Ameliorating of Residential Building Energy Performance by using Nanotechnology

Al-Rass Housing - a Case study

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***Abstract*— Recent years have witnessed progress in equipping residential buildings using different methods, building materials and types, some of them compatible with the surrounding environment, and many of them are not suitable, which leads to high rates of energy consumption within them. This confirms the necessity to search for new ways to rationalize energy consumption, especially in residential buildings.**

With the rapid technological development, there are now many advanced architectural treatments that increase the interior quality of life, and greatly contribute to rationalizing energy consumption.

Therefore, this study came to contribute to raising the internal environmental efficiency of Saudi housing, which lacks many modern applications that can be used, due to its suitability to the difficult nature of Saudi housing.

Nanotechnology was used in the finishing of residential buildings in the study area, due to its various properties that enable it to resist difficult environmental factors, and an advanced program was used to measure the environmental efficiency of buildings before and after the use of the most effective architectural elements and finishes. Then come up with a set of findings and recommendations that must be considered in the future.

Keywords—Residential buildings; Nano technology; Energy consumptio;, Thermal comfort.

I. INTRODUCTION

In recent years, many unexpected climate changes have occurred in the world in general, and in the cities of Saudi Arabia in particular, and this has led to an increase in energy consumption rates, especially in residential buildings, which were not sufficiently equipped to face these changes. As the per capita consumption of electricity increased from (7019 kw/h) in 2007 to (9137 kw/h) in 2014 [1].

In order to rationalize energy consumption, the Kingdom established the Saudi Energy Efficiency Center, which has undertaken many initiatives in this field, perhaps with the aim of creating and raising the level of community awareness of the importance of rationalizing energy consumption through a set of correct environmental behaviors that in the future lead to reducing consumption [2].

That is why the Kingdom's Vision 2030 came to work to improve the quality of life for its residents and to develop plans and strategies that achieve this goal. Where the advanced infrastructure has been established, in addition to developing future plans to complete the requirements and needs that create an integrated environment for its citizens that includes basic services of high quality, we raise the level of quality of life for everyone [3].

II. PREVIOUS STUDIES

A group of previous studies conducted in 2014 with the aim of knowing the percentage of experience of workers in the construction sector and related to knowledge of new design solutions related to energy efficiency and rationalization within residential buildings, where the results indicated that only 31% of the respondents in the questionnaire have only knowledge without practice, While only 12% have the experience and practice, the study also indicated that real estate developers, contractors, and investors are among the least familiar with these solutions [4].

A second study in which researchers used simulation software (DOE) on an apartment building in Dammam, and it resulted in the possibility of reducing energy consumption in buildings if the design and operation were done using passive design strategies. The study confirmed that the building's external envelope, including building materials, the size of the windows, or the type of glass used, in addition to the behaviors used in the operation of the building have a pivotal and important role to reduce energy consumption, which amounts to 38% of the total energy consumed annually [5].

III. METHODOLOGY

Based on the results of the second research study, the research will follow the same analytical approach, by studying an existing residential building affiliated with a new residential neighborhood in a city in the Kingdom of Saudi Arabia, and using one of the advanced measurement programs (Hourly Analysis Program - HAP) to know the thermal behavior of the building in the current situation, And then changing the materials of its outer surface (external walls, outer ceiling, glass), with alternative materials of nanotechnology, then measuring again and knowing the new thermal behavior of the building, then measuring the amount of thermal decline of the building, and comparing the results.

IV. ENERGY CONSUPTION IN THE KINGDOM'S RESIDENTIAL BUILDINGS

In 1995, (43,733) building permits were issued, and this number increased greatly to reach in 2005 to (113,519) permits, and this is based on the report submitted by the Ministry of Municipal and Rural Affairs for building permits in the construction sector in the Kingdom [6]. On the other hand, a scientific study confirmed that the Kingdom needs to build more than 2.32 million residential buildings until 2020 [7].

Most of the buildings that were built have met the residents' living requirements, without considering the environmental standards, which resulted in buildings with low thermal performance, and therefore energy-consuming mechanical solutions were relied upon to provide an appropriate environment and thermal comfort inside the buildings.

On the other hand, we find that the housing sector in the Kingdom consumes 44.9% of the total energy sales of the Saudi Electricity Company, while the government sector consumes 15.1%, the commercial sector 16.1%, and the industrial sector 17.6%, according to the statistical report. The annual statistical manual of the Saudi Electricity Regulatory Authority, which was issued in 2018 [8].

Moreover, these residential buildings contributed to increasing the emission rates of carbon dioxide, because the air-conditioning units used in them with a capacity (2 tons), resulting in emissions of carbon dioxide gas at a volume of (2 kg/hr.) [9].

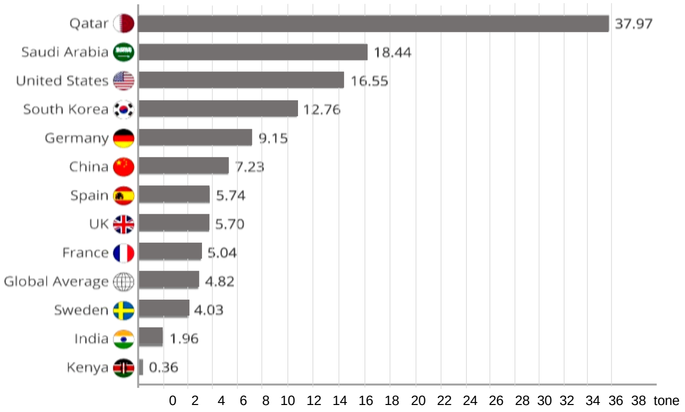

Fig. 1. Carbon dioxide emissions in the KingdomArabia (K.S.A) compared to some countries (in tons) in 2018.

V. NANOMATRIALS

Nanotechnology was able to open new horizons to the world in the field of building and construction, by providing many building materials with improved qualities and functions, which contributed to rationalizing energy consumption, and this technology now seeks to reach low-cost building materials that increase the life span of the building, and reduce of his need for maintenance work.

A. Nzno-isolation

Today, nanoscale insulation materials are used to raise the energy efficiency of buildings and reduce the rate of pollutant emissions, as the efficiency of these materials is 30% higher han traditional insulation materials. These materials can be used in a variety of forms, including solid panels, thin films, and insulating coatings [10]. The research will address thermal insulation only as it is considered the most appropriate for the project under study.

B. Thermal nano isolation

The Saudi Ministry of Electricity issued a statement last year, in which it stated that the consumption of air-conditioners alone in the summer reaches 70% of the total electrical energy consumption at the level of the Kingdom (Electricity Company, 2019). Here comes the role of thermal insulation materials as one of the most important materials that must be used to rationalize energy consumption. There are several types of Nano composition, the most important of which are:

C. Vacuum Insulation Panels - VIPs

These panels are characterized by large thermal insulation, with a thin thickness of (8-35 mm), and the coefficient of thermal conductivity of them) reaches (0,0035 W /m^2 K) at (25 degrees) . It is less than (5-10) times of materials Traditional insulation, and its life span ranges from (30-50) years, and it also does not require regular maintenance [11].

D. Aerogel

It is a low-density gel in which the liquid is replaced by gas. It consists of 5% solids and the rest gaseous substances. It is characterized by low weight (60-80 kg/m^3), high thermal insulation capacity (0,28 W/m^{2}K), with transmittance to natural lighting (up to 75%). It can carry even (2000 times) heavier than its weight [12].

E. Thin - Film Insulation

It is used for thermal insulation of window glass, and it consists of a thin layer of Nano steel fibers resistant to rust, which reduces the rate of passage of sunlight, as it blocks (97% of infrared radiation), (99% of The permissible temperature of the inner space is (2-3 °C) compared to traditional insulation material [13].

VI. AL-RASS HOUSING PROJECT - CASE STUDY

The Al-Rass housing project is located in Al-Rass governorate of the Al-Qassim region from the ɛastern side, and is about 85 km from the city center of Buraidah. It is one of the housing projects of the Ministry of Housing, which was completed in July 2020, and the project contains 94 identical housing units on an area of 245,000 square meters. It is now available for sale [14].

Fig. 2. Al- Rass housing project location in Al-Rass governorate of Al-Qassim rigion.

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Fig. 3. Up (The Project layout), Bottom (Housing facades).

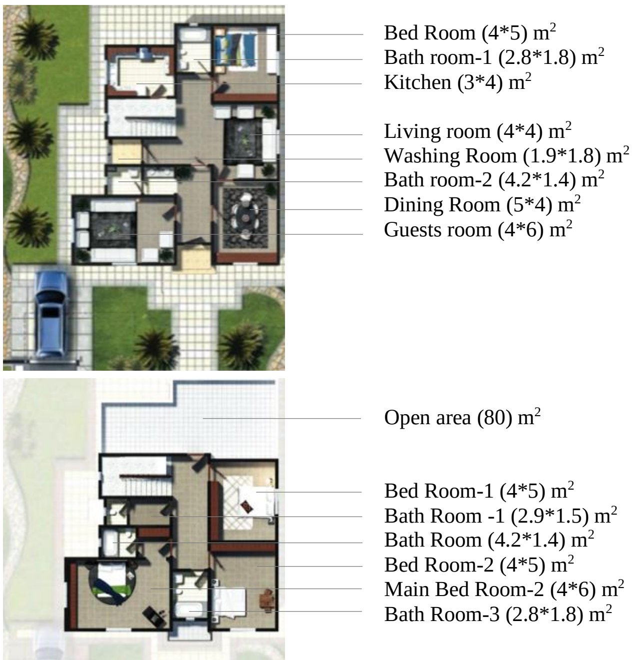

Fig. 4. Top: (The project ground floor plan spaces), bottom (first floor plan spaces).

A. Reasons for choosing the project

- Knowing the specifications and standards of Saudi construction, and the extent of its compliance with the Saudi Building Code.
- The site of the project, which prevails in hot summer weather (Al-Rass Governorate - Al-Qassim region).
- One of the development projects of the Housing Ministry.
- Housing projects needs for more energy conservation.
- The large number of housing projects in the Kingdom, similar to this one.

B. Climate for the case study

The climate of Al-Rass governorate in Al-Qassim (very hot desert, especially in summer - and very cold in winter), so the general climate is described as arid, and it is characterized by irregular rains throughout the year, especially in the summer, and the Qassim region is generally known by the frequent seasonal dust storms [15].

C. Climatic data for the study site

The Climate Consultant program was used to know the temperatures, wind speed and humidity, and the thermal comfort scheme inside the spaces for different periods of time, and to study the best methods and strategies proposed by the program to achieve thermal comfort standards for the buildings of the area under study.

WEATHER DATA SUMMARY

LOCATION: Qassim Abdulaziz Intl AP, QS, SAU
Latitude/Longitude: 26.3° North, 43.767° East, Time Zone from Greenwich 3
Data Source: ISD-TMYx 404050 WMO Station Number, Elevation 648 m

MONTHLY MEANS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
Global Horiz Radiation (Avg Hourly)	397	456	510	510	562	591	589	577	562	499	384	365	Wh/sq.m
Direct Normal Radiation (Avg Hourly)	528	526	507	445	504	550	550	550	585	568	442	484	Wh/sq.m
Diffuse Radiation (Avg Hourly)	120	143	170	184	173	162	160	159	143	135	137	117	Wh/sq.m
Global Horiz Radiation (Max Hourly)	758	867	1003	1025	1036	1039	1034	1028	993	908	788	682	Wh/sq.m
Direct Normal Radiation (Max Hourly)	870	873	877	862	860	847	849	857	867	865	867	868	Wh/sq.m
Diffuse Radiation (Max Hourly)	336	397	461	488	454	271	266	502	251	361	368	323	Wh/sq.m
Global Horiz Radiation (Avg Daily Total)	4194	5047	6048	6457	7488	8059	7937	7449	6839	5674	4120	3789	Wh/sq.m
Direct Normal Radiation (Avg Daily Total)	5577	5818	6008	5637	6724	7503	7414	7102	7106	6454	4750	5024	Wh/sq.m
Diffuse Radiation (Avg Daily Total)	1273	1588	2028	2326	2301	2217	2166	2052	1749	1537	1467	1223	Wh/sq.m
Global Horiz Illumination (Avg Hourly)	46866	53925	60565	60746	67429	71374	71163	69631	67879	59664	45133	42854	lux
Direct Normal Illumination (Avg Hourly)	32164	34163	35810	28261	33193	37407	36932	36037	37833	37143	26525	29043	lux
Dry Bulb Temperature (Avg Monthly)	14	17	20	26	32	35	36	36	34	27	21	14	degrees C
Dew Point Temperature (Avg Monthly)	3	4	-1	13	11	7	9	10	8	5	10	5	degrees C
Relative Humidity (Avg Monthly)	51	44	25	47	33	19	20	21	21	27	56	56	percent
Wind Direction (Monthly Mode)	10	30	20	30	30	0	330	30	30	30	40	30	degrees
Wind Speed (Avg Monthly)	3	3	3	3	3	3	3	2	2	2	2	2	m/s
Ground Temperature (Avg Monthly of 3 Depths)	20	18	19	20	25	29	32	33	32	30	26	22	degrees C

Fig. 5. The minimum and maximum temperature for the study area

We note that, the average temperature rises for the months of July and August (39 °C), which is high compared to December and January (14 °C). As for humidity, its highest rates are in November and December (56%), and the lowest in the month July (19%) only, which is an indication of severe drought, with which it is necessary to find suitable solutions to increase the humidity rate for this period, and the wind speeds in the region in general are close, reaching a maximum (3 m/sec). second and a minimum of (2 m/sec).

D. Climatic data for the study site

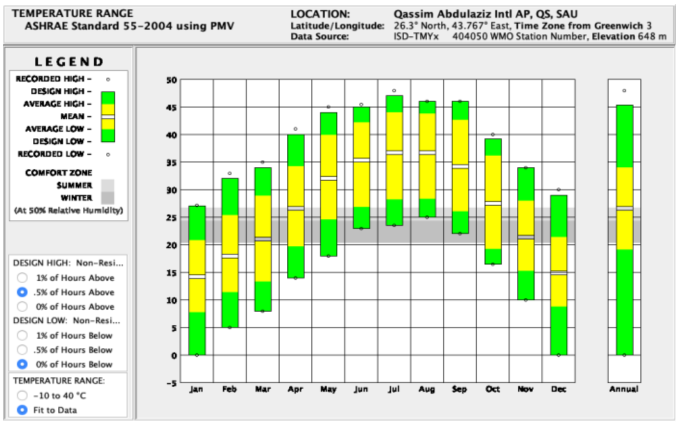

Fig. 6. The difference between the maximum and minimum temperatures for the study area

The graph shows that the highest temperature for the observation point is in July, reaching more than (45 °C), and the lowest temperature in the months of January and December (0 °C). This large discrepancy between daily degrees requires the choice of design strategies such as high thermal insulation Efficiency for walls and ceilings, and it is noted that the thermal comfort zone is located between (20 - 27°C) throughout the year.

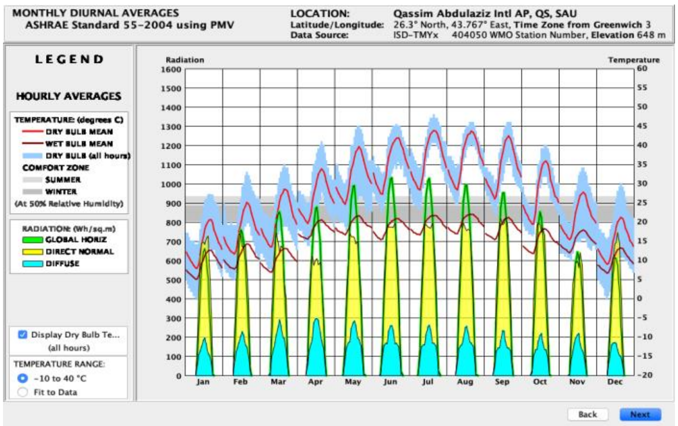

Fig. 7. The intensity of solar radiation for the study area.

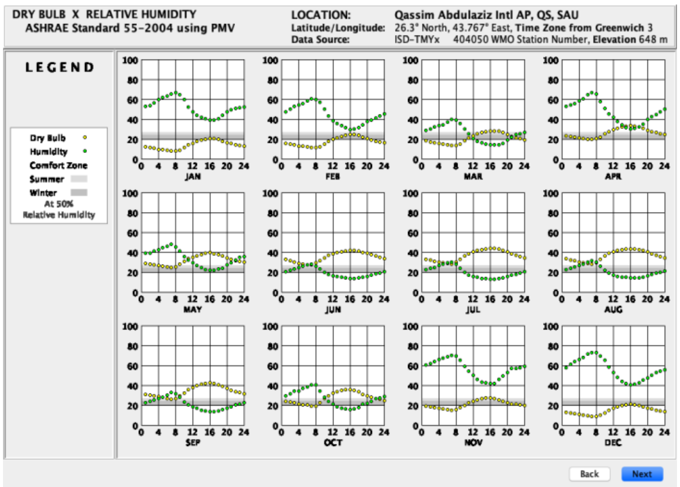

Fig. 8. Humidity levels for the study area.

VII. SIMULATION SOFTWARE USED TO CALCULATE THERMAL LOADS

To calculate the thermal loads of the housing unit under study, the Hourly Analysis Program, which is known as (HAP) of the International Carrier Company, will be used. The building material used for the building exterior.

Fig. 9. Hourly Analysis Program (HAP) of the North American Commercial Corporation of Carrier

VIII. AMELOPATING THE BUILDING ENERGY PERFORMANCE

It is need to be assessed the following characteristics:

A. *Heat transfer coefficient - U (W/m^2k)*

Heat transfer coefficient (Thermal transmittance), is the sum of the resistors (Rc) for each building material and the external surface resistors (Rso) and the envelope inner faces.

B. *The R-value (m^2k /W):*

This is the material thermal resistance, and calculated from relation: $R= t/\lambda$ (m^2k/W), (t) material thickness in meter, (λ) the thermal conductivity of material.

IX. CURRENT STATUS OF HOUSING UNIT

Heat transfer coefficient will be calculated for each component separately by detailing the building materials used for the residential unit in its current state, and then improving some properties of the building materials used using nanotechnology, and then calculating the thermal transmittance again as follows:

A. *External Walls*

The External walls of the residential units consists of several layers and their arrangement from inside to outside as following:

- Plaster layer with thickness 1.5cm.
- Cement layer with thickness 2cm.
- Concrete block with thickness 20cm.
- Cement layer with thickness 2cm.
- Plaster layer with thickness 1.5cm.

Wall Assembly Name: Wall OUTSIDE NOW
Outside Surface Color: Medium — Absorptivity: 0.675

Layers: Inside to Outside	Thickness mm	Density kg/m³	Specific Ht. kJ/kg/K	R-Value m²-K/W	Weight kg/m²
Inside surface resistance	0.000	0.0	0.00	0.12300	0.0
plaster in	15.000	720.8	0.19	0.07900	10.8
cement	20.000	1570.0	0.10	0.20000	31.4
concrete block	200.000	608.7	0.50	0.40000	121.7
cement	20.000	1570.0	0.10	0.20000	31.4
plaster out	15.000	720.8	0.19	0.07900	10.8
Outside surface resistance	0.000	0.0	0.00	0.04000	0.0
Totals	270.000			1.12	206.2
			Overall U-Value:	0.892 W/m²/K	

Fig. 10. Heat transfer coefficient of external walls layers in the current situation

By entering this data into the program, it will calculate the Heat transfer coefficient of each layer separately, and the final average of the surface layers, Wich equal (0.892 W/m^2k).

B. *External Ceiling (The Roof)*

The ceiling of the residential units consists of several layers and their arrangement from bottom to up as following:

- Gypsum layer with thickness 2cm.
- Reinforced concrete layer with thickness 15cm.
- Heat insulating layer with thickness 5cm.
- Sand layer with thickness 6cm.

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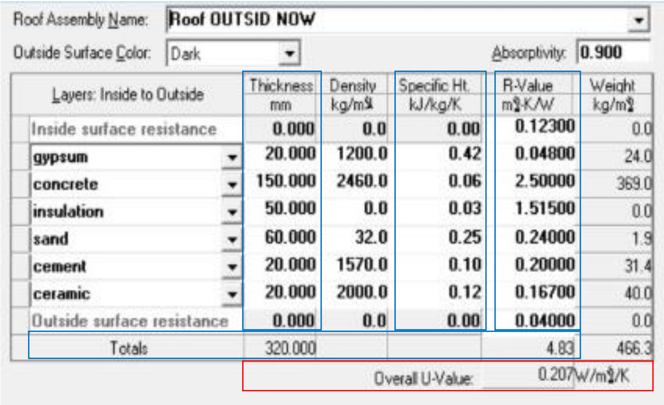
- Regular concrete layer with thickness 20cm.

Ceramic tiles layer with thickness 2cm.



Roof Assembly Name: Roof OUTSID NOW
Outside Surface Color: Dark — Absorptivity: 0.900

Layers: Inside to Outside	Thickness mm	Density kg/m³	Specific Ht. kJ/kg/K	R-Value m²-K/W	Weight kg/m²
Inside surface resistance	0.000	0.0	0.00	0.12300	0.0
gypsum	20.000	1200.0	0.42	0.04800	24.0
concrete	150.000	2460.0	0.06	2.50000	369.0
insulation	50.000	0.0	0.03	1.51500	0.0
sand	60.000	32.0	0.25	0.24000	1.9
cement	20.000	1570.0	0.10	0.20000	31.4
ceramic	20.000	2000.0	0.12	0.16700	40.0
Outside surface resistance	0.000	0.0	0.00	0.04000	0.0
Totals	320.000			4.83	466.3

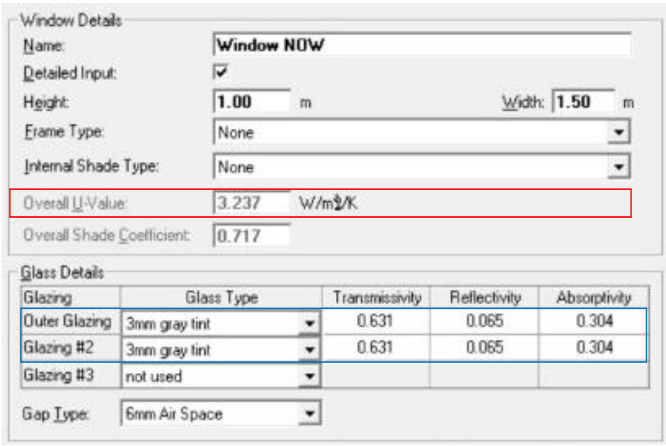
Overall U-Value: 0.207 W/m²/K

Fig. 11. The heat transfer coefficient of the ceiling layers in the current situation

The program calculated the heat transfer coefficient of each layer separately, and the final average of the surface layers, Wich equal (0.207 W/m^{2}k).

C. External Windows

In the current situation of the residential unit, double-glazed windows (3 mm) and an air layer between them (6 mm) were used, and the overal shade coefficient (0.717). the value of the thermal transfer coefficient for it was (3,237 W/m^{2}K).



Window Details
Name: Window NOW
Detailed Input: ☑
Height: 1.00 m — Width: 1.50 m
Frame Type: None
Internal Shade Type: None
Overall U-Value: 3.237 W/m²/K
Overall Shade Coefficient: 0.717

Glass Details

Glazing	Glass Type	Transmissivity	Reflectivity	Absorptivity
Outer Glazing	3mm gray tint	0.631	0.065	0.304
Glazing #2	3mm gray tint	0.631	0.065	0.304
Glazing #3	not used			

Gap Type: 6mm Air Space

Fig. 12. Heat transfer coefficient of the external windows in the current situation

X. THE PROPOSED STATUS OF HOUSING UNIT

In the proposed status of the building, the insulation material used in the outer shell was changed, and the glass used in the windows was changed to materials developed using nanotechnology techniques, namely:

- Vacuum insulation Panels (VIPs) is used in walls and ceilings.
- Aerogel was used in windows.

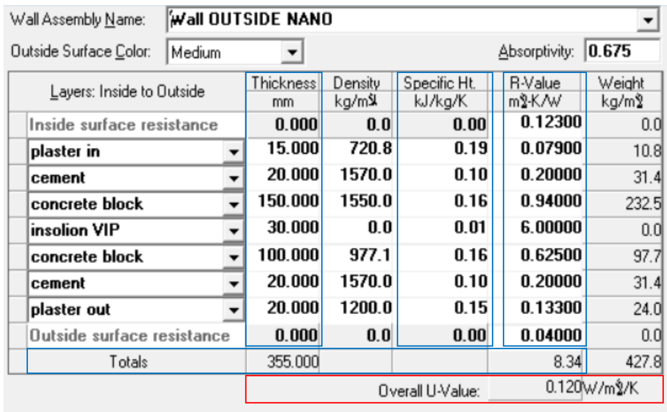
This is because of their advantages in reducing thermal loads and improving the quality of the internal environment of the building.

A. External Walls

In the proposed status for the residential unit, it was proposed to insulate the external walls by addiding vacuum insulation panels or what is known as (Vacuum Insulation Panels - VIPs), which are characterized by a low thermal conductivity of (0.005 W/m^{2}k), [16] as shown in figure (13).

The new external walls layers and their arrangement from inside to outside as following:

- Plaster layer with thickness 1.5cm.
- Cement layer with thickness 2cm.
- Concrete block with thickness 15 cm.
- Vacuum Insulation Panels (VIP) with thickness 3 cm.
- Concrete block with thickness 10 cm.
- Cement layer with thickness 2 cm.
- Plaster layer with thickness 2 cm.
- Absorptivity 0.675, and
- Outside surface color is medium.



Wall Assembly Name: Wall OUTSIDE NANO
Outside Surface Color: Medium — Absorptivity: 0.675

Layers: Inside to Outside	Thickness mm	Density kg/m³	Specific Ht. kJ/kg/K	R-Value m²-K/W	Weight kg/m²
Inside surface resistance	0.000	0.0	0.00	0.12300	0.0
plaster in	15.000	720.8	0.19	0.07900	10.8
cement	20.000	1570.0	0.10	0.20000	31.4
concrete block	150.000	1550.0	0.16	0.94000	232.5
insolion VIP	30.000	0.0	0.01	6.00000	0.0
concrete block	100.000	977.1	0.16	0.62500	97.7
cement	20.000	1570.0	0.10	0.20000	31.4
plaster out	20.000	1200.0	0.15	0.13300	24.0
Outside surface resistance	0.000	0.0	0.00	0.04000	0.0
Totals	355.000			8.34	427.8

Overall U-Value: 0.120 W/m²/K

Fig. 13. Heat transfer coefficient of external walls layers in the proposed status

The total thermal transfer coefficient for the walls in the proposed status is (0.120 W/m^{2}k).

B. External Ceiling (The Roof)

In the proposed status, it was proposed to remove the current insulation of external ceiling and use vacuum insulation panels or what is known as (Vacuum Insulation Panels - VIPs), which are characterized by a low thermal conductivity of (0.005 W/m^{2}k), [16] as shown in figure (14).

The new external ceiling layers and their arrangement from bottom to up as following:

- Gypsum layer with thickness 2cm.
- Reinforced concrete layer with thickness 15cm.
- Vacuum Insulation Panels (VIP) with thickness 3cm.
- Sand layer with thickness 6cm.
- Regular concrete layer with thickness 20cm.
- Ceramic tiles layer with thickness 2cm.

To achieve the best possible results both will be assumed

- Absorptivity 0.900, and
- Outside surface color is dark rather than the medium color.

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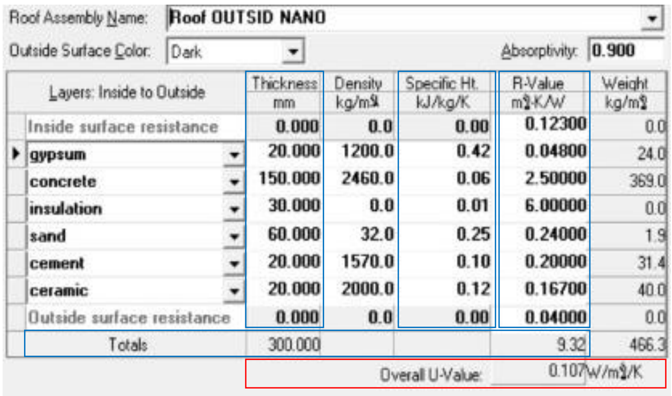

Fig. 14. Heat transfer coefficient of the external windows in the proposed situation

The total thermal transfer coefficient for the external ceiling in the proposed status is (0.107 W/m²k).

C. External Windows

In the proposed status for the residential unit, windows of one of the applications of nanostructures, which are characterized by low thermal permeability, are used, which are called (Aerogel), one of the products of the air gel, and the overal shade coefficient (0.811). the thermal transfer coefficient is (0,600 W/m²k) at a thickness of (30 mm) [17].

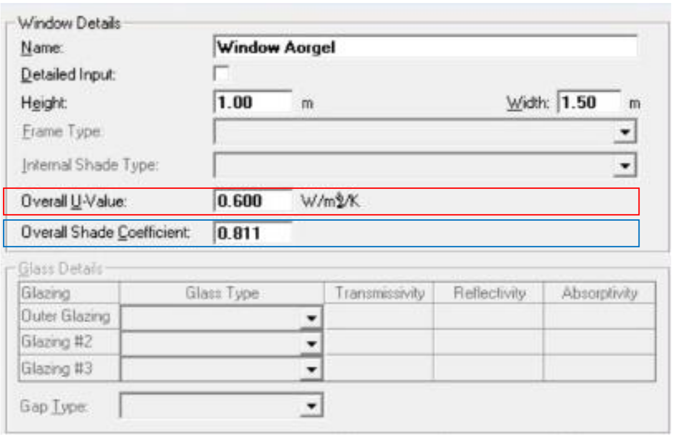

Fig. 15. Heat transfer coefficient of external ceiling layers in the proposed status

XI. THERMAL TRANSFER COEFFICIENT/ THERMAL TRANSMITTANCE (U-VALUE)

A. Buiding Spaces

To calculate Thermal transfer coefficient (U-value) for the building and to know the difference before and after the improvement, the building must be divided into several spaces, and calculating both:

- Spaces area,
- Openings space (windows),
- Exterior wall smear, and
- Roof space, as follows:

Both (Bathrooms - Corridors - Laundry room) will not be calculated (U-value) for it.

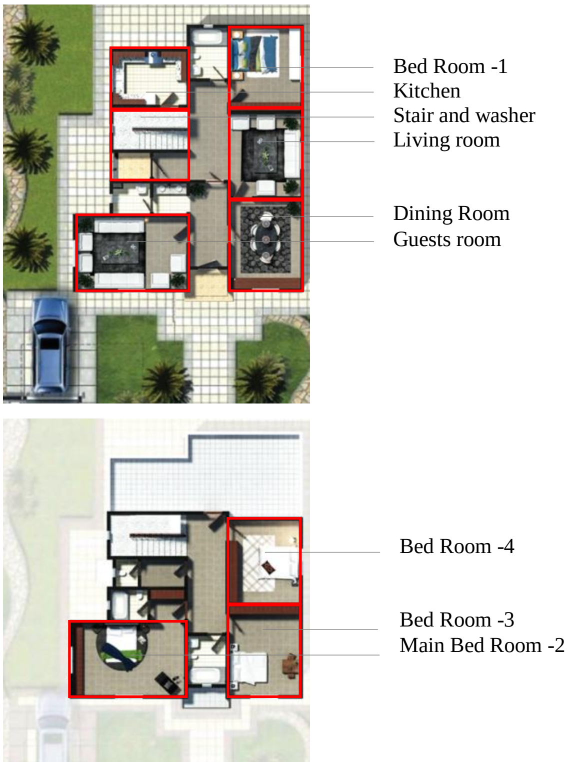

Fig. 16. Up (Ground floor plan zonnings), Bottom (First floor plan zonnings).

TABLE I. DIFFERENT (SPACESM WINDOWS, EXTERNAL WALLS, EXTERNAL CEILLING) SPACES OF THE BUILDING

Elements	Space Area (m^2)	Windows Area (m^2)	External Walls Area (m^2)	External Ceiling Area (m^2)
Guest Room	24	3	42	-
Living Room	16	1.5	12	16
Dinning Room	20	1.5	30	-
Kitchen	12	1.5	21	12
Bed Room -1	20	1.5	27	20
Main Bed Room	24	3	42	24
Bed Room -2	20	1.5	39	20
Bed Room -3	20	1.5	12	16
Stair and washer	24	-	12	24

B. The Monitering Point

After the spaces were divided, their area and window areas were calculated and each space was directed separately, as shown in the following tables, and the locations of the voids were clarified for the unit and its direction.

- Safety factor: 10%
- The monitoring point listed in the (HAP) program is King Abdulaziz Airport in Qassim

2017 ASHRAE Handbook - Foundamentals (SI)						
GASSIM PRINCE ABDULAZIZ, SAUDI ARABIA (WMO: 404050)						
Lat:**26.300N**	Long:**43.767E**	Elev:**648**	StdP: **93.78**	Time zone:**3.00**	Period:**90-14**	WBAN:**99999**

Annual Heating and Humidification Design Conditions

Coldest Month	Heating DB		Humidification DP/MCDB and HR						Coldest month WS/MCDB				MCWS/PCWD to 99.6% DB	
			99.6%			99%			0.4%		1%			
	99.6%	99%	DP	HR	MCDB	DP	HR	MCDB	WS	MCDB	WS	MCDB	MCWS	PCWD
1	**3.2**	**5.2**	**-12.8**	**1.3**	**26.8**	**-10.8**	**1.6**	**26.0**	**9.6**	**15.6**	**8.4**	**16.3**	**1.0**	**30**

Annual Cooling, Dehumidification, and Enthalpy Design Conditions

Hottest Month	Hottest Month DB Range	Cooling DB/MCWB						Evaporation WB/MCDB						MCWS/PCWD to 0.4% DB	
		0.4%		1%		2%		0.4%		1%		2%			
		DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	WB	MCDB	MCWS	PCWD
8	**16.2**	**45.0**	**20.7**	**44.1**	**19.9**	**43.1**	**19.4**	**22.4**	**40.5**	**21.7**	**40.2**	**21.1**	**39.6**	**3.6**	**30**

Dehumidification DP/MCDB and HR									Enthalpy/MCDB						Extreme Max WB
0.4%			1%			2%			0.4%		1%		2%		
DP	HR	MCDB	DP	HR	MCDB	DP	HR	MCDB	Enth	MCDB	Enth	MCDB	Enth	MCDB	
18.8	**14.8**	**24.2**	**17.1**	**13.2**	**23.5**	**15.9**	**12.2**	**23.0**	**69.0**	**41.9**	**66.3**	**40.2**	**64.0**	**39.6**	**33.0**

Fig. 17. Details of the monitoring point for King Abdulaziz Airport in Al-Qassim region included in the (HAP) program.

C. *Thermal transfer coefficient in current status*

The thermal transfer coefficients of the building are calculated for each space, and the envelope materials used in the outer envelope of walls, ceilings and windows are calculated in their current state - which was previously detailed.

TABLE II. THERMAL TRANSFER COEFFICIENT (U-VALUE) FOR ALL BUILDING ZONES IN CURRENT STATUS.

Zone name	Space Area (m^2)	Windows Area (m^2)	General Space lighting (W)	Time to calculate	**U-value (W/m²k)**
Guest Room	24	3	600	15:00 July	4
Living Room	16	1.5	400	15:00 July	2.5
Dinning Room	20	1.5	500	15:00 July	2.7
Kitchen	12	1.5	400	15:00 July	2.0
Bed Room -1	20	1.5	600	15:00 July	2.3
Main Bed Room	24	3	600	15:00 July	2.9
Bed Room -2	20	1.5	500	15:00 July	2.2
Bed Room -3	20	1.5	500	15:00 July	2.0
Stair and washer	24	-	400	15:00 July	2.2
Total	180	13.5	4500	-	**22.8**

D. *Thermal transfer coefficient in propuused status*

The thermal transfer coefficients of the building were calculated for each space, but only at this stage the outer shell material was changed from walls, ceilings and windows to nanotechnology materials, where:

- Vacuum insulation material (VIPs) are used in walls and ceilings.
- Aerogel was used in windows.

TABLE III. THERMAL TRANSFER COEFFICIENT (U-VALUE) FOR ALL BUILDING ZONES IN PROPUUSED STATUS.

Zone name	Space Area (m^2)	Windows Area (m^2)	General Space lighting (W)	Time to calculate	**U-value (W/m²k)**
Guest Room	24	3	600	15:00 July	2.9
Living Room	16	1.5	400	15:00 July	1.9
Dinning Room	20	1.5	500	15:00 July	1.9
Kitchen	12	1.5	400	15:00 July	1.6
Bed Room -1	20	1.5	600	15:00 July	1.6
Main Bed Room	24	3	600	15:00 July	2.0
Bed Room -2	20	1.5	500	15:00 July	1.5
Bed Room -3	20	1.5	500	15:00 July	1.3
Stair and washer	24	-	400	15:00 July	1.2
Total	180	13.5	4500	-	**15.9**

By comparing the housing unit in its current state and after changing the materials used with nanomaterials with the highest energy efficiency, then measuring it using the HAP simulation program, where the measurement was made at the highest time of the year, and by fixing both the study area and the safety factor: 10% found that:

- The thermal transfer coefficients of the housing unit in the current situation: (**22.8** W/m²k)
- The thermal transfer coefficients of the housing unit in the proposed situation: (**15.9** W/m²k)
- The thermal transfer coefficients decrease by: (**6.9** W/m²k)

XII. CONCLUSION

The project under study belongs to the Saudi Ministry of Housing, and it is one of the projects that require high energy efficiency.

This project is very similar to many of the current Saudi housing projects, and therefore the results of this study can be used in developing existing housing projects in general, and specifically planned to be implemented in the future.

Internal residential spaces are directly affected by the external climate, which is transmitted from outside to inside through the outer envelope that includes (walls, ceilings, and openings) external. Each of these three elements has a direct effect on the thermal transfer between the internal and external climate, and therefore the cover of the residential building under study was studied before and after the use of nanomaterials, and the study showed the effectiveness of these new materials in reducing the building's external heat acquisition rates by (6.9 W/m²k). In addition to taking into account both (orientation, shape, and shading) of the building.

From the above, we find that nanotechnology for architecture has succeeded in achieving many solutions to raise the efficiency of the materials used, extend their life span, and thus raise the energy efficiency of the building and increase its resistance to surrounding environmental factors, as well as contribute to preserving the surrounding environment by reducing carbon dioxide emissions, as well as reducing the depletion of non-renewable natural resources.

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