)	Self-Cleaning (Photocatalysis)	Easy to Clean (ETC)
Properties	Hydrophobic (water trickles off).	Hydrophilic surfaces. Deposited dirt is broken down and lies loose on the surface.	Hydrophobic (water-repellent and often also oleophobic). Surface Repellence without using the Lotus-Effect.
Specifications	Microscopically rough, not smooth. Well suited for surfaces that are regularly exposed to sufficient quantities of water.	A water film washes dirt away. UV light and water are required. Light transmissions for glazing and translucent membranes are improved.	Smooth surfaces with reduced surface attraction. Surfaces have a lower force of surface attraction due to a decrease in their surface energy.
Usage	For better optimal use and low maintenance facades.	Reduce the extent of dirt adhesion on surfaces.	Are most commonly found in interiors, but can also be employed outdoors for better weather protection.

Fig.1. The Lotus Leaf with its natural self-cleaning "Lotus-Effect"

- Example for the use of the self-cleaning Lotus Effect: Ara Pacis Museum, Rome, Italy [10], *Fig. 2.*

Fig. 2. Ara Pacis Museum exterior, showing Self-cleaning coating [10].

2) Self-Cleaning (Photocatalysis)

Photocatalytic self-cleaning is probably the most widely used nano function in building construction. Its primary effect is that it greatly reduces the extent of dirt adhesion on surface. Generally, photocatalytic self-cleaning is a low-maintenance and trouble-free solution [11]. See Fig. 3.

Fig. 3. Comparison of conventional and self-cleaning glasses. (adapted from Pro Clean Window 2018) [12].

- Example for the use of the self-cleaning Photocatalysis: Muhammad Ali Center MAC, Louisville, USA [13], Fig. 4.

Fig. 4. Muhammad Ali Center MAC facades [13].

3) Easy-to-clean (ETC)

Easy-to-clean surfaces are water repellent and smooth rather than rough with reduced surface attraction resulting in reduced surface adhesion. This causes water to be repelled, forming droplets, and running off. Easy-to-clean surfaces are therefore hydrophobic, i.e. water repellent, and often also oleophobic, i.e. oil repellent [14]. See Fig. 5.

Fig. 5. Left without ETC coating, right with ETC coating [14].

- Example for the use of the Easy-To-Clean (ETC): Science to Business Center Nanotronics & Bio, Marl, Germany [14], Fig. 6.

Fig. 6. Science to Business Center Nanotronics & Bio [14].

B. Insulation (Energy Saving Materials)

1) Thermal insulation (Vacuum insulation panels- VIPs)

Vacuum insulation panels (VIPs) are ideally suited for providing very good thermal insulation with a much thinner insulation thickness than usual [15]. See Fig. 7.

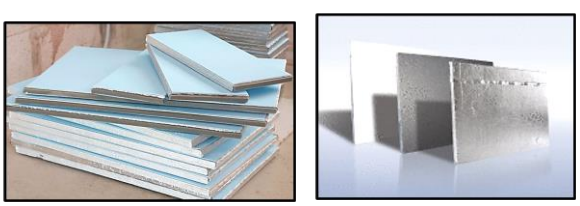


Fig. 7. Vacuum insulation panels with a protective encasement [15] [16].

- Example for the use of the Vacuum insulation panels (VIP): The Grand Tower, Frankfurt, Germany, Fig. 8.

Fig. 8. VIP used in façade insulation (BRUSSELS, 9 November 2018)

2) Thermal insulation (Aerogel)

A product known as Nanogel, a form of aerogel, not only provides high performance thermal insulation but also effective sound insulation [17]. See Fig. 9.

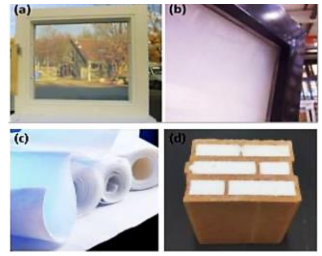


Fig. 9 (a) specular aerogel glazing.
(b) Diffuse aerogel glazing.
(c) Aerogel as thermal insulation material (Aspen Aerogel Inc.).
(d) Brick with aerogel filling [18].

- Example for the use of the Aerogel: Levanger primary school, Norway [18], Fig. 10.

Fig. 10. Levanger primary school, Norway [18].

3) Temperature regulation (Phase change material- PCMs)

Correct use of PCMs can reduce peak heating and cooling loads, and may also allow for smaller dimensions of technical equipment for heating and cooling [19]. See Fig. 11.

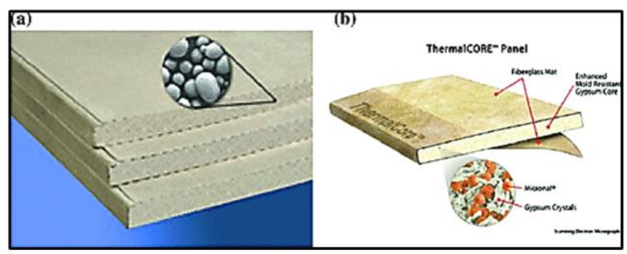


Fig. 11. (a) Gypsum wallboard with Micronal PCM (from BASF).
(b) Thermal CORE phase change drywall (from National Gypsum) [19].

- Example for the use of the Phase Change Material (PCMs): New Construction Training Center, Chula Vista, California, USA, Fig. 12.

Fig. 12. Phase Change Material in New Construction Training Center (From Emerging Technologies Coordinating Council).
(b) Thermal CORE phase change drywall (from National Gypsum) [19].

III. NANOMATERIALS TYPES

Nanoparticles can be classified into different types according to the size, morphology, chemical and physical properties.

1) Nanoparticles for applications are already commercially available in a wide range of forms that can support a host of applications [20].
2) Titanium dioxide (TiO_2), widely used in its anatase (one of the tetragonal forms of titanium dioxide, usually found as brown crystals, used as a pigment in paints and inks) [21] form for photocatalytic applications (self-cleaning, antimicrobial) [21].
3) Nanoparticles can also come in varying levels of treatments. Various Nanoparticles can be obtained that, for example, already have hydrophobic or hydrophilic properties useful in a wide range of applications [20].
4) Carbon Nanotubes for applications are available in a wide variety of single-walled (SWNT) and multi-walled (MWNT) forms, including different lengths, diameters, and purities [20].

IV. THE PROBLEM

Architecture practice faces a number of major environmental challenges that resulted in deficiencies in architectural building performance. This has affected society and the surrounding environment. It has required a search for modern technologies to achieve the environmental standards and requirements needed to build a clean and sustainable architectural environment that seeks to conserve environmental resources. Major problems include:

1) Increasing energy consumption rates through buildings' air-conditioning operations in a way that is not commensurate
2) With the energy production rates.
3) Not using advanced technologies such as nanotechnology to improve the performance of the building and then preserve environmental resources.
4) Building performance analyses are commonly completed after the planning of the architectural and structural designs where the shortening of the constant sustainability analysis during the planning process prompts an ineffective process of retroactive modification to the design to accomplish a lot of performance criteria.
5) Hence the inability of the building to preserve the environment, achieve the concepts of sustainability, and provide many resources.

V. THE AIMS OF RESEARCH

1) Reflection of the better-use of nanotechnology to achieve sustainability in architecture.
2) Clarify the significance of nanotechnology to architecture and the integration between them to show the nanoarchitecture and spotlight on the impact on architecture.
3) Trying to avoid nanotechnology's negative effects and stop the energy drain by finding alternative ways to conserve energy using nanomaterials.

VI. THE OBJECTIVS OF RESEARCH

1) Know the positive benefits of nanomaterials in architecture and it's applied to clarify the potential risks and avoid them.
2) Identifying nanomaterials from their types, properties and use them in architecture.
3) Perfectly rethinking the connection between structure and skin in light of nanomaterials technology.
4) Applying the simulation model and analyze the outcome.

VII. METHODOLOGY

The research methodology is based on simulation strategy that tries to modify some aspects of the physical environment in one of the various modes, from digital simulation software to a real scale status imitation.

1) Applications

The case study includes evaluation of energy performance and cooling loads for the “Specific Programs Building, Mansoura University” and comparison between the building in base case with normal materials and with nanomaterials case through a computer simulation program "Design-Builder" to measure the impact of nanotechnology on the amount of energy consumed in the process of cooling and the average temperature of the thermal energy gained in the internal environment to achieve the main objective of the research.

2) Charts

- Specify the location of the case study and climate data.
- Prepare the drawing plans for the building.
- Analysis of the current state of the building using the Design-Builder.
- Specify alternative solutions using Nanomaterials by the Design-Builder.
- Make a Comparison between the results for the current state case and the building after using Nanomaterials.

A. Case Study Information

The “Specific Programs Building” attached to the “Faculty of Engineering, Mansoura University” was chosen to be the case study. Fig. 13 shows the building and its location on Satellite Map.

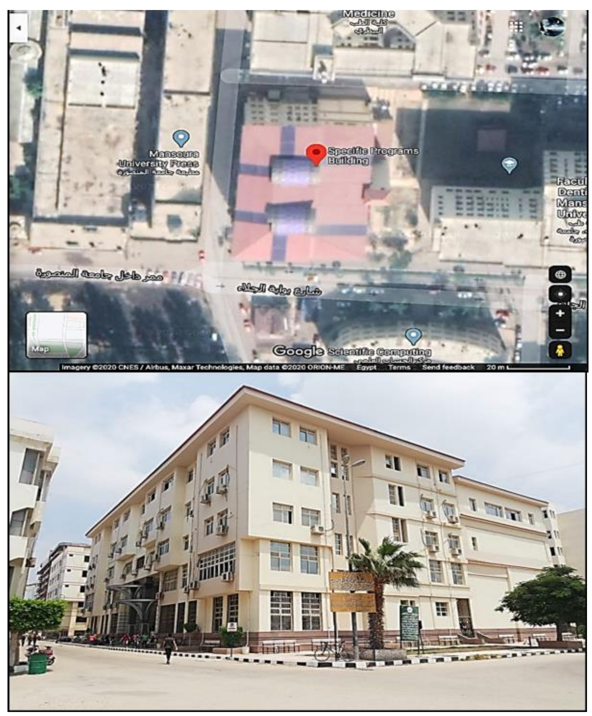


Fig. 13. Specific Programs Building, Mansoura University and Satellite Map.

B. The Climatic Data Used in Simulation

The case study simulation is applied at Mansoura city “related to Cairo and Delta region”. The climate of Mansoura city is similar to Cairo’s climate.

1) Temperature

The temperature ranges between 42 ° C in June as the highest temperature recorded in summer and 7 ° C in January as the lowest temperature recorded in winter as shown in Fig. 14 that was extracted from the "Climate Consultant" software.

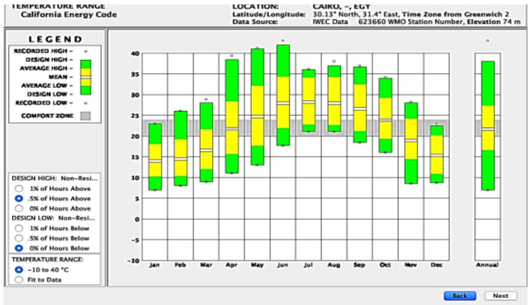


Fig. 14. Temperature range for Delta region generated by Climate Consultant.

2) Psychrometric Chart

The psychrometric chart of the Delta Region determines the characteristics of the climate which achieves the thermal comfort of the user from temperature as shown in Fig. 15 from the "Climate Consultant" software.

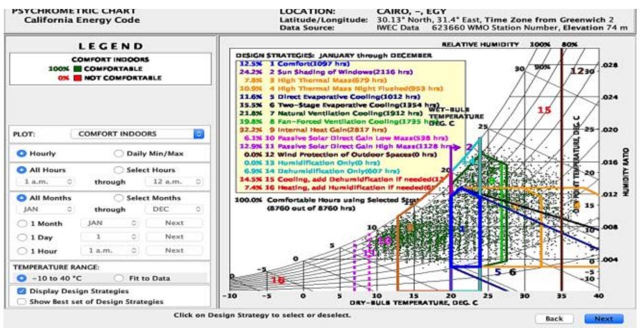


Fig. 15. Psychrometric chart of Delta generated by Climate Consultant.

C. Modeling and Design the Case Study

The building was simulated using "Design Builder" whereas; it is a state of the art software tool for checking building energy and comfort performance.

D. Modeling and Design the Case Study

1) Current Materials

a) Walls Materials

Walls consist of Brick-Burned with 20 cm thickness and two layers of Mortar-Cement with 2.5 cm thickness. Table 4 shows the physical characteristics for the wall.

TABLE 4
PHYSICAL CHARACTERISTICS OF THE WALL LAYERS.

Component	Thickness (cm)	Conductivity (W/m.K)	Specific Heat (J/kg.K)	Density (kg/m3)	Resistance (m^2.K/W)
Mortar-cement	2.5	0.72	840	1860	0.022
Brick-burned	20	0.85	840	1500	0.41
Mortar-cement	2.5	0.72	840	1860	0.022
R-value	**0.475 (m^2.K/W)**				
U-value	**2.106 (W/m2.K)**				

b) Windows

The glass used in the case study envelope is single-glazed with thickness 6mm. Table 5 shows the optical and physical properties of the glass used in the case study.

Table 6 shows the relationship between solid and void in the building envelope.

TABLE 5
OPTICAL AND PHYSICAL PROPERTIES OF THE USED GLASS.

Type of glass	SHGC	VT	U-value (W/m2.K)
Single glass 6mm	0.819	0.881	5.778

TABLE 6
WINDOWS-WALL RATIO IN FACADES.

Orientation	Facade Area (m2)	Wall Area (m2)	Window Area (m2)	Window-Wall Ratio (%)
North	820	719.45	100.55	12.26%
East	1090	1081.36	8.64	0.79%
South	820	719.45	100.55	12.26%
West	1149.82	779.17	370.65	32.23%
Total	**3879.82**	**1498.62**	**580.39**	**14.96%**

c) Ceiling Materials

Table 7 shows the physical characteristics for the ceiling.

TABLE 7
PHYSICAL CHARACTERISTICS FOR THE CEILING LAYERS.

Component	Thickness (cm)	Conductivity (W/m.K)	Specific Heat (J/kg.K)	Density (kg/m3)	Resistance (m^2.K/W)
Mortar-cement	5	0.72	840	1860	0.022
Concrete, Reinforced (with 2% steel)	20	2.5	1000	2400	0.008
Mortar-cement	5	0.72	840	1860	0.022
Ceiling Tiles	5	0.056	1000	360	0.05
R-value	**1.252 (m^2.K/W)**				
U-value	**0.799 (W/m2.K)**				

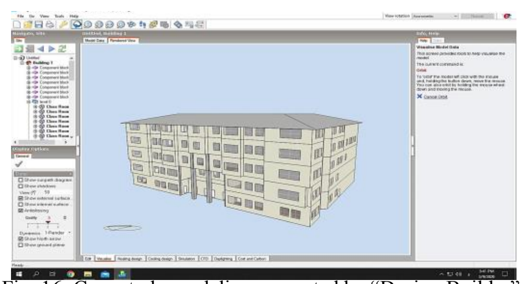


Fig. 16. Case study modeling presented by "Design Builder".

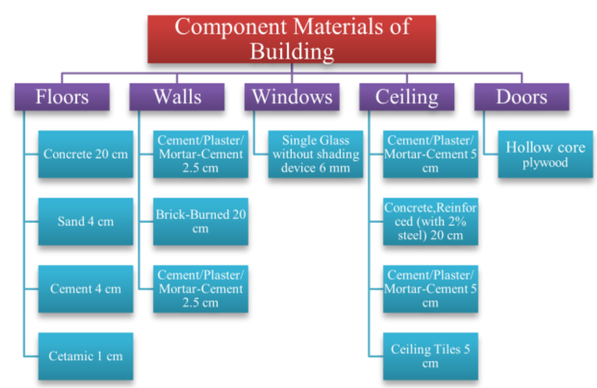


Fig. 17. Case study Current Materials.

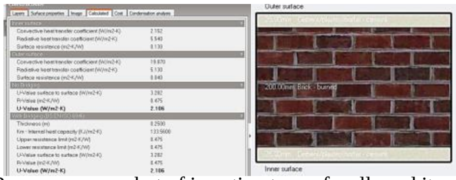


Fig. 18. Program screenshot of inserting type of walls and its properties.

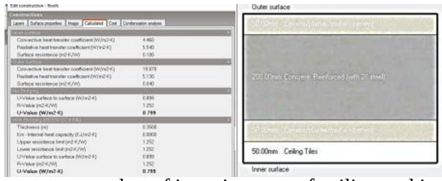


Fig. 19. Program screenshot of inserting type of ceiling and its properties.

2) *Activity Operation*

a) *Set point temperatures (Cooling– Heating)*

Setting of set point temperature for the cooling and heating shown in Fig. 20.

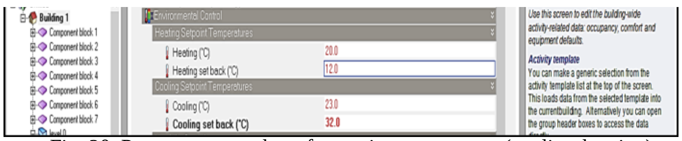
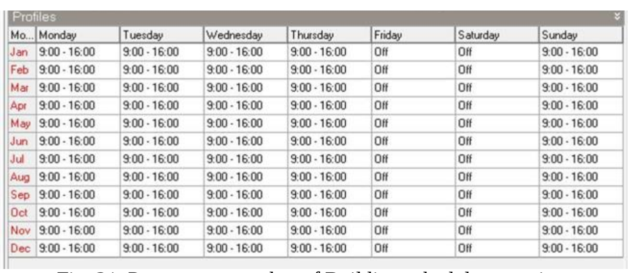


Fig. 20. Program screenshot of set point temperature (cooling-heating).

b) *Schedule Operation*

Building schedule operation shown in Fig. 21.



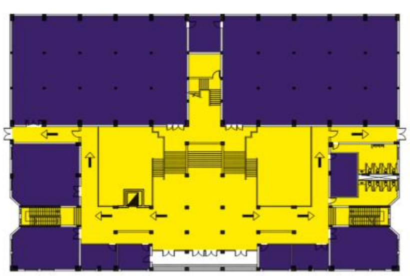
Profiles

Mo...	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Jan	9:00 - 16:00	9:00 - 16:00	9:00 - 16:00	9:00 - 16:00	Off	Off	9:00 - 16:00
Feb	9:00 - 16:00	9:00 - 16:00	9:00 - 16:00	9:00 - 16:00	Off	Off	9:00 - 16:00
Mar	9:00 - 16:00	9:00 - 16:00	9:00 - 16:00	9:00 - 16:00	Off	Off	9:00 - 16:00
Apr	9:00 - 16:00	9:00 - 16:00	9:00 - 16:00	9:00 - 16:00	Off	Off	9:00 - 16:00
May	9:00 - 16:00	9:00 - 16:00	9:00 - 16:00	9:00 - 16:00	Off	Off	9:00 - 16:00
Jun	9:00 - 16:00	9:00 - 16:00	9:00 - 16:00	9:00 - 16:00	Off	Off	9:00 - 16:00
Jul	9:00 - 16:00	9:00 - 16:00	9:00 - 16:00	9:00 - 16:00	Off	Off	9:00 - 16:00
Aug	9:00 - 16:00	9:00 - 16:00	9:00 - 16:00	9:00 - 16:00	Off	Off	9:00 - 16:00
Sep	9:00 - 16:00	9:00 - 16:00	9:00 - 16:00	9:00 - 16:00	Off	Off	9:00 - 16:00
Oct	9:00 - 16:00	9:00 - 16:00	9:00 - 16:00	9:00 - 16:00	Off	Off	9:00 - 16:00
Nov	9:00 - 16:00	9:00 - 16:00	9:00 - 16:00	9:00 - 16:00	Off	Off	9:00 - 16:00
Dec	9:00 - 16:00	9:00 - 16:00	9:00 - 16:00	9:00 - 16:00	Off	Off	9:00 - 16:00

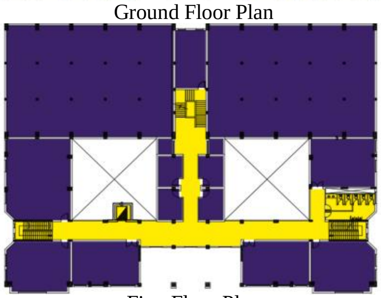
Fig. 21. Program screenshot of Building schedule operation.

3) *HVAC (Heating, Ventilation, and Air Conditioning)*

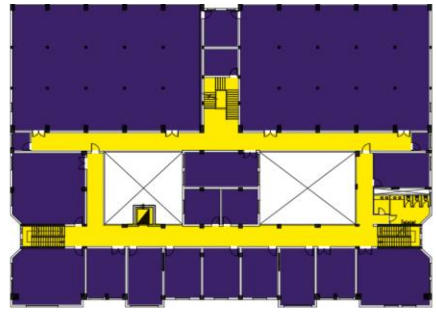
Air conditioning system used in the building (split no fresh air).



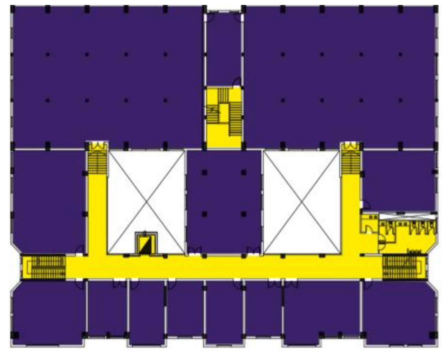
Ground Floor Plan



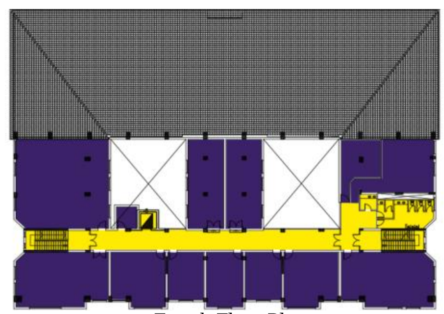
First Floor Plan



Second Floor Plan



Third Floor Plan



Fourth Floor Plan

Fig. 22. Conditioner and non-conditioner spaces.

4) *Output Data*

a) *Cooling Power Consumption Rates for Interior Spaces*

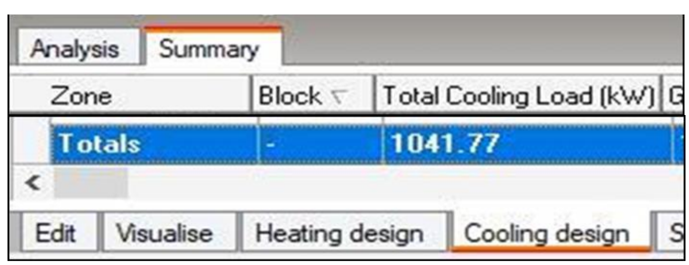


Fig. 23. Program screenshot of cooling load in “Base Case” on 15 July.

Total Cooling Load Over the Day = 1041.75 kW

Total Cooling Load Over the Year = 535258.6818 kWh

Total Cooling (Electricity) Over the Year = 297365.9562 kWh

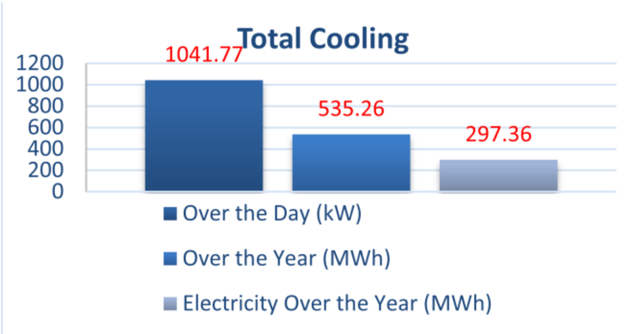


Chart 1. Total cooling loads in "Base Case".

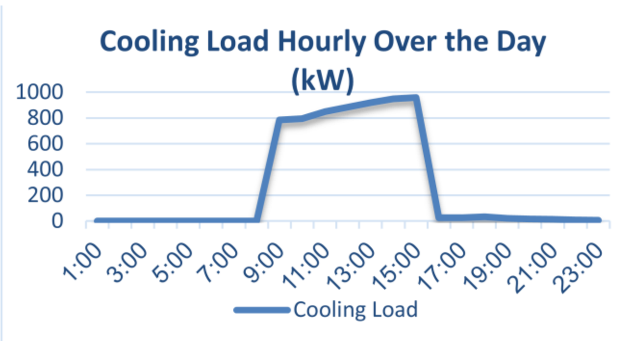
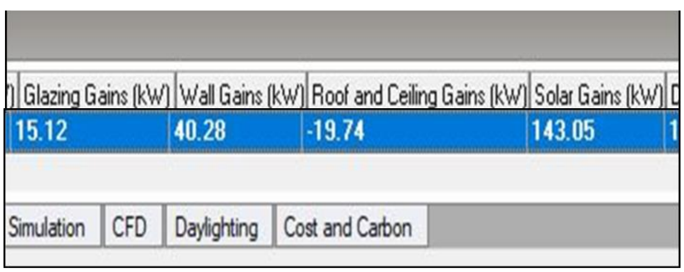


Chart 2. Cooling load hourly over the day in "Base Case".

b) Heat Gains Over the Day from Outside



Glazing Gains (kW)	Wall Gains (kW)	Roof and Ceiling Gains (kW)	Solar Gains (kW)
15.12	40.28	-19.74	143.05

Fig. 24. Program screenshot of heat gains in" Base Case" on 15 July.

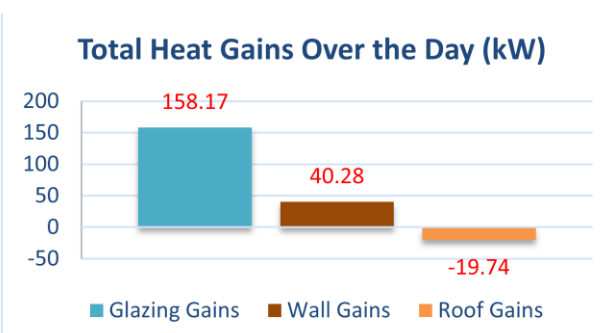


Chart 3. Total heat gains over the day in "Base Case".

c) Heat Gains Hourly Rate Over the Day from Outside

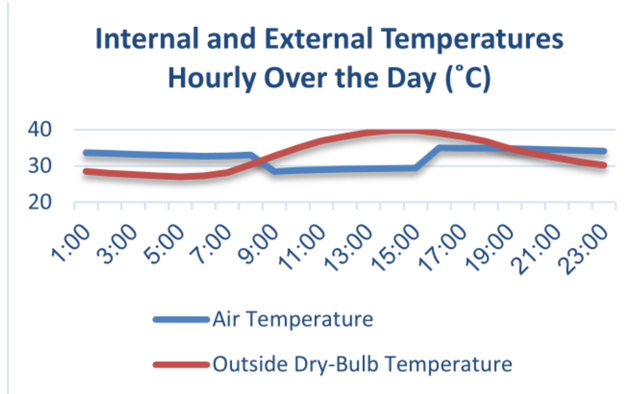


Chart 4. Int. and ext. temperature hourly over the day in "Base Case".

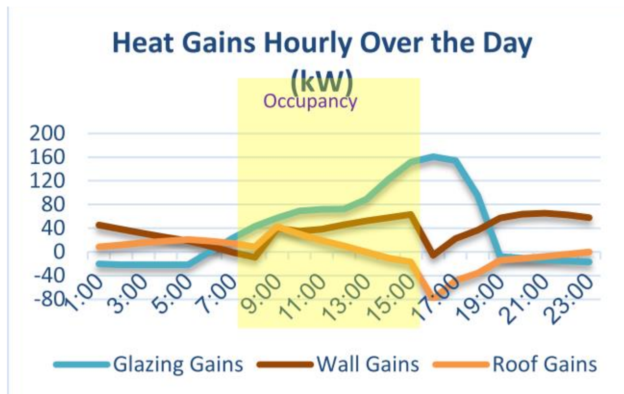


Chart 5. Heat gains hourly over the day in "Base Case".

d) Comfort and Setpoint Not Met Summary

Comfort and Setpoint Not Met Summary

	Facility [Hours]
Time Setpoint Not Met During Occupied Heating	0.00
Time Setpoint Not Met During Occupied Cooling	48.00
Time Not Comfortable Based on Simple ASHRAE 55-2004	1561.00

Fig. 25. Comfort and Setpoint Not Met Summary in "Base Case".

E. Nano Vacuum Insulation Panels (VIP) Case

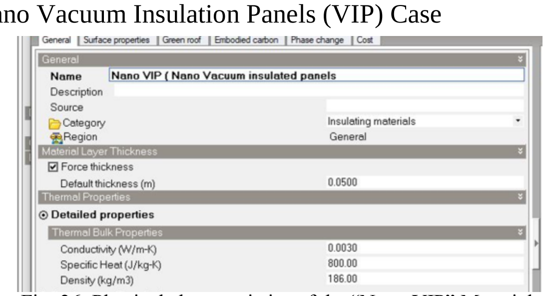


Fig. 26. Physical characteristics of the "Nano VIP" Material.

1) Current Materials

a) Walls Materials

Fig. 27. Program screenshot of inserting type of walls and its properties.

b) Ceiling Materials

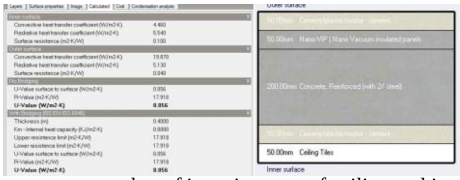


Fig. 28. Program screenshot of inserting type of ceiling and its properties.

2) Output Data

a) Cooling Power Consumption Rates for Interior Spaces

Zone	Block	Total Cooling Load (kW)
Totals	-	906.36

Analysis | Summary — Edit | Visualise | Heating design | Cooling design

Fig. 29. Program screenshot of total cooling load in "VIP Case" on 15 July.

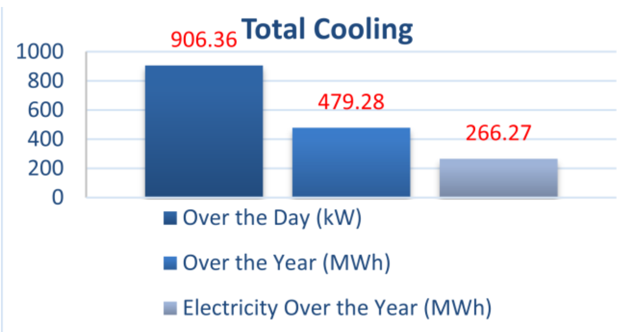


Chart 6. Total cooling loads in "VIP Case".

Total Cooling Load Over the Day = 906.36 kW.
Total Cooling Load Over the Year = 479286.58 kWh.
Total Cooling (Electricity) Over the Year = 266270.4 kWh.

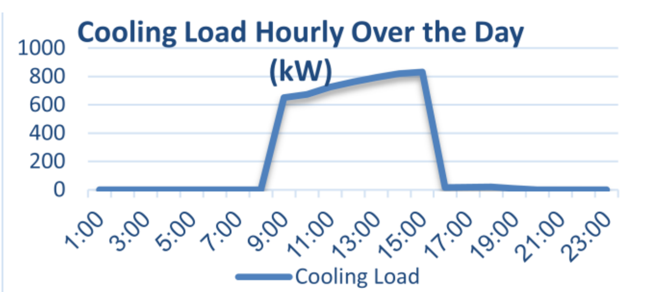


Chart 7. Cooling load hourly over the day in "VIP Case".

b) Heat Gains Over the Day from Outside

Glazing Gains (kW)	Wall Gains (kW)	Roof and Ceiling Gains (kW)	Solar Gains (kW)
16.36	-16.07	-27.47	142.63

Simulation | CFD | Daylighting | Cost and Carbon

Fig. 30. Program screenshot of heat gains in "VIP Case" on 15 July.

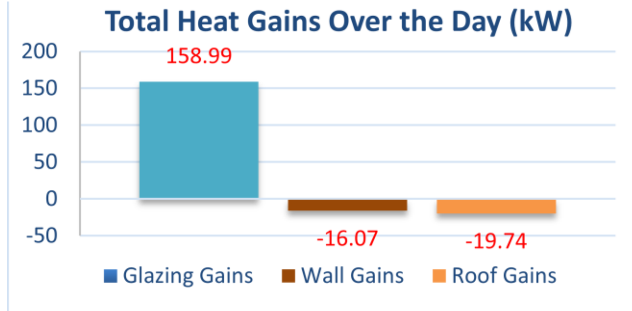


Chart 8. Total heat gains over the day in "VIP Case".

c) Heat Gains Hourly Rate Over the Day from Outside

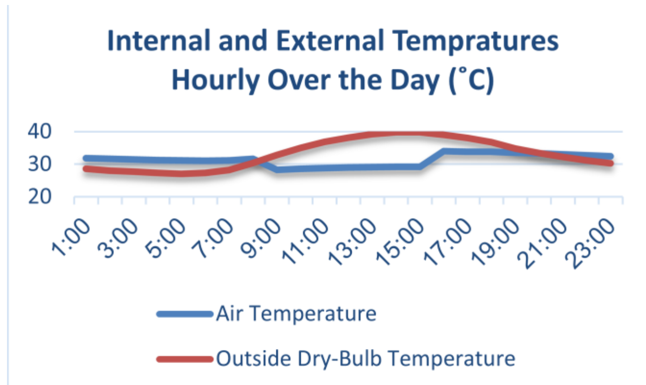


Chart 9. Int. and ext. temperature hourly over the day in "VIP Case".

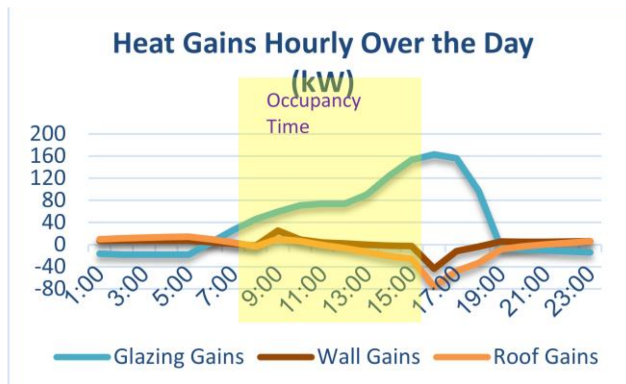


Chart 10. Heat gains hourly over the day in "VIP Case".

d) Comfort and Setpoint Not Met Summary

Comfort and Setpoint Not Met Summary

	Facility [Hours]
Time Setpoint Not Met During Occupied Heating	0.00
Time Setpoint Not Met During Occupied Cooling	107.50
Time Not Comfortable Based on Simple ASHRAE 55-2004	1524.00

Fig. 31. Comfort and Setpoint Not Met Summary "VIP Case".

F. Aerogel Case

Name	AEROGEL 10MM
Source	BS EN 673 / E+
Category	Other
Thickness (mm)	10.000
Gas definition	2-Custom
Custom	
Conductivity coefficient A (W/m-K)	0.00287300
Conductivity coefficient B (W/m-K2)	0.00007760
Conductivity coefficient C (W/m-K3)	0.00000000
Viscosity coefficient A (kg/m-s)	0.0000037230
Viscosity coefficient B (kg/m-s-K)	0.0000000494
Viscosity coefficient C (kg/m-s-K2)	0.0000000000
Specific heat coefficient A (J/kg-K)	1002.7400
Specific heat coefficient B (J/kg-K2)	0.0000000
Specific heat coefficient C (J/kg-K3)	0.0000000
Molecular weight (kg/kmol)	28.970
Specific heat ratio	1.500

Fig. 32. Physical characteristics of the "Aerogel" Material.

1) Current Materials

a) Windows

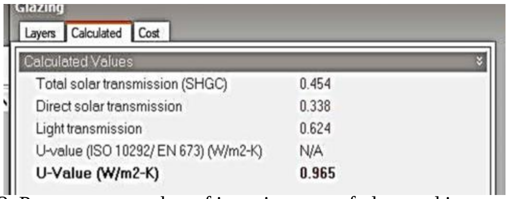


Fig. 33. Program screenshot of inserting type of glass and its properties.

2) Output Data

a) Cooling Power Consumption Rates for Interior Spaces

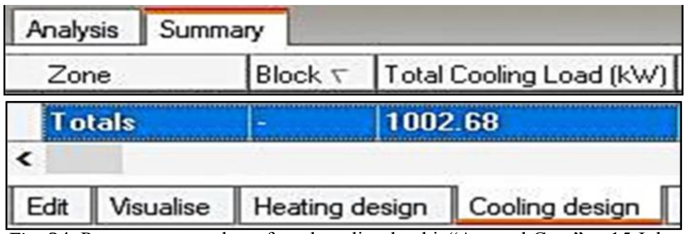


Fig. 34. Program screenshot of total cooling load in“Aerogel Case”on 15 July.

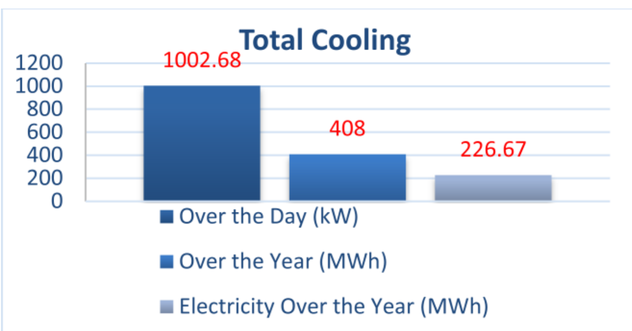


Chart 11. Total cooling loads in “Aerogel Case”.

Total Cooling Load Over the Day = 1002.68 kW.
Total Cooling Load Over the Year = 408004.61 kWh.
Total Cooling (Electricity) Over the Year = 226669.23 kWh.

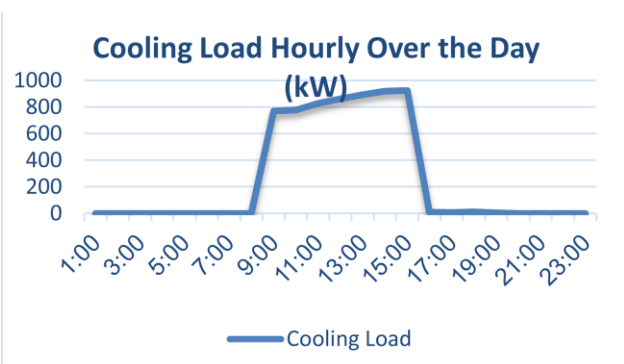


Chart 12. Cooling load hourly over the day in “Aerogel Case”.

b) Heat Gains Over the Day from Outside

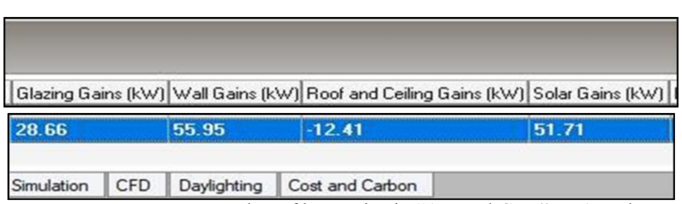


Fig. 35. Program screenshot of heat gains in “Aerogel Case” on 15 July.

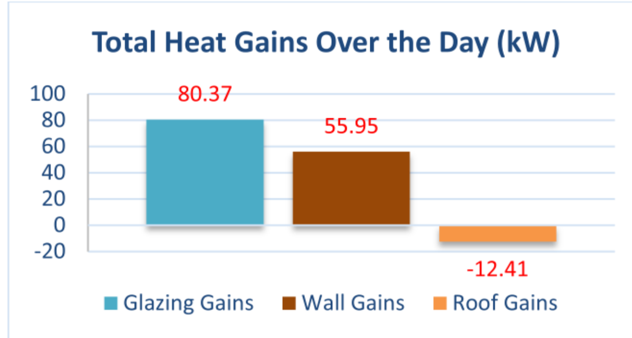


Chart 13. Total heat gains over the day in “Aerogel Case”.

c) Heat Gains Hourly Rate Over the Day from Outside

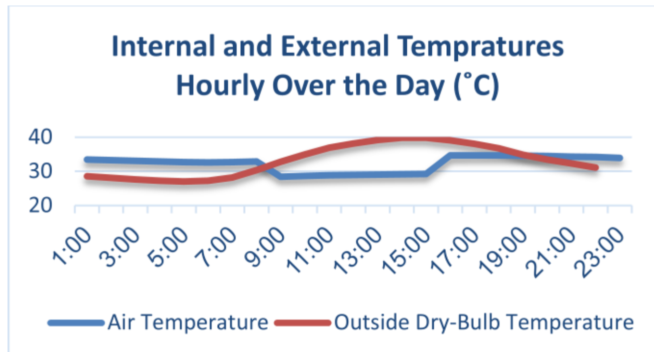


Chart 14. Int. and ext. temperature hourly over the day in “Aerogel Case”.

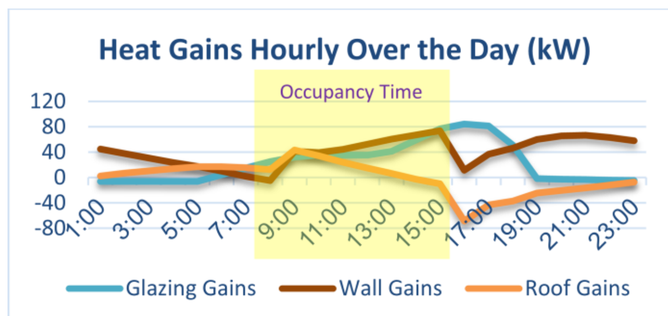
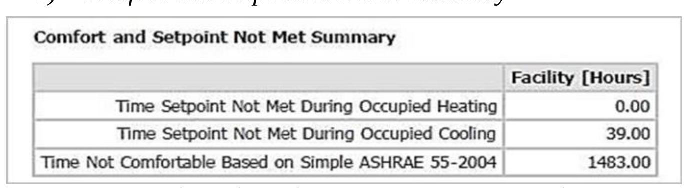


Chart 15. Heat gains hourly over the day in “Aerogel Case”.

d) Comfort and Setpoint Not Met Summary



Comfort and Setpoint Not Met Summary

	Facility [Hours]
Time Setpoint Not Met During Occupied Heating	0.00
Time Setpoint Not Met During Occupied Cooling	39.00
Time Not Comfortable Based on Simple ASHRAE 55-2004	1483.00

Fig. 36. Comfort and Setpoint Not Met Summary “Aerogel Case”.

G. VIP + Aerogel Case

1) Output Data

a) Cooling Power Consumption Rates for Interior Spaces

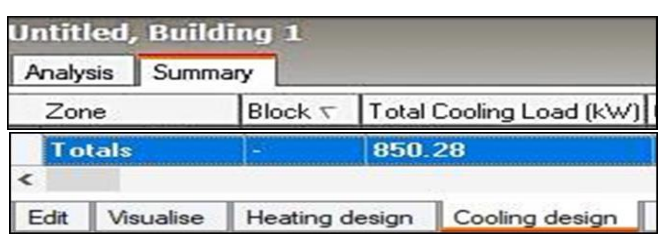


Fig. 37. Program screenshot of total cooling load in”VIP+Aerogel”on 15 July.

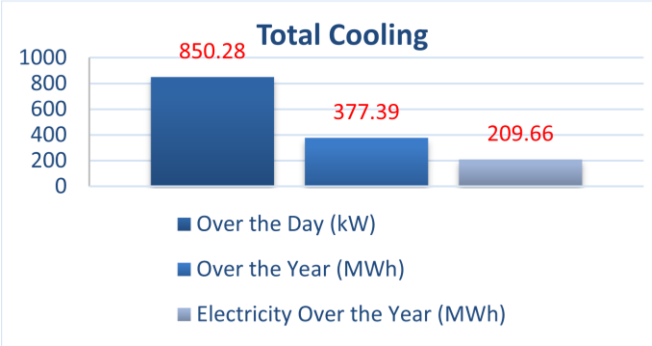


Chart 16. Total cooling loads in "VIP+Aerogel".

Total Cooling Load Over the Day = 850.28 kW.
Total Cooling Load Over the Year = 377392.1375 kWh.
Total Cooling (Electricity) Over the Year = 209662.241 kWh.

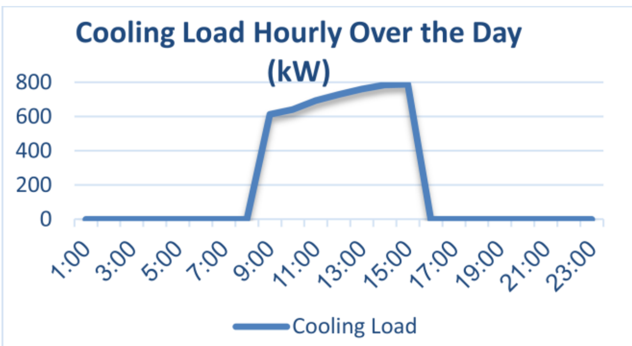


Chart 17. Cooling load hourly over the day in "VIP+Aerogel".

b)Heat Gains Over the Day from Outside

Glazing Gains (kW)	Wall Gains (kW)	Roof and Ceiling Gains (kW)	Solar Gains (kW)
29.35	-12.57	-22.50	51.88

Fig. 38. Program screenshot of heat gains in "VIP+Aerogel" on 15 July.

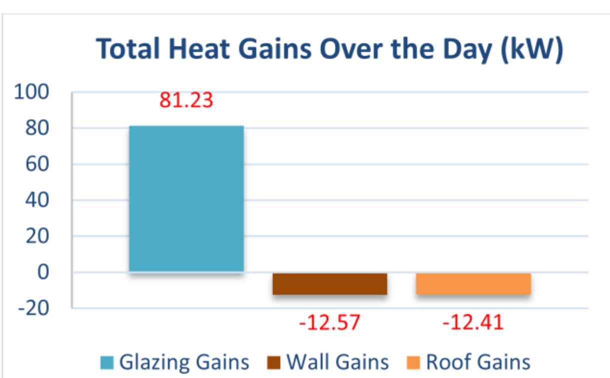


Chart 18. Total heat gains over the day in "VIP+Aerogel".

c) Heat Gains Hourly Rate Over the Day from Outside

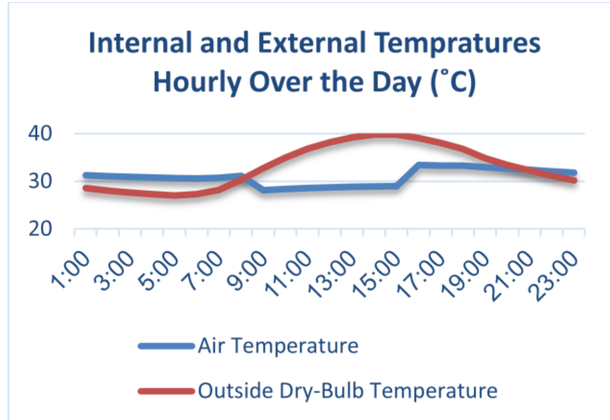


Chart 19. Int. and ext. temperature hourly over the day in "VIP+Aerogel".

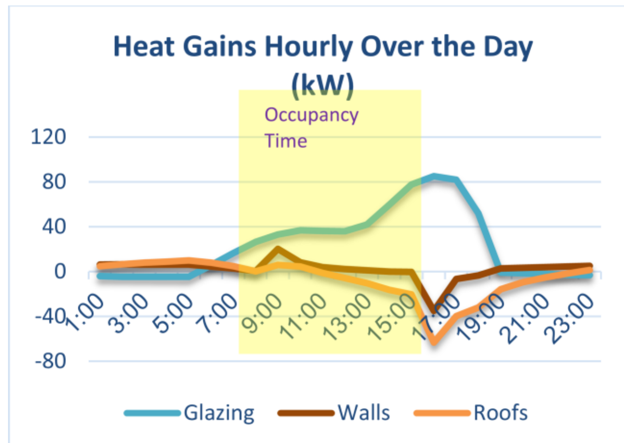


Chart 20. Heat gains hourly over the day in "VIP+Aerogel".

d) Comfort and Setpoint Not Met Summary

Comfort and Setpoint Not Met Summary

	Facility [Hours]
Time Setpoint Not Met During Occupied Heating	0.00
Time Setpoint Not Met During Occupied Cooling	127.00
Time Not Comfortable Based on Simple ASHRAE 55-2004	1417.00

Fig. 39. Comfort and Setpoint Not Met Summary "VIP+Aerogel".

VIII. RESULTS

By Comparing "Base Case" with other cases, the following is concluded:

1. Cooling Power Consumption Rates for Interior Spaces

Charts 21, 22, 23 show the total cooling loads and electricity for all cases.

- Nano Vacuum Insulation Panels (VIP) Case:
  Total cooling loads over the day decreased by 13%.
  Total cooling loads over the year decreased by 10.5%.
  Total cooling (Electricity) over the year decreased by 10.5%.

- Aerogel Case:
  Total cooling loads over the day decreased by 3.8%.
  Total cooling loads over the year decreased by 23.8%.
  Total cooling (Electricity) over the year decreased by 23.8%.

- VIP+Aerogel Case:
  Total cooling loads over the day decreased by 18.4%.
  Total cooling loads over the year decreased by 29.5%.
  Total cooling (Electricity) over the year decreased by 29.5%.

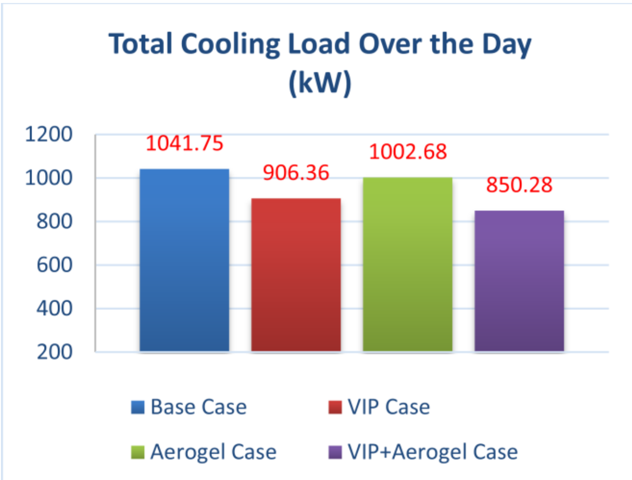


Chart 21. Total cooling load over the day.

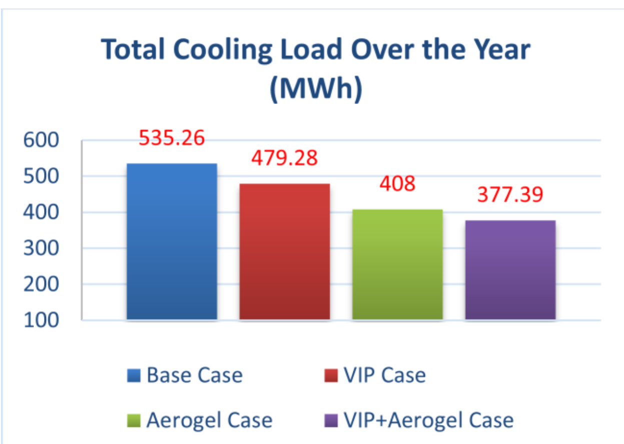


Chart 22. Total cooling load over the year.

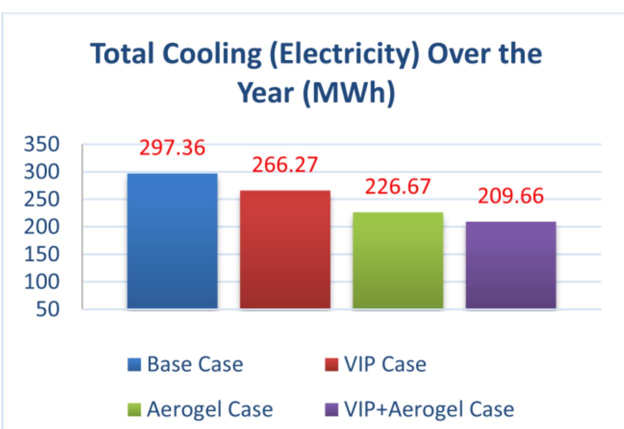


Chart 23. Total cooling (Electricity) over the year.

2. Heat Gains Over the Day from Outside

Chart 24 shows the total heat gains from the outer shell of the building over the day (glazing, walls and roofs).

- In "VIP Case", the heat gain decreased by 35.4% from "Base Case".
- In "Aerogel Case", the heat gain decreased by 30.7% from "Base Case".
- In "VIP+Aerogel Case", the heat gain decreased by 74.2% from "Base Case".

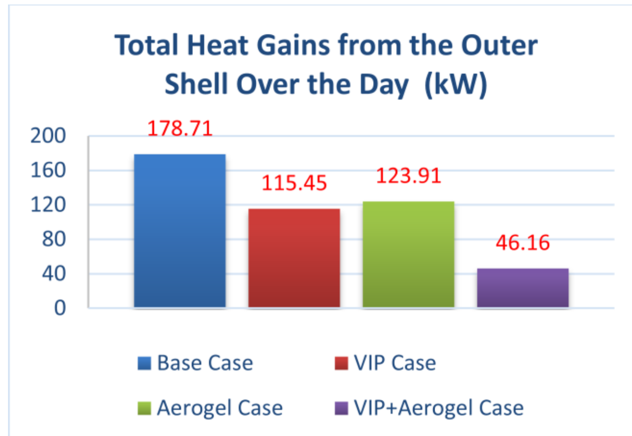


Chart 24. Total heat gains from the outer shell over the day.

3. Comfort and Setpoint Not Met Summary

- In "VIP Case", the time setpoint not met during occupied cooling decreased by 2.4% from "Base Case".
- In "Aerogel Case", the time setpoint not met during occupied cooling decreased by 5% from "Base Case".
- In "VIP+Aerogel Case", the time setpoint not met during occupied cooling decreased by 9.2% from "Base Case".

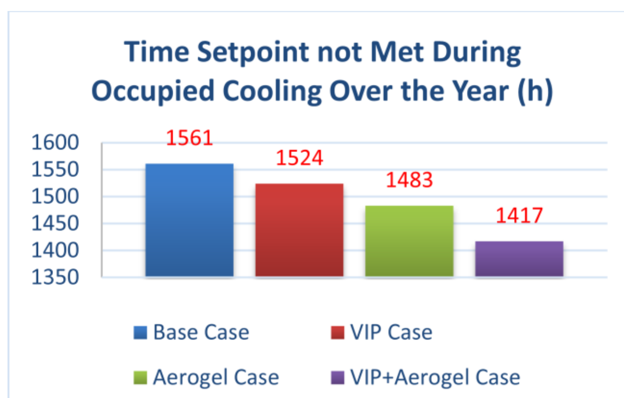


Chart 25. Time setpoint not met during occupied cooling over the year.

From the previous results, it is observed that the "VIP+Aerogel case" is the most optimized as the cooling power consumption decreased by 29.5%, the heat gain decreased by 74.2% and the time setpoint not met during occupied cooling decreased by 9.2% from the "Base Case". Table 8.

TABLE 8
COMPARISON BETWEEN DECLINE RATES IN THREE CASES.

	Cooling Power Consumption Rates for Interior Spaces			**Heat Gains Over the Day from Outside**	**Comfort and Setpoint Not Met Summary**
	Total cooling loads over the day	**Total cooling loads over the year**	**Total cooling (Electricity) over the year**		
VIP	13 %	10.5 %	10.5 %	35.4 %	2.4 %
Aerogel	3.8 %	23.8 %	23.8 %	30.7 %	5 %
VIP+Aerogel	**18.4 %**	**29.5 %**	**29.5 %**	**74.2 %**	**9.2 %**

IX. CONCLUSION AND RECOMMENDATIONS

Nanotechnology has enormous potential to advance human life, and the use of nanomaterials in construction has helped increase the performance and high rating of buildings to achieve sustainability compatible with the environment and with advanced classifications in global building evaluation systems.
This research recommends the following:

- Use "Design Builder" or any similar software as a building simulation tool to ensure the best design while applying sustainability principles to increase user comfort inside the Space.
- Use Aerogel as a nanomaterial insulation system for windows and curtain walls to reduce heat gain from the outside and thus increase the efficiency of the cooling system.
- Use vacuum insulation panels (VIPs) in the building envelope to reduce the temperature rise in conjunction with high energy consumption in the building cooling process.
- Using more than one insulation system at the same time to completely isolate the building envelope, which leads to rationalizing energy consumption and reducing its cost, thus reducing the energy crisis in general.

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Title Arabic:

تقنيات النانو المتآلفة بيئياً في العمارة من أجل تطبيقات الجيل التالي من البناء المستدام

Arabic Abstract:

يسلط البحث الضوء على التطور الملحوظ في الفترة الأخيرة من تقدم في مجال التكنولوجيا بصوره متسارعة مما يستلزم مواكبه هذا التسارع في العلوم التكنولوجية

ومن أهم هذه التطورات الحديثة هو التطور في علوم تكنولوجيا النانو التي أصبحت من أهم العلوم الحديثة التي ترتبط بحياة الإنسان والأنشطة والمجالات المتعددة في الحياة. وقد أصبح العديد من المنتجات المطروحة بالأسواق تعتمد في صناعتها على تكنولوجيا النانو حيث أن التحكم في المواد في مقياس النانو الصغير جدا في الحجم هو بمثابة ثورة في التكنولوجيا المعاصرة في جميع مجالات الحياة و لا سيما في تصميم المواد، طرق البناء، و التطبيقات المعمارية. و قد تطرق البحث للتعرف على تقنيات النانو و تطبيقاتها من خلال استخدام مواد نانونية و تطبيقها في مجالات البناء مما أدى الى ارتفاع تقييم المباني كمباني مستدامة متوافقة مع البيئة.

تم اختيار مبنى البرامج المتنوعة الملحق بكلية الهندسة بجامعة المنصورة ليكون بمثابة دراسة حالة و تم تطبيق مواد عزل نانونية تساعد على تحسين أداء المبنى و تقليل الطاقة المستهلكة خاصة في عمليات التبريد.