Architectural Solutions Effect on Energy Efficiency at College Buildings

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Abstract: ***Architectural design solutions can be employed to achieve greater energy efficiency at any building. However, currently this possibility is not sufficiently utilized. The paper provides a comparative analysis of architectural solutions in college building, presenting the ones that not only allow for a reduction in energy losses through the external envelope especially the roof of a building considering the local climatic conditions; but also make it possible to increase the energy efficiency. The research problem represents the absence of a clear methodology for assessing the energy performance of college buildings after the Works. The study aims to raise the energy efficiency in Universities and Colleges Buildings via create architectural design solution and building design tools which estimating the design interactions within a building. These interactions include the use of energy (electricity for lighting, heating and cooling), climatic conditions (ventilation, daylight and thermal loads) and heat generated by building's occupants.***

Keywords: College Building Design Tools**,** Architectural Solutions, Energy Efficiency, Design Process, Costs.

1. Introduction

Egyptian Universities and Colleges Buildings represent a high share of energy consumption reaching about 5.4% of the total energy consumption. The high rates of consumption necessitated an urgent action to be taken where studies have been conducted recently to study and investigate the energy efficiency and conservation opportunities within the Egyptian Government Buildings. As a result of this study the cabinet has issued a directive to apply energy efficiency measures in colleges' buildings starting energy audits and by applying efficient applications. Colleges and universities in Egypt spend an average of $1.10 per square foot (ft2) on electricity and 18¢/ft2 on ventilation annually. In a typical college or university classroom building, lighting represents 31 percent and space ventilating accounts for 28 percent of total energy use, making those systems the best targets for energy savings. While most colleges and universities have tight facility budgets, so it's especially important to find low- or no-cost architectural solutions to reduce energy expenditures. One of the most important challenges facing architects today is to design and create a sustainable building design that can not only minimize the impact on the environment, but also remain practical, economical and comfortable for use. Energy efficiency is one of the most essential aspects of the sustainability of college buildings depends on architectural design & thermal comfort requirements to avoid consumption increase and reduce energy waste via create environmental integration systems such as: insulation, ventilation, solar Acquisition, natural lighting, thermal mass, heating and cooling. Implications of building energy standard for sustainable energy efficient design in campuses not only save money, but are also comfortable contribute a more effective learning environment.

2. Literature Survey

Building design tools is the tools of estimating the design interactions within a building. These interactions include the use of energy (electricity for lighting, heating and cooling), climatic conditions (ventilation, daylight and thermal loads) and heat generated by building's occupants. Also BDTs determine the equipment types and sizes needed to meet the previous loads, and the cost to operate these equipment's. The purpose of BDTs is to simulate the different design systems in order to reach the optimal design. Figure1 shows the major elements of building design simulation system; two basic models are used to present the major components that affect the building's design decision: Building model and Control system model. Also an economic model may be added for life cycle analysis. The inputs to the simulation system are the building descriptions and design parameters, and the boundary condition is the climatic factors. The simulation outputs major of interest to designers are the energy performance and indoor environmental conditions.

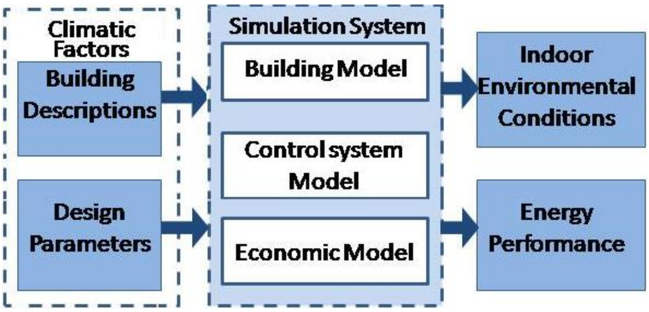


Figure 1: Building Design Simulation system

3. Problem Definition

The problem researched on "Architectural Design Solutions Affecting Energy Efficiency in College Building ". This meant the Quantity and Quality of Energy Saving Efficiency and Environmental Comfort Requirements (according to Egyptian code standards).The Causes of the problem are: the stress of traditional concepts of architectural design that must be in proportion to the climate and the identity, the lack of the environmental design awareness about energy saving strategies, environmental strains and the zone's climatic potentials. It is also for overcoming the high energy consumption in the universities sector by new and renewable energy tools.

4. Methodology / Approach

In early stages of the design process, designer can estimate the energy consumption which achieve the occupants comfort factors of the building using the design simulation programs, which can help the designer to have more reliable prediction because it is able to simulate the building, the weather conditions, the thermal behavior and the operating schedules of the building, and then correct some of the architectural features of the college building, to improve the climatic and energy performance. Achieving better energy efficiency in the building has become more important, as approximately one third of the primary energy supply is consumed in buildings, so buildings are a primary contributor to global warming and ozone depletion. The comfort requirements of the building depend not only on the individual performance of the building envelope components (walls, windows and roofs), HVAC and lighting systems, but also on an overall performance as an integrated system in the whole building. Design tools is performed to analyze the energy performance of a building and to understand the relationships between the design parameters and climatic characteristic of the site, and energy use characteristics of the building. The effects of all kinds of changes can be simulated in a fraction of time and with a fraction of cost it would take to be studied in real life. In practice, simulation tools can be utilized for the following functions: evaluate design options and investigate design optimization, facilitate the investigation of new ideas, check compliance with building energy codes and determine the impact of energy conservation measures. The selection of the simulation program for a given task depends on the project requirements, time and cost. It also depends on type of input and output data, the capability of the program to deal with the required application and how easy it is to deal with the program. it is more compactable to use Ecotect software with plugins Radiance for lighting analysis and CFDesign for ventilation, as a tool to improve that architectural solutions effect on energy efficiency at college buildings. ECOTECT Was selected for the following reasons:complete environmental design tool which gives extensive solar, thermal, lighting and ventilation analysis functions, which matches the project requirements, provides essential feedback analysis which guides the user as more detailed design information becomes available, allows user to "play" with design ideas and different applications, it can import 3DS and DXF files, and it can export to: RADIANCE for lighting analysis, and export to CFDesign for ventilation and airflow analysis.The program gives Informative graphs and table which is easy to understand. And finally, It is easy to deal with the program as it has 3D CAD interface allows validation of the simplest sketch design to highly complex 3D models.

A number of colleges and universities are successfully having architectural solutions using no-cost and low-cost public awareness campaigns to reduce energy use on campus. Therefore Beni Suef University seeks to advance a permanent development in its educational process, promote the quality of performance, Preparing a qualified graduates fully equipped with scientific knowledge and experiences in different fields of specialization. Enabling them to offer, create, and compete in labor market whether locally, regionally or internationally, Providing a new generations of remarkable scientists, intellectuals, and men of letters who can make an effective participation in society by promoting its culture and environment. The university seeks to achieve its mission through understanding of the relationship between architecture design, student health and Performance, and increase energy efficiency of colleges Buildings.

The purpose of the research study is to provide a comparative analysis of architectural solutions on the new heightening floor of the Faculty of Literature (fourth floor). While the success of the functional performance of educational building depends on two main determinants that are the realization of users' objectives and need besides respecting the surrounding natural and built environment. Architectural program works as a design tool for environmental principles solutions and more effectively in simulating the design processes stages through analyzing the building solar performance (Air Temperatures, Heat Gain and Loss, Thermal Resistance), Natural lighting and ventilation and air flow in the building and their energy consumption. And thus can determine the extent of comfort within the building spaces in order to reach the optimal design. The functional performance of the college integrates through four systems: building usage system, prevalent climate system, building effecting & affecting system (thermal-lighting-ventilation…etc.) and air-conditioning mechanical system and modern systems. Fourth floor area around 2000 m^2, college lower floors designed as a traditional concept of architectural solutions depend only on windows. View of the need an upper floor to meet the functional needs of users beside the need to reduce construction loads, Structural engineer recommend to use gypsum board for walls and corrugated sheets for roof. Selected architectural solutions affect on energy efficiency as shown in simulation matrix which including: skylights, false ceiling covering some of the class rooms, adding extra upper windows opening at the corridors, wind catchers, operable sky light windows and adding a long hangover in the inlet window of the wind catcher. Design tools are performed to analyze a set of design and modification matrix as following:

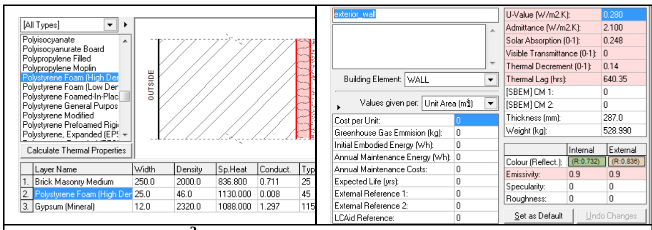
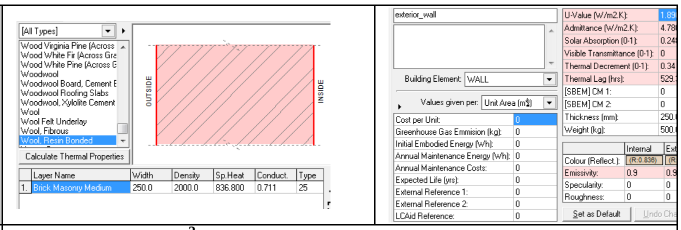
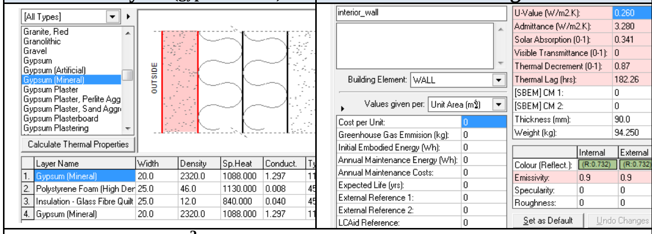
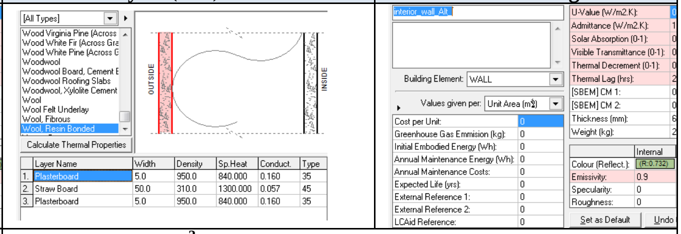
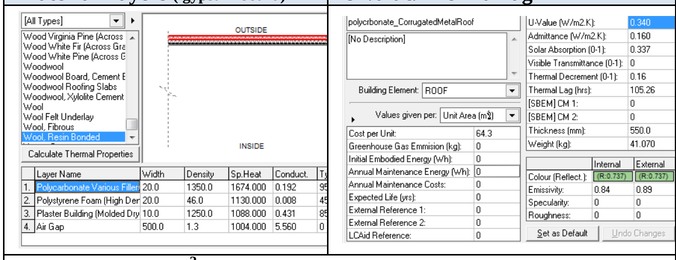
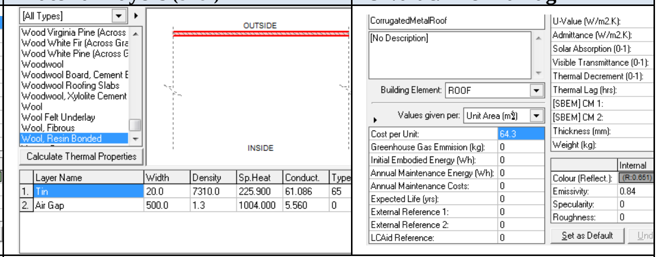
A- Thermal Analysis:

1. The Building Envelope Material Properties as shown in following:

5. Results & Discussion

Table1: **Comparative Analysis between using usual brick and gypsum board for external and internal walls.**

The Designed Case (gypsum board)		**The Alternative Case** (brick)	
External Walls:			
Material Layers	**U-value/Thermal lag**	**Material Layers**	**U-value/Thermal lag**

	
U-value=0.28 W/m^2.K, Thermal lag=640.35 hrs.	U-value=1.89 W/m^2.K, Thermal lag=529.31 hrs.
Internal Walls:	
Material Layers (gypsum board) / **U-value/Thermal lag**	**Material Layers** (brick) / **U-value/Thermal lag**
	
U-value=0.26 W/m^2.K, Thermal lag=182.26 hrs.	U-value=0.89 W/m^2.K, Thermal lag=214.29 hrs.
The Roof:	
Material Layers (gypsum board) / **U-value/Thermal lag**	**Material Layers** (brick) / **U-value/Thermal lag**
	
U-value=0.34 W/m^2.K, Thermal lag=105.26 hrs.	U-value=2.79 W/m^2.K, Thermal lag=15.11 hrs.

For the Designed Case only, Table 2: the used Skylights Windows Properties as shown in:

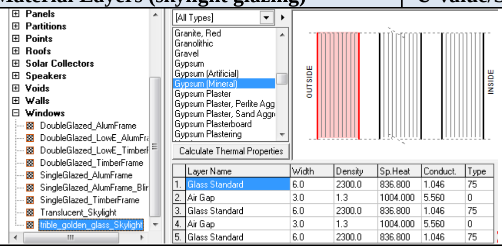
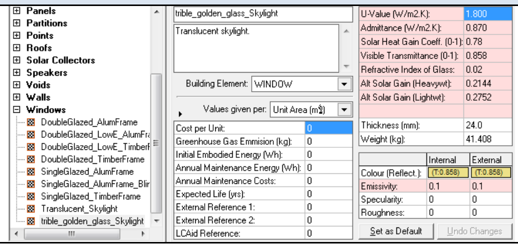
Material Layers (skylight glazing)	U-value/Solar Heat Gain Coeff.
	
U-value=1.8 W/m^2.K, Solar Heat Gain Coeff.= 0.78	

Table 3: Comparing Table between different Materials U-values and the CODE required U-value:

<table>
<tr><th></th><th>The Designed Case U-value</th><th>The Alternative Case U-value</th><th colspan="2">Egyptian CODE U-value</th></tr>
<tr><td rowspan="3">External walls</td><td rowspan="3">0.28</td><td rowspan="3">1.89</td><td>W\E</td><td>0.9</td></tr>
<tr><td>N</td><td>1.4</td></tr>
<tr><td>S</td><td>1.3</td></tr>
<tr><td>Roof</td><td>0.34</td><td>2.79</td><td colspan="2">0.4</td></tr>
<tr><td>Roof Skylights</td><td colspan="2">1.8</td><td colspan="2"></td></tr>
<tr><td>Results</td><td colspan="4">The U-value rates of the building envelope layers in the Designed Case which the program given, are within the CODE rates. However in the Alternative Case are out of the CODE rates.</td></tr>
</table>

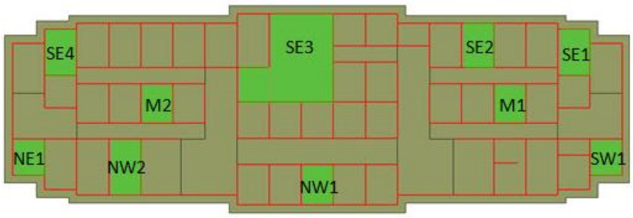


Figure 2: Key Plan of the Calculated Zones

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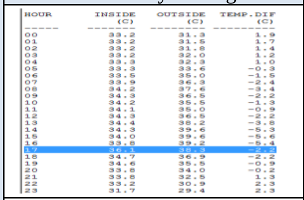
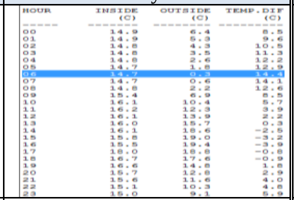
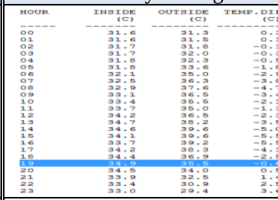
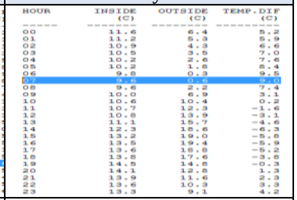
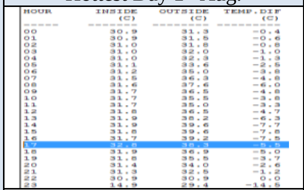
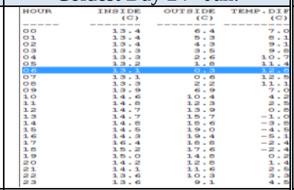
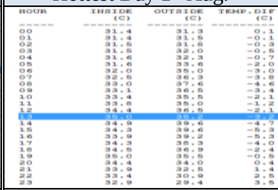
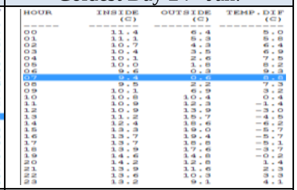
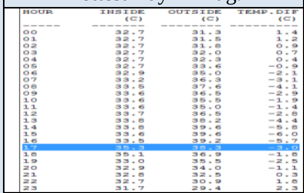
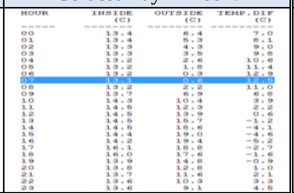
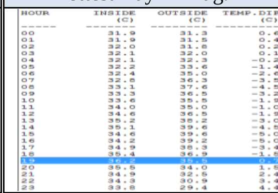
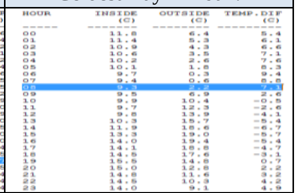
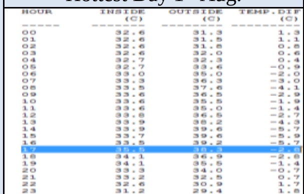
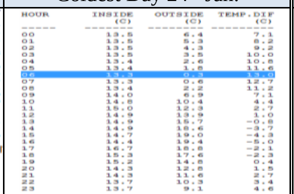
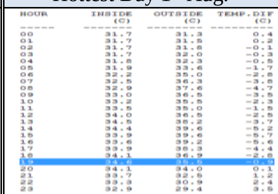
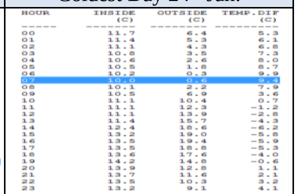
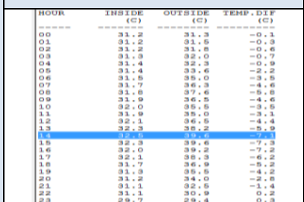
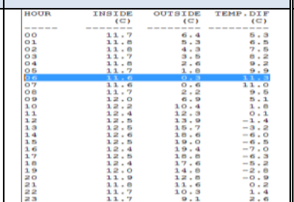
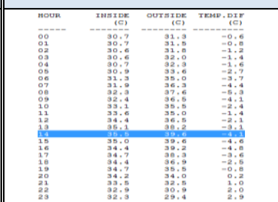
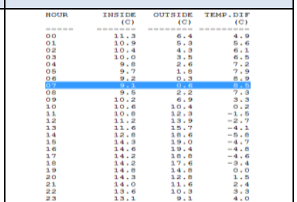
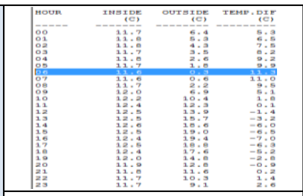
2. Temperature Analysis Table: (In case of Naturally Ventilated spaces)

Hourly Temperature Profile as shown in following **Table 4**.

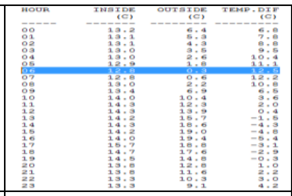
Table 4: Temperature Analysis Profile

		The Designed Case		The Alternative Case	
South-East	SE 1	Hottest Day 1st Aug.	Coldest Day 24th Jan.	Hottest Day 1st Aug.	Coldest Day 24th Jan.
					
		This Zone reaches the highest Temp. 35.5˚ at 17:00, when the outer Temp. is 36.1˚	This Zone reaches the lowest Temp. 14.7˚ at 6:00, when the outer Temp. is 0.3˚	This Zone reaches the highest Temp. 34.9˚ at 19:00, when the outer Temp. is 35.5˚	This Zone reaches the lowest Temp. 9.6˚ at 7:00, when the outer Temp. is 0.6˚
	SE 2	Hottest Day 1st Aug.	Coldest Day 24th Jan.	Hottest Day 1st Aug.	Coldest Day 24th Jan.
					
		This Zone reaches the highest Temp. 32.8˚ at 17:00, when the outer Temp. is 38.3˚	This Zone reaches the lowest Temp. 13.1˚ at 6:00, when the outer Temp. is 0.3˚	This Zone reaches the highest Temp. 35.0˚ at 13:00, when the outer Temp. is 38.2˚	This Zone reaches the lowest Temp. 9.4˚ at 7:00, when the outer Temp. is 0.6˚
	SE 3	Hottest Day 1st Aug.	Coldest Day 24th Jan.	Hottest Day 1st Aug.	Coldest Day 24th Jan.
					
		This Zone reaches the highest Temp. 35.3˚ at 17:00, when the outer Temp. is 38.3˚	This Zone reaches the lowest Temp. 13.1˚ at 7:00, when the outer Temp. is 0.6˚	This Zone reaches the highest Temp. 36.2˚ at 19:00, when the outer Temp. is 35.5˚	This Zone reaches the lowest Temp. 9.3˚ at 8:00, when the outer Temp. is 2.2˚
	SE 4	Hottest Day 1st Aug.	Coldest Day 24th Jan.	Hottest Day 1st Aug.	Coldest Day 24th Jan.
					
		This Zone reaches the highest Temp. 35.5˚ at 17:00, when the outer Temp. is 38.3˚	This Zone reaches the lowest Temp. 13.3˚ at 6:00, when the outer Temp. is 0.3˚	This Zone reaches the highest Temp. 34.6˚ at 19:00, when the outer Temp. is 35.5˚	This Zone reaches the lowest Temp. 10.0˚ at 7:00, when the outer Temp. is 0.6˚
South-West	SW 1	Hottest Day 1st Aug.	Coldest Day 24th Jan.	Hottest Day 1st Aug.	Coldest Day 24th Jan.
					
		This Zone reaches the highest Temp. 32.5˚ at 14:00, when the outer Temp. is 39.6˚	This Zone reaches the lowest Temp. 11.6˚ at 6:00, when the outer Temp. is 0.3˚	This Zone reaches the highest Temp. 35.5˚ at 14:00, when the outer Temp. is 39.6˚	This Zone reaches the lowest Temp. 9.1˚ at 7:00, when the outer Temp. is 0.6˚
rth-	NE 1	Hottest Day 1st Aug.	Coldest Day 24th Jan.	Hottest Day 1st Aug.	Coldest Day 24th Jan.



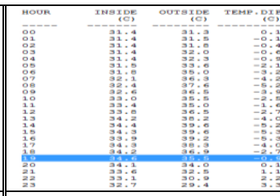
HOUR	INSIDE (C)	OUTSIDE (C)	TEMP.DIF (C)
00	11.7	6.4	5.3
01	11.8	5.3	6.5
02	11.8	4.3	7.5
03	11.7	3.5	8.2
04	11.8	2.6	9.2
05	11.7	1.8	9.9
06	11.6	0.3	11.3
07	11.6	0.6	11.0
08	11.7	2.2	9.5
09	12.0	6.9	5.1
10	12.2	10.4	1.8
11	12.4	12.3	0.1
12	12.5	13.9	-1.4
13	12.5	15.7	-3.2
14	12.6	18.6	-6.0
15	12.5	19.0	-6.5
16	12.4	19.4	-7.0
17	12.5	18.8	-6.3
18	12.4	17.6	-5.2
19	12.0	14.8	-2.8
20	11.9	12.8	-0.9
21	11.8	11.6	0.2
22	11.7	10.3	1.4
23	11.7	9.1	2.6

This Zone reaches the highest Temp. 32.5˚ at 17:00, when the outer Temp. is 38.3˚

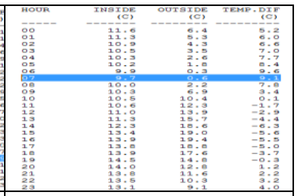


HOUR	INSIDE (C)	OUTSIDE (C)	TEMP.DIF (C)
00	13.2	6.4	6.8
01	13.1	5.3	7.8
02	13.1	4.3	8.8
03	13.0	3.5	9.5
04	13.0	2.6	10.4
05	12.9	1.8	11.1
06	12.8	0.3	12.5
07	12.8	0.6	12.2
08	13.0	2.2	10.8
09	13.4	6.9	6.5
10	14.0	10.4	3.6
11	14.3	12.3	2.0
12	14.3	13.9	0.4
13	14.2	15.7	-1.5
14	14.3	18.6	-4.3
15	14.2	19.0	-4.8
16	14.0	19.4	-5.4
17	15.7	18.8	-3.1
18	14.7	17.6	-2.9
19	14.5	14.8	-0.3
20	13.8	12.8	1.0
21	13.8	11.6	2.2
22	13.3	10.3	3.0
23	13.3	9.1	4.2

This Zone reaches the lowest Temp. 12.8˚ at 6:00, when the outer Temp. is 0.3˚



This Zone reaches the highest Temp. 34.6˚ at 19:00, when the outer Temp. is 35.5˚

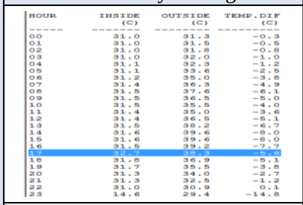


This Zone reaches the lowest Temp. 9.7˚ at 7:00, when the outer Temp. is 0.6˚

North-West

NW 1

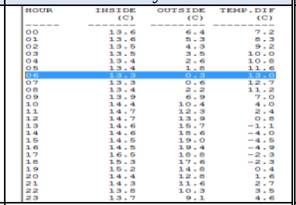
Hottest Day 1st Aug.



HOUR	INSIDE (C)	OUTSIDE (C)	TEMP.DIF (C)
00	31.0	31.3	-0.3
01	31.0	31.5	-0.5
02	31.0	31.8	-0.8
03	31.0	32.0	-1.0
04	31.1	32.3	-1.2
05	31.1	33.6	-2.5
06	31.2	35.0	-3.8
07	31.4	36.3	-4.9
08	31.5	37.6	-6.1
09	31.5	36.5	-5.0
10	31.5	35.5	-4.0
11	31.4	35.0	-3.6
12	31.4	36.5	-5.1
13	31.5	38.2	-6.7
14	31.6	39.6	-8.0
15	31.6	39.6	-8.0
16	31.5	39.2	-7.7
17	32.7	38.3	-5.6
18	31.8	36.9	-5.1
19	31.7	35.5	-3.8
20	31.3	34.0	-2.7
21	31.3	32.5	-1.2
22	31.0	30.9	0.1
23	14.6	29.4	-14.8

This Zone reaches the highest Temp. 32.7˚ at 17:00, when the outer Temp. is 38.3˚

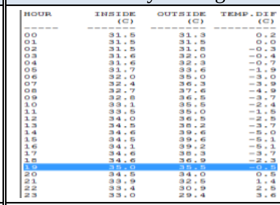
Coldest Day 24th Jan.



HOUR	INSIDE (C)	OUTSIDE (C)	TEMP.DIF (C)
00	13.6	6.4	7.2
01	13.6	5.3	8.3
02	13.5	4.3	9.2
03	13.5	3.5	10.0
04	13.4	2.6	10.8
05	13.4	1.8	11.6
06	13.3	0.3	13.0
07	13.3	0.6	12.7
08	13.4	2.2	11.2
09	13.9	6.9	7.0
10	14.4	10.4	4.0
11	14.7	12.3	2.4
12	14.7	13.9	0.8
13	14.6	15.7	-1.1
14	14.6	18.6	-4.0
15	14.5	19.0	-4.5
16	14.5	19.4	-4.9
17	16.5	18.8	-2.3
18	15.3	17.6	-2.3
19	15.2	14.8	0.4
20	14.4	12.8	1.6
21	14.3	11.6	2.7
22	13.8	10.3	3.5
23	13.7	9.1	4.6

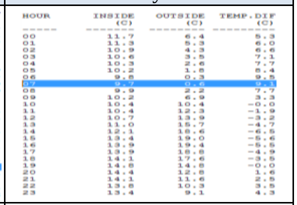
This Zone reaches the lowest Temp. 13.3˚ at 6:00, when the outer Temp. is 0.3˚

Hottest Day 1st Aug.



This Zone reaches the highest Temp. 35.0˚ at 19:00, when the outer Temp. is 35.5˚

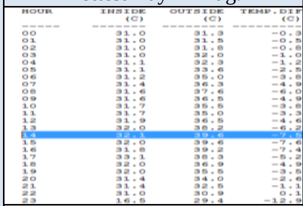
Coldest Day 24th Jan.



This Zone reaches the lowest Temp. 9.7˚ at 7:00, when the outer Temp. is 0.6˚

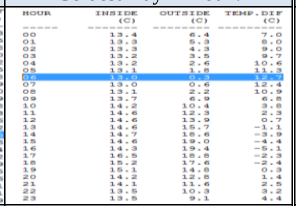
NW 2

Hottest Day 1st Aug.



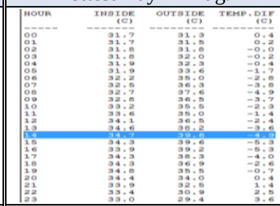
This Zone reaches the highest Temp. 32.1˚ at 14:00, when the outer Temp. is 39.6˚

Coldest Day 24th Jan.



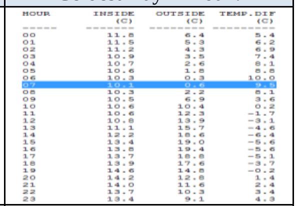
This Zone reaches the lowest Temp. 13.0˚ at 6:00, when the outer Temp. is 0.3˚

Hottest Day 1st Aug.



This Zone reaches the highest Temp. 34.9˚ at 14:00, when the outer Temp. is 39.6˚

Coldest Day 24th Jan.

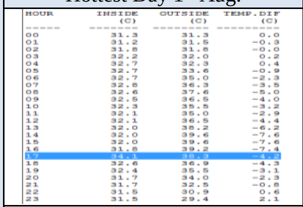


This Zone reaches the lowest Temp. 10.1˚ at 7:00, when the outer Temp. is 0.6˚

Middle Spaces

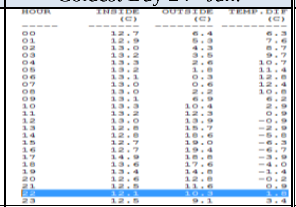
M 1

Hottest Day 1st Aug.



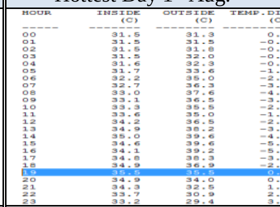
This Zone reaches the highest Temp. 34.1˚ at 17:00, when the outer Temp. is 38.3˚

Coldest Day 24th Jan.



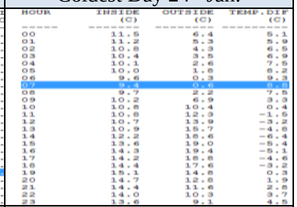
This Zone reaches the lowest Temp. 12.1˚ at 22:00, when the outer Temp. is 10.3˚

Hottest Day 1st Aug.



This Zone reaches the highest Temp. 35.5˚ at 19:00, when the outer Temp. is 35.5˚

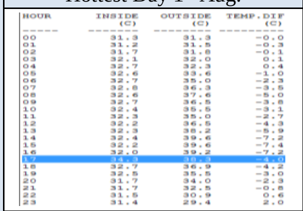
Coldest Day 24th Jan.



This Zone reaches the lowest Temp. 9.4˚ at 7:00, when the outer Temp. is 0.6˚

M 2

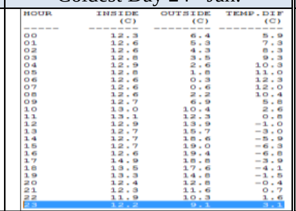
Hottest Day 1st Aug.



HOUR	INSIDE (C)	OUTSIDE (C)	TEMP.DIF (C)
00	31.3	31.3	-0.0
01	31.2	31.5	-0.3
02	31.7	31.8	-0.1
03	32.1	32.0	0.1
04	32.7	32.3	0.4
05	32.6	33.6	-1.0
06	32.7	35.0	-2.3
07	32.8	36.3	-3.5
08	32.6	37.6	-5.0
09	32.7	36.5	-3.8
10	32.4	35.5	-3.1
11	32.3	35.0	-2.7
12	32.2	36.5	-4.3
13	32.3	38.2	-5.9
14	32.4	39.6	-7.2
15	32.2	39.6	-7.4
16	32.0	39.2	-7.2
17	34.3	38.3	-4.0
18	32.7	36.9	-4.2
19	32.5	35.5	-3.0
20	31.7	34.0	-2.3
21	31.7	32.5	-0.8
22	31.5	30.9	0.6
23	31.4	29.4	2.0

This Zone reaches the highest Temp. 34.3˚ at 17:00, when the outer Temp. is 38.3˚

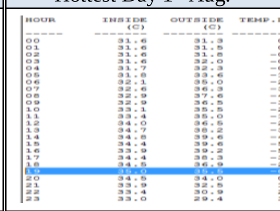
Coldest Day 24th Jan.



HOUR	INSIDE (C)	OUTSIDE (C)	TEMP.DIF (C)
00	12.3	6.4	5.9
01	12.6	5.3	7.3
02	12.6	4.3	8.3
03	12.8	3.5	9.3
04	12.9	2.6	10.3
05	12.8	1.8	11.0
06	12.6	0.3	12.3
07	12.6	0.6	12.0
08	12.6	2.2	10.4
09	12.7	6.9	5.8
10	13.0	10.4	2.6
11	13.1	12.3	0.8
12	12.9	13.9	-1.0
13	12.7	15.7	-3.0
14	12.7	18.6	-5.9
15	12.7	19.0	-6.3
16	12.6	19.4	-6.8
17	14.9	18.8	-3.9
18	13.5	17.6	-4.1
19	13.3	14.8	-1.5
20	12.4	12.8	-0.4
21	12.3	11.6	0.7
22	11.9	10.3	1.6
23	12.2	9.1	3.1

This Zone reaches the lowest Temp. 12.2˚ at 23:00, when the outer Temp. is 9.1˚

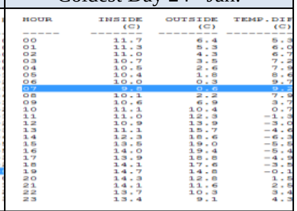
Hottest Day 1st Aug.



HOUR	INSIDE (C)	OUTSIDE (C)	TEMP.
00	31.6	31.3	
01	31.6	31.5	
02	31.6	31.8	
03	31.6	32.0	
04	31.7	32.3	
05	31.8	33.6	
06	32.1	35.0	
07	32.6	36.3	
08	32.9	37.6	
09	32.9	36.5	
10	33.1	35.5	
11	33.4	35.0	
12	34.0	36.5	
13	34.7	38.2	
14	34.8	39.6	
15	34.4	39.6	
16	33.9	39.2	
17	34.4	38.3	
18	34.5	36.9	
19	35.0	35.5	
20	34.5	34.0	
21	33.9	32.5	
22	33.4	30.9	
23	33.0	29.4	

This Zone reaches the highest Temp. 35.0˚ at 19:00, when the outer Temp. is 35.5˚

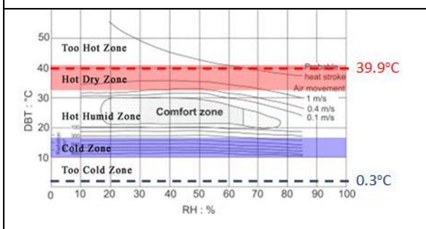
Coldest Day 24th Jan.



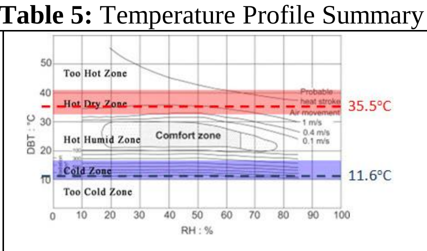
HOUR	INSIDE (C)	OUTSIDE (C)	TEMP.DIF (C)
00	11.7	6.4	5.3
01	11.3	5.3	6.0
02	11.0	4.3	6.7
03	10.7	3.5	7.2
04	10.5	2.6	7.9
05	10.4	1.8	8.6
06	10.0	0.3	9.7
07	9.8	0.6	9.2
08	10.1	2.2	7.9
09	10.6	6.9	3.7
10	11.1	10.4	0.7
11	11.0	12.3	-1.3
12	10.9	13.9	-3.0
13	11.1	15.7	-4.6
14	12.3	18.6	-6.3
15	13.5	19.0	-5.5
16	14.0	19.4	-5.4
17	13.9	18.8	-4.9
18	14.1	17.6	-3.5
19	14.7	14.8	-0.1
20	14.3	12.8	1.5
21	14.1	11.6	2.5
22	13.7	10.3	3.4
23	13.4	9.1	4.3

This Zone reaches the lowest Temp. 9.8˚ at 7:00, when the outer Temp. is 0.6˚

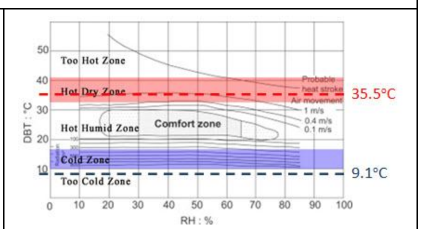
Table 5: Temperature Profile Summary



The Thermal Comfort Zone (the relationship



The Thermal Comfort Zone in the Designed



The Thermal Comfort Zone in the

between temperature and humidity and temperature fields) in Benisuef Climatic Zone	Case	Alternative Case

After studying the lowest and highest Zone's temperatures in the hottest and coldest days, it is found that, in the Designed Case the zones reached its highest temperature of 35.5℃ and reached its lowest temperature of 11.6℃ although there are horizontal Skylights in the roof. And by comparing these results with the Alternative Case the zones reached its highest temperature of 35.5℃ and reached its lowest temperature of 9.1℃ even there isn't any skylights.

As in the Designed Case by adding Pergolas over the Roof's Skylights, these Pergolas could prevent unwanted direct sun rays which increases the gained heat, and in the same time let the wanted indirect sun rays which enhances the natural light inside the spaces without increasing the inside temperature.

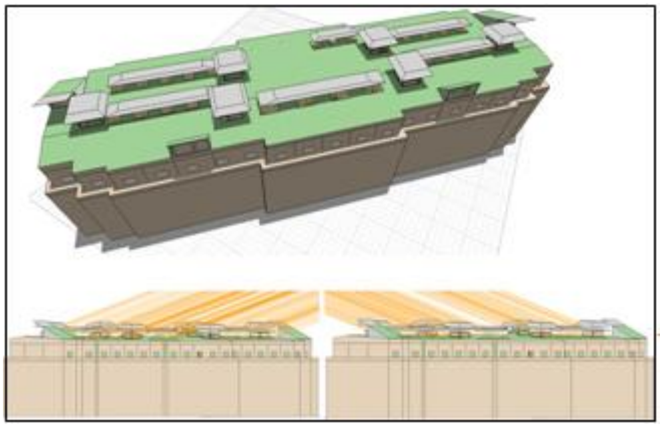


Figure 3: Adding Pergolas over the Roof's Skylights to prevent Heat Gain

The presence of these Pergolas doesn't prevent the wanted sun rays in the early morning or in the end of the day time, in order to enhance the inside daylight in these periods.

3. Heat Gain and Loss Graph:

- **For the Alternative Design case:**

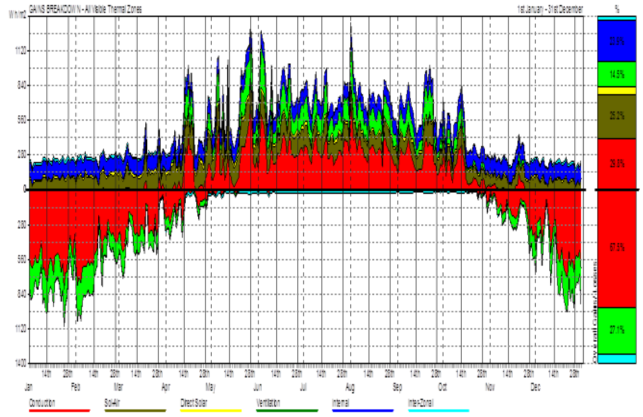


Figure 4: Hourly Heat Gains/Losses from Whole Building in the Alternative Design case

4. Results of Hourly Heat Gains/Losses Analysis:

Figure 5 shows Hourly Heat Gains (above zero level) its highest cause is Wall Conduction (Red color) with percentage of 29.8% due to building envelope. Followed by 25.2% of air movement (Sol Air) (Dark Green color), this is due to the building's longest side orientation to the east-west axis, and 23.9% from Internal Heat Transfer (Blue color), this is due to thermal infiltration between internal spaces of the Green effect which is caused by the false ceiling (as mentioned in a previous analysis).

CATEGORY	LOSSES	GAINS
FABRIC	67.5%	29.8%
SOL-AIR	0.0%	25.2%
SOLAR	0.0%	4.4%
VENTILATION	27.1%	14.5%
INTERNAL	0.0%	23.9%
INTER-ZONAL	5.4%	2.3%

Figure 5: %Heat Gains/Losses

And for Hourly Heat Losses (under zero level) its highest cause is due to building envelope Conduction (Red color) equals 67.5%, and Lake of Ventilation (Light Green color) causes 27.1%.

- **For the Designed case:**

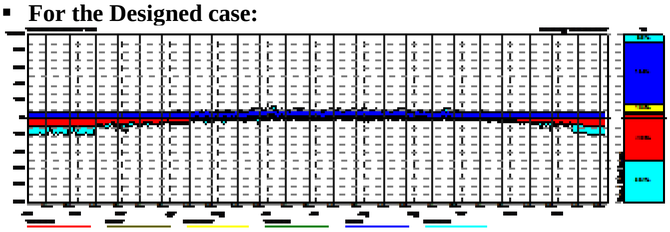


Figure 6: Hourly Heat Gains/Losses from Whole Building in the Designed case

CATEGORY	LOSSES	GAINS
FABRIC	49.6%	5.4%
SOL-AIR	0.0%	1.9%
SOLAR	0.0%	10.5%
VENTILATION	0.0%	0.0%
INTERNAL	0.0%	73.3%
INTER-ZONAL	50.4%	8.9%

Figure 7: %Heat Gains/Losses

5. Results of Hourly Heat Gains/Losses Analysis:

As it is shown from the previous Hourly Heat Gains/Losses Graphs (Figures 6, 7), while the designed and the Alternative Design Cases and by comparing the results shown in them, it is obviously found that due to the modifications done in the Design case the amount of Hourly Heat Gain and Loss is sharply decreased to a very small quantities, lower than 140 Wh\m^2 unlike in the Alternative design which reaches higher than 1120 Wh\m^2.

6. Discomfort Hours Graph(Figure 8):

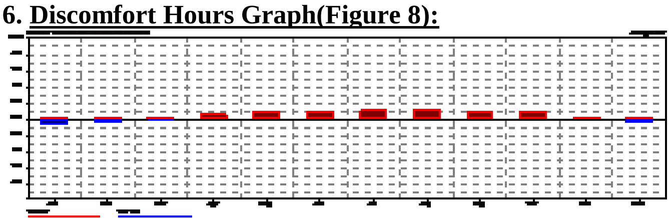


Figure 8: Discomfort degree Hours for the Whole Building in the Alternative Design case

Figure 9, represents hours out of thermal discomfort of the year, 3446.3 hour outside of the building thermal comfort equivalent to 39.3% of the year hours. Almost 80% of them are for hot hours and the other are for Cool hours.

MONTH	TOO HOT (Hrs)	TOO COOL (Hrs)	TOTAL (Hrs)
Jan	27.48	293.03	320.52
Feb	26.71	160.97	187.68
Mar	56.74	34.66	91.40
Apr	208.27	0.68	208.95
May	390.65	0.00	390.65
Jun	393.89	0.00	393.89
Jul	407.90	0.00	407.90
Aug	408.00	0.00	408.00
Sep	393.15	0.00	393.15
Oct	327.85	0.00	327.85
Nov	68.37	7.92	76.29
Dec	28.56	211.44	240.00
TOTAL	2737.6	708.7	3446.3

Figure 9: Hours out of thermal Discomfort of the year

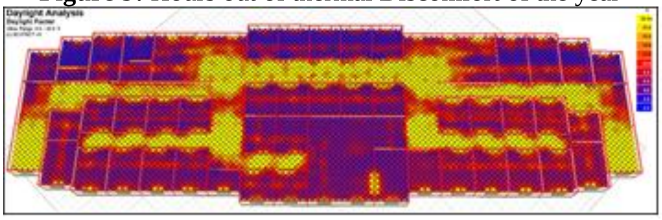


Figure 10: Discomfort degree Hours for the Whole Building in the Designed case

Figure 11, represents hours out of thermal discomfort of the year, 875 hour outside of the building thermal comfort equivalent to 10% only of the year hours. Almost 37% of them are for hot hours and 63% are for Cool hours.

MONTH	TOO HOT (Hrs)	TOO COOL (Hrs)	TOTAL (Hrs)
Jan	0.00	130.00	130.00
Feb	0.00	114.00	114.00
Mar	0.00	82.00	82.00
Apr	19.00	33.00	52.00
May	48.00	0.00	48.00
Jun	59.00	0.00	59.00
Jul	66.00	0.00	66.00
Aug	89.00	0.00	89.00
Sep	36.00	0.00	36.00
Oct	7.00	3.00	10.00
Nov	1.00	71.00	72.00
Dec	0.00	117.00	117.00
TOTAL	325.0	550.0	875.0

Figure 11: Hours out of thermal Discomfort of the year

7. Results of Discomfort degree Hours Analysis:

As it is shown from the previous Discomfort degree Hours Graphs for the designed and the Alternative Design Cases and by comparing the results shown in them, it is obviously found that due to the modifications done in the Design case the number of Discomfort Hours is sharply decreased to a small number of discomfort hours during the whole year.

B- Daylight Analysis:

Building daylight analysis is at 9:00 in the morning in the most thermal loads days (1stAugust) because in these days the sun is in the highest level inside the space, and it is almost perpendicular to the building's facade, so it penetrate to the space in its higher level and have the most natural light. Figures from 12 to 16 show architectural solution for increase the efficiency of daylight inside building.

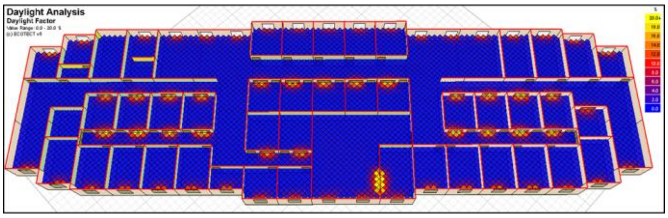


Figure 12: Daylight Factor inside spaces, without the designed skylights and false ceiling covering the class rooms

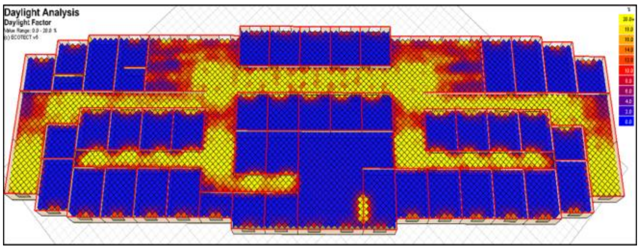


Figure 13: Daylight Factor inside spaces, by having the designed skylights and false ceiling covering the class rooms

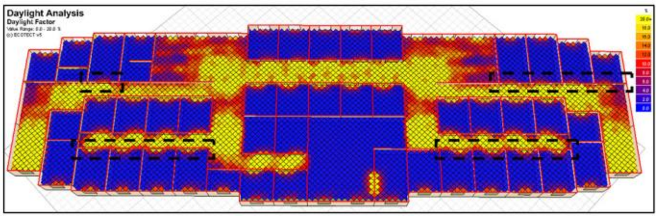


Figure 14: Daylight Factor inside spaces, by having the designed skylights + false ceiling covering the class rooms and having extra upper windows opening at the corridors

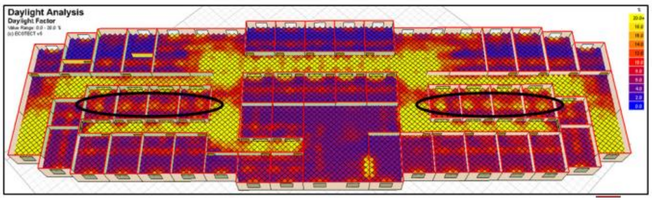


Figure 15: Daylight Factor inside spaces, by having the designed skylights + without false ceiling covering the class rooms.

Marked areas have too much Glare (uncomforted light) for a studying room

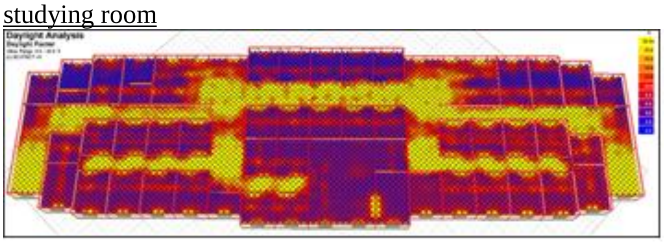


Figure 16: Daylight Factor inside spaces, by having the designed skylights, designed false ceiling covering some of

the class rooms and having extra upper windows opening at the corridors

C- Ventilation Analysis:

The Ventilation was taken in the Hottest day in this climate zone (1st August) at 9:00am. Figure 17 shows Horizontal and Vertical Sections was taken to prove the effect of the Designed Wind Catchers and Operable Skylight Windows on improving the airflow rate inside the building spaces. Figures from 17 to 32 show architectural solution for increase the efficiency of ventilation inside building.

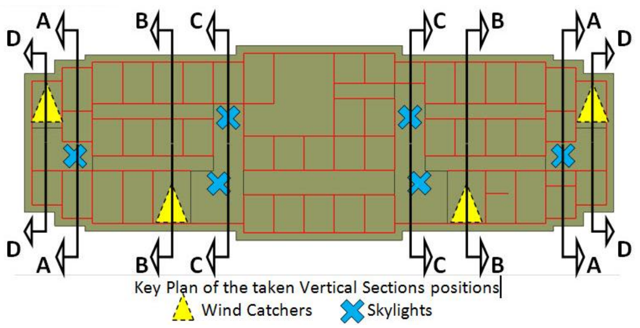


Figure 17: Key Plan of the taken Vertical Sections positions

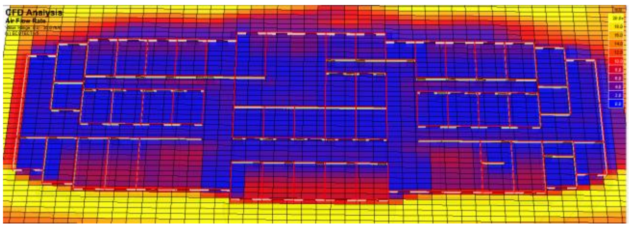


Figure 18: Airflow Rate inside spaces without adding the Designed Wind catchers and Operable skylight windows.

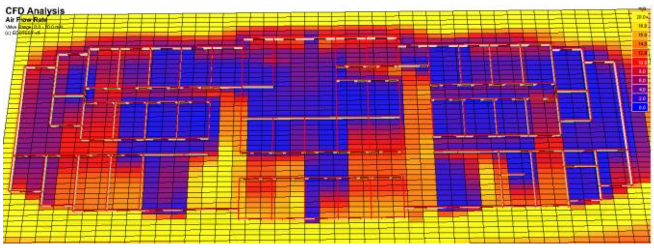


Figure 19: The effect of adding the Designed Wind catchers and Operable skylight windows on Enhancing Airflow Rate inside spaces.

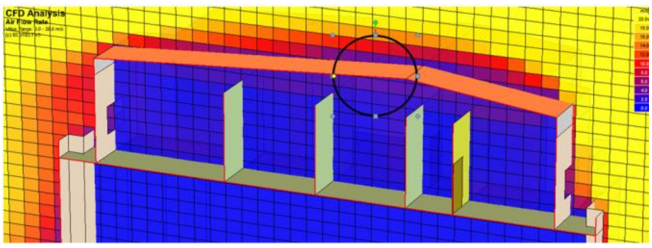


Figure 20: Section (A-A) shows airflow rate inside spaces without adding the designed operable skylight windows.

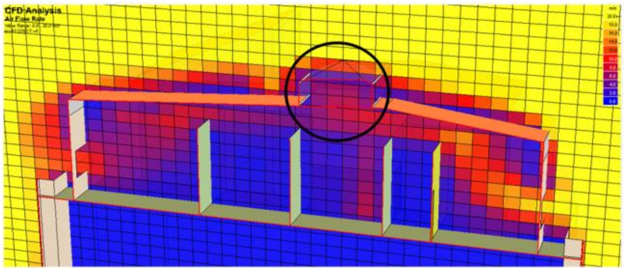


Figure 21: Section (A-A) shows effect of adding the designed operable skylight windows on enhancing airflow rate inside spaces.

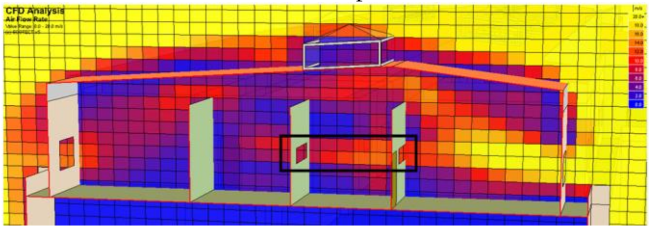


Figure 22: Section (A-A) shows also by adding upper windows in the inner classes' effect on Enhancing Airflow Rate inside these spaces.

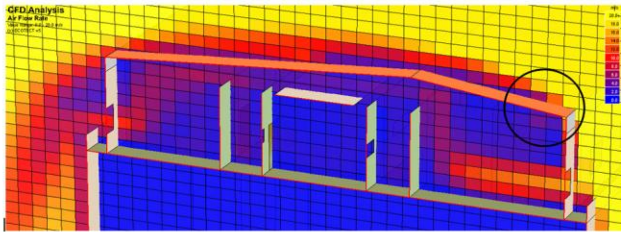


Figure 23: Section (B-B) shows airflow rate inside spaces without adding the designed wind catchers.

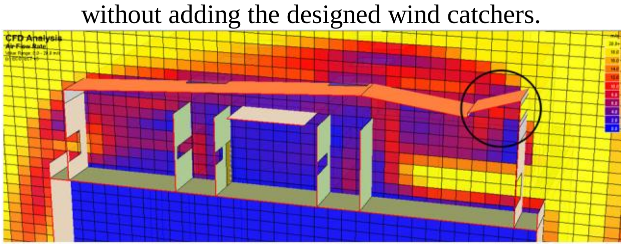


Figure 24: Section (B-B) shows the effect of adding the designed wind catchers on enhancing airflow rate inside spaces.

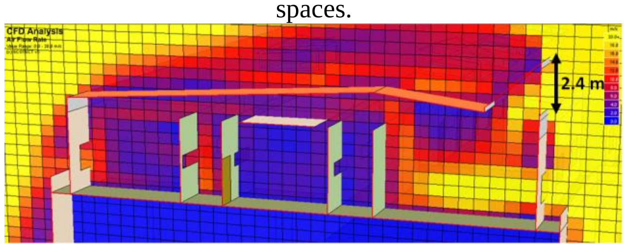


Figure 25: Section (B-B) shows that using a higher wind catcher, this affects more effective on enhancing airflow rate inside these spaces.

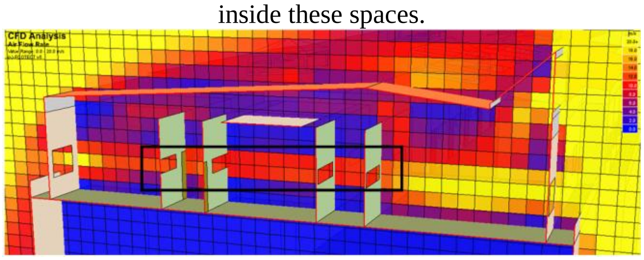


Figure 26: Section (B-B) shows that adding upper windows in the inner classes effect on enhancing airflow rate inside these spaces.

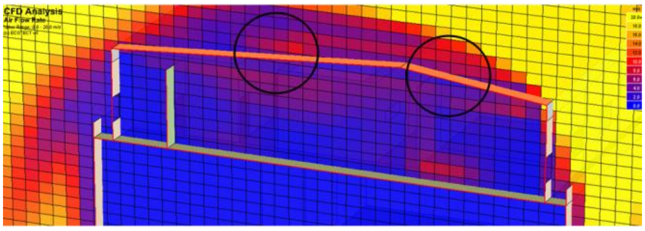


Figure 27: Section (C-C) shows airflow rate inside spaces without adding the designed operable skylights windows.

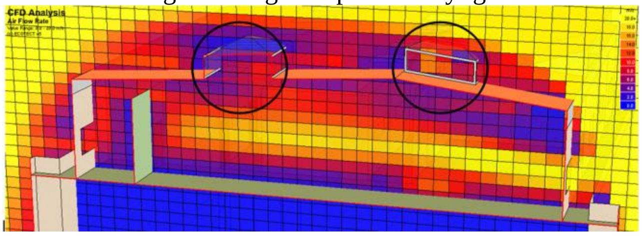


Figure 28: Section (C-C) shows the effect of adding the designed operable skylights windows on enhancing airflow rate inside spaces.

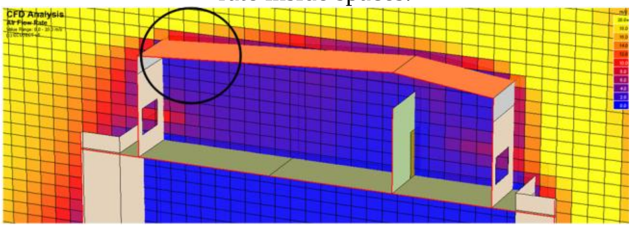


Figure 29: Section (D-D) shows airflow rate inside spaces without adding the designed wind catcher.

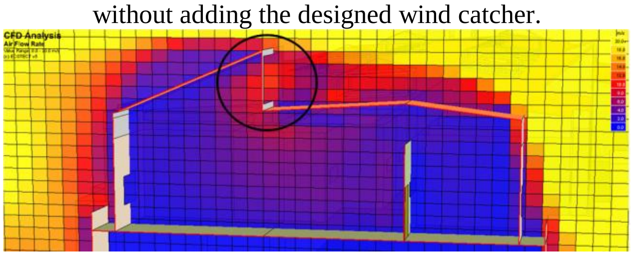


Figure 30: Section (D-D) shows the effect of adding the designed high wind catcher on enhancing airflow rate inside spaces

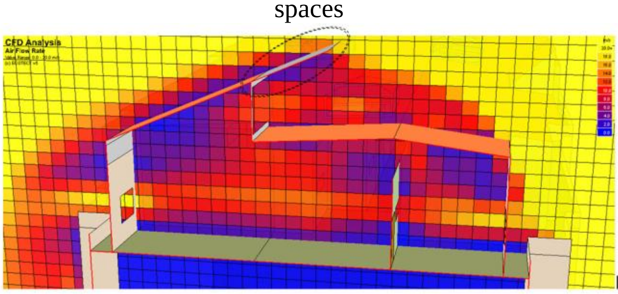


Figure 31 Section (D-D) shows adding a Long Hangover in the inlet window of the wind catcher effects on enhancing airflow rate inside these spaces

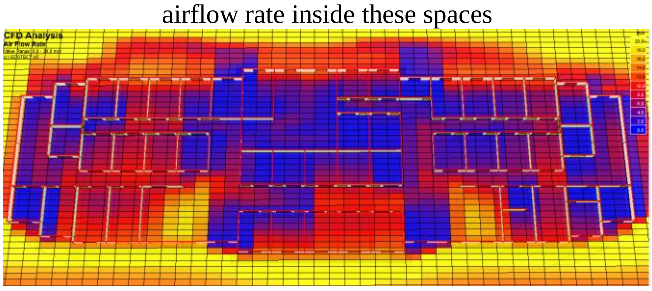
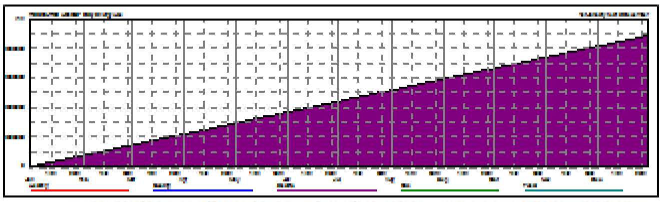


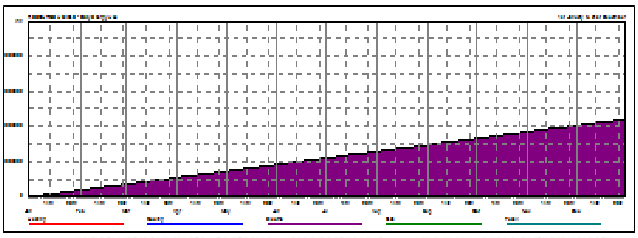
Figure 32: The effect of adding the designed wind catchers and operable skylight windows after adding the last modifications on enhancing airflow rate inside spaces

D- Electricity usage before adding skylights (Figure 33):



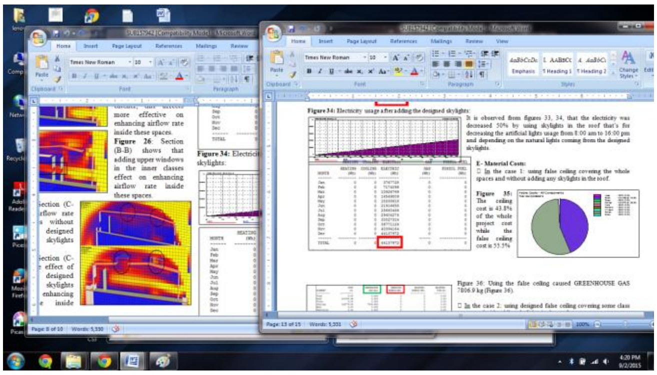
MONTH	HEATING (Wh)	COOLING (Wh)	ELECTRIC (Wh)	GAS (Wh)	FOSSIL FUEL (Wh)
Jan	0	0	7535456	0	0
Feb	0	0	14348192	0	0
Mar	0	0	21853538	0	0
Apr	0	0	29099618	0	0
May	0	0	36587236	0	0
Jun	0	0	43833316	0	0
Jul	0	0	51320932	0	0
Aug	0	0	58808548	0	0
Sep	0	0	66054628	0	0
Oct	0	0	73542248	0	0
Nov	0	0	80788328	0	0
Dec	0	0	88275944	0	0
TOTAL	0	0	88275944	0	0

Figure 34: Electricity usage after adding the designed skylights:



MONTH	HEATING (Wh)	COOLING (Wh)	ELECTRIC (Wh)	GAS (Wh)	FOSSIL FUEL (Wh)
Jan	0	0	3767728	0	0
Feb	0	0	7174096	0	0
Mar	0	0	10926769	0	0
Apr	0	0	14549809	0	0
May	0	0	18293618	0	0
Jun	0	0	21916658	0	0
Jul	0	0	25660466	0	0
Aug	0	0	29404274	0	0
Sep	0	0	33027314	0	0
Oct	0	0	36771124	0	0
Nov	0	0	40394164	0	0
Dec	0	0	44137972	0	0
TOTAL	0	0	44137972	0	0

It is observed from figures 33, 34, that the electricity was decreased 50% by using skylights in the roof that's for decreasing the artificial lights usage from 8:00 am to 16:00 pm and depending on the natural lights coming from the designed skylights.



E- Material Costs:

In the case 1: using false ceiling covering the whole spaces and without adding any skylights in the roof.

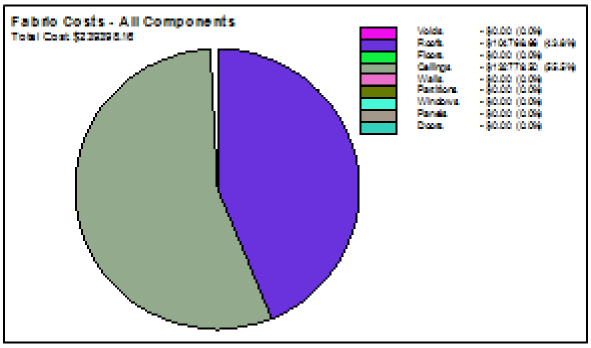


Figure 35: The ceiling cost is 43.8% of the whole project cost while the false ceiling cost is 55.5%

ELEMENT	COST ($)	GREENHOUSE GAS (kg)	EMBODIED ENERGY (Wh)	MAINTEN. ENERGY (Wh)	MAINTEN. COST ($)
Void	0.00	0.000	0	0	0.00
Roof	104768.66	0.000	0	0	0.00
Floor	0.00	0.000	0	0	0.00
Ceiling	132779.50	7806.943	0	0	0.00
Wall	0.00	0.000	0	0	0.00
Partition	0.00	0.000	0	0	0.00
Window	0.00	0.000	0	0	0.00
Panel	0.00	0.000	0	0	0.00
Door	0.00	0.000	0	0	0.00
TOTAL	239398.16	7806.943	26640000	0	0.00

ELEMENT	COST ($)	GREENHOUSE GAS (kg)	EMBODIED ENERGY (Wh)	MAINTEN. ENERGY (Wh)	MAINTEN. COST ($)
Void	0.00	0.000	0	0	0.00
Roof	94496.23	0.000	0	0	0.00
Floor	0.00	0.000	0	0	0.00
Ceiling	0.00	0.000	0	0	0.00
Wall	0.00	0.000	0	0	0.00
Partition	0.00	0.000	0	0	0.00
Window	0.00	0.000	0	0	0.00
Panel	0.00	0.000	0	0	0.00
Door	0.00	0.000	0	0	0.00
TOTAL	96346.23	0.000	13320000	0	0.00

Figure 36: Using the false ceiling caused GREENHOUSE GAS 7806.9 kg (Figure 36).

In the case 2: using designed false ceiling covering some class rooms and with adding skylights in the roof.

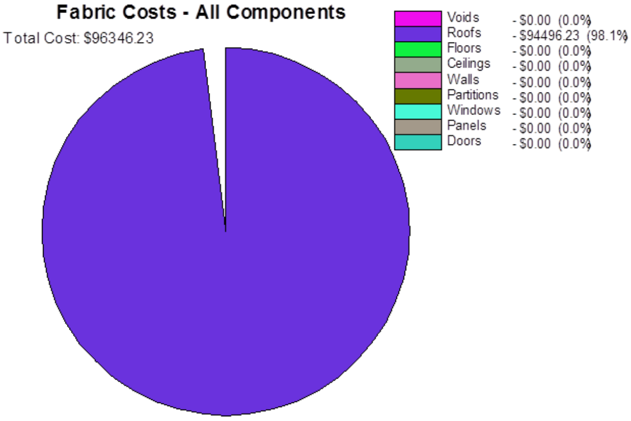


Figure 37: the whole cost is for roof construction but the used Embodied Energy decreased 50%, also there is no GREENHOUSE GAS gained.

F- Electricity Usage and Light Lamps cost:

Watt\Lamp = 36 watt
Expected Life time (hrs) = 10.000 h
Used energy (KW\h) = (36*10.000)\1000 = 360 KW\h
Cost of KW\h = 0.18 EGP
Cost of used Energy\h = 0.18*360 = 64.8 EGP

In the case 1:
Light usage period = 8:00 to 21:00 = 13 h\day
= 3640 h\year
Annual Electricity usage = 235,872 EGP

In the case 2:
Light usage period = 16:00 to 21:00 = 5 h\day
= 1400 h\year
Annual Electricity usage = 90,720 EGP

6. Conclusion

1) Architectural design solutions affecting on increase the energy efficiency reduction in energy losses through the external envelope especially the roof of a building considering the local climatic conditions.
2) The major elements of building design simulation system; two basic models are used to present the major components that affect the building's design decision: Building model and Control system model.
3) Simulation tools can be utilized for the following functions: evaluate design options and investigate design optimization, facilitate the investigation of new ideas, check compliance with building energy codes and determine the impact of energy conservation measures.
4) The success of the functional performance of educational building depends on two main determinants that are the realization of users' objectives and need besides respecting the surrounding natural and built environment.
5) Architectural program works as a design tool for environmental principles solutions and more effectively in simulating the design processes stages through analyzing the building solar performance (Air Temperatures, Heat Gain and Loss, Thermal Resistance), Natural lighting and ventilation and air flow in the building and their energy consumption.

6) Architectural solutions effect on energy efficiency as shown in simulation matrix which including: skylights, false ceiling covering some of the class rooms, adding extra upper windows opening at the corridors, wind catchers, operable sky light windows and adding a long hangover in the inlet window of the wind catcher.
7) Architectural design approach are summarized in three main sectors; Environment, Climate and Energy. The sequence of the design process appeared in three stages: forward analysis stage, design development stage and element design stage. These stages are used in explaining the types of activities inside the building and its fundamental importance in terms of climatic impact on the building design degree of thermal comfort, natural lighting and natural ventilation define the comfort zone.
8) Prove the importance of the building envelope, shading, natural lighting and natural ventilation systems to achieve thermal comfort for the user on a year-round to access the results of energy consumption lowest rates.
9) Results associated with the use of ECOTECT program as a tool for analysis and design of studying samples, include the following: Ecotect don't calculate the building material Thermal Lag, in a naturally ventilated the program gives an output of discomfort hot\cool hours, but in a full air-conditioned it gives a monthly heating\cooling loads, zones operation hours schedule has to input in the program manually, and airflow analysis depends on user's visual observations.
10) Results associated from the analyzed case study: The U-value rates of the building envelope gypsum board layers are within the CODE rates. However bricks are out of the CODE rates, Pergolas could prevent unwanted direct sun rays which increases the gained heat, and in the same time let the wanted indirect sun rays which enhances the natural light inside the spaces without increasing the inside temperature but it doesn't prevent the wanted sun rays in the early morning or in the end of the day time, in order to enhance the inside daylight in these periods.
11) In Beni-Suef Buildings, daylight analysis is at 9:00 in the morning in the most thermal loads days (1st August) because in these days the sun is in the highest level inside the space, and it is almost perpendicular to the building's facade, so it penetrate to the space in its higher level and have the most natural light.
12) The effect of adding the Designed Wind catchers and Operable skylight windows after adding the last modifications on Enhancing Airflow Rate inside spaces.
13) The electricity was decreased 50% by using skylights in the roof that’s for decreasing the artificial lights usage and depend ing on the natural lights coming from the designed skylights .
14) Energy efficiency improvements using to achieve the design requirements & thermal comforts to avoid consumption increased and reduce energy wastage. As well as environmental integration systems such as: insulation, ventilation, solar Acquisition, natural lighting, thermal mass, heating and cooling.
15) Enhancing the efficiency architectural solutions in education buildings using Ecotect simulation software to improve quality and quantity of comfort levels which affect efficiency of architectural energy saving design approach

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