Ain Shams University
Faculty of Engineering
Architectural Department

Optimizing Building Envelope Parameters for Thermal Comfort Provision in School Classrooms

(With special reference to one of prototype schools designed by Educational Building Authority at Egypt)

By

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B.Sc. Architectural Engineering
Ain Shams University, 2010

A REPORT

Submitted in Partial Fulfillment for Requirement of the Degree of

MASTER OF ENGINEERING IN ARCHITECTURAL ENGINEERING

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July 2014

Statement

This report is submitted to Ain Shams University, Cairo, Egypt, on July 2014 for the degree of Master of Engineering in Architectural Engineering.

No part of this report has been submitted for a degree or qualification at any other University or Institute.

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Acknowledgement

First of all, I would like to thank Allah for every gift bestowed on me………..

Next, I would like to extend my warmest heartfelt gratitude to all my family especially my parents, who stood by me and supported me in every step of my life. I would like to deeply thank them and convey my sincere appreciation for their assistance, encouragement, support, understanding, and patience.

Moreover, I would like to express my sincerest appreciation to my advisor, Dr. Abeer Eisa and, for her continuous valuable guidance, her constant encouragement, support, and friendship which was the motivating force that kept work on my research in force until completion, and the investments, giving me the opportunity to be involved in such interesting research. I would like to express my admiration and thanks forher loyalty and trustfulness.

I would like to send my thanks to Al-Fanar Co. for their support and providing helpful sources of scientific data and time.

Finally, there are no words can express my sincere gratitude to the love of my life my husband and the great support of my dear brothers, to them this report is dedicated.

Mariam Badieh

To my parents, whom, I owe too much. To my husband whom encouraged me so much.

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1-Introduction:

Increased energy consumption continuously arises as one of the global stressing problems for human kind, the rising price of oil is threatening World's economies. In addition, the pollution caused by fossil fuels and climate change are becoming major source of concern worldwide. The World Energy Outlook published in 2007 by the International Energy Agency, estimated a continuous growth in the demand of energy that would, by2030, require 55% more energy that used of today. On the other hand, about 86% of the actual energy demand is now met with fossil fuels.[1]

Considering the case of Egypt, which has recently become a net oil importer country; it is observed that its low capability to pass changes in international oil price to its domestic market results in high amounts of subsidies. Amidst broader economic instability and reduced production rates of oil and natural gas the energy deficit is manifesting in electrical shortages throughout Cairo, Alexandria, Luxor, and Aswan particularly in summer due to electricity consumption peaks.[2]

Indoor thermal comfort and energy needs relevant were targeted by many studies especially after the oil crisis in 1970s.Architects and researches ,interests were oriented towards finding alternative sources of energy and reducing energy consumption using passive systems by interacting with the environment.

The significance of design decisions starting from site selection , building orientation ending with material selection , has been more realized in terms of passively coping with climate and environment .Building envelope design represents one of the most effective approaches in passive architecture.

1- Mediavilla. M., Miguel. L., Castro .C.,From fossil fuels to renewable energies, University of Valladolid, Spain, 2008,p1

2- El-Deke .H. ,Hamdy. N., Does Non-renewable Energy Utilization in Egypt Generate Net Gain or Net Loss?, National Society for Economic Policy (NSEP) ,August 2010.p3.

Students spend long periods of time in classrooms, thus a good indoor environment can help to optimize conditions for students' performance. [1]

Recent data suggests that thermal satisfaction may directly enhance a person's ability to perform specific mental tasks requiring concentration, calculation, or memory. In addition practical experiments proved that moderate high class room air temperature, improved the performance of school students.[2]

The different design techniques of educational buildings could improve thermal comfort; vary greatly from one climatic region to another. Passive design systems have noticeable impact on improving the thermal performance of buildings particularly in hot arid regions such as Egypt; however people are no longer using them.[3]

2-ProblemDefinition:

Providing thermal comfort in classrooms is a necessity as during school days students spend up to one third of the day in educational facilities. The indoor spaces in educational facilities have been much less studied than in other buildings such as offices and hospitals Students performance is affected by comfort level, as discomfort decreases attention when temperature exceed their comfort zone.[4]

3-Research Objective:

The research aims at providing thermal comfort for government school classrooms in Cairo, So as to improve the educational performance.

1- Dewidar .M., Mahmoud. H., Moussa. R., Enhancing The Human Thermal Comfort inside Educational Buildings in Hot Arid Regions, British University, Cairo, 2009.p2

2- Wargocki. P., Wyon .D., The Effects of Moderately Raised Classroom Temperatures Rate on the Performance of Schoolwork by Children (RP-1257),HVAC&R RESEARCH, June 2006. p1.

3- Op. cit.: Enhancing The Human Thermal Comfort, p2.

4- Op. cit.: Enhancing The HumanThermal Comfort, p3.

4-Methodology:

A classroom at one of the prototype schools established by the Educational Building Authority at Cairo is chosen as the base case .Thermal performance is simulated at the four main orientations (East-South-West-North) as this prototype school could be established at various plots with different orientations, so the thermal performance of the class room should be simulated at the four orientations to be evaluated as a base case.

Several alternatives for the classroom envelope components (walls –glazing –shading devices) are determined and thermal performance is simulated on every orientation (E-W-S-N), and the best alternative for achieving thermal comfort is chosen for every component.

Simulation was done at every hour of the school occupied periods which were (1372)hours , internal air temperature results were compared to thermal comfort limits (21°c-28°c)by calculating thermal difference above (28°c)which is considered as positive cooling loads , and under (21°c)which is considered as negative heating loads, in such that :the larger the difference between internal temperatures and the comfort limits(21°c-28°c) , the worse the status in terms of providing thermal comfort.

DesignBuilder software was used to build the school building model with energy plus as it is simulation engine. The results are then exported to Microsoft Excel program to further analyze and compare them.

5-Thermal Comfort Range as Criteria of Evaluation:

ANSI/ASHRAE-55 and ISO 7730 defined the thermal comfort as ''the condition of mind which expresses satisfaction with the thermal environment''. The human thermal comfort depends on environmental conditions and person factors.

Extensive laboratory and field data have been collected that provide the necessary statistical data to define conditions that a specified percentage of occupants will find thermally comfortable. It is permissible to apply Graphic Comfort Zone Method for Typical Indoor Environments in to spaces where the occupants have activity levels that result in metabolic rates between 1.0 and 1.3 met and where clothing is worn that provides between 0.5 and 1.0 (clo) of thermal insulation. for 80% occupant acceptability. This is based on a 10% dissatisfaction criterion for general (whole body), figure (1).[1]

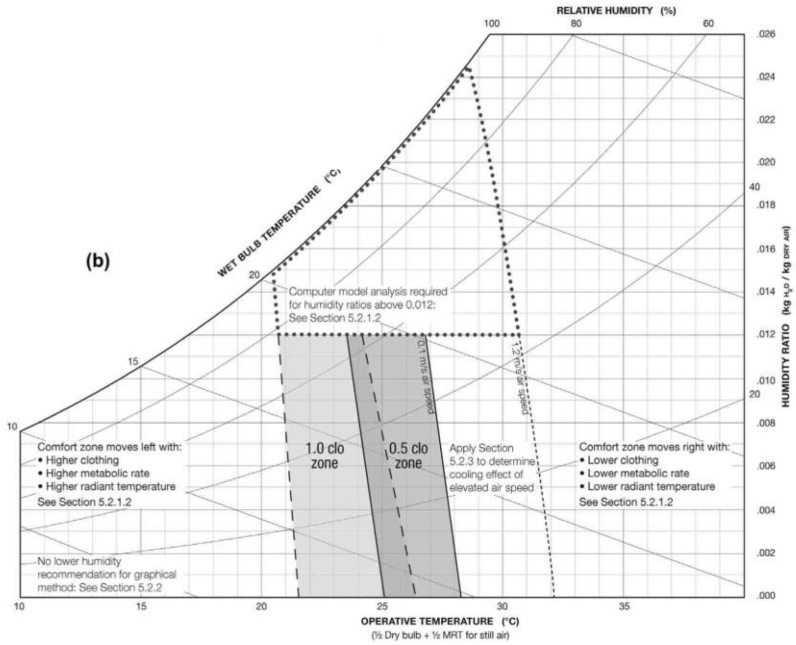


Figure (1): Graphic Comfort Zone for Typical Indoor Environments

(range from 21° c to 28° c)

Source: ANSI/ASHRAE Standard 55-2010American Society of Heating,

1- ANSI/ASHRAE Standard 55-2010American Society of Heating, Refrigerating and Air-Conditioning Engineers, International organization for Standardizations; 2010.p25

Understanding the indoor thermal comfort helps the architects and designers in providing a comfort environment for the users and that does not impair the health and performance of the people inside these buildings.

The thermal indoor environment in the building is very important because people stay most of the time in indoor environment spending around 90% of their time in buildings. Therefore, optimal indoor thermal comfort is important for everyone. The indoor environment quality will influence people's productivity, comfort and health of these people.[1]

Thermal satisfaction may directly enhance a person's ability to perform specific mental tasks requiring concentration, calculation, or memory. In addition practical experiments proved that moderate high class room air temperature, improved the performance of school students.[2]

6-Base Case Description:

The General Authority for Educational Buildings (GAEB) at Egypt follows the Ministry of Education, it represents the biggest governmental organization responsible for planning, operating and maintaining schools in Egypt, it is also responsible for identifying and development of the design specifications and codes for educational buildings at Egypt.

A class room at one of the prototype schools designed by the above described authority at Cairo (Al sayedasomia at Shubra) was taken as a case study to investigate options for thermal comfort optimization, The school was designed by Educational building authority at Egypt, It consists of four floors and the selected classroom is at the typical floor, as shown as figures (2), (3).

1- Op. cit.: Enhancing The Human Thermal Comfort, p2.

2- Op. cit.:The Effects of Moderately Classroom Temperatures Rate on the Performance ,p1

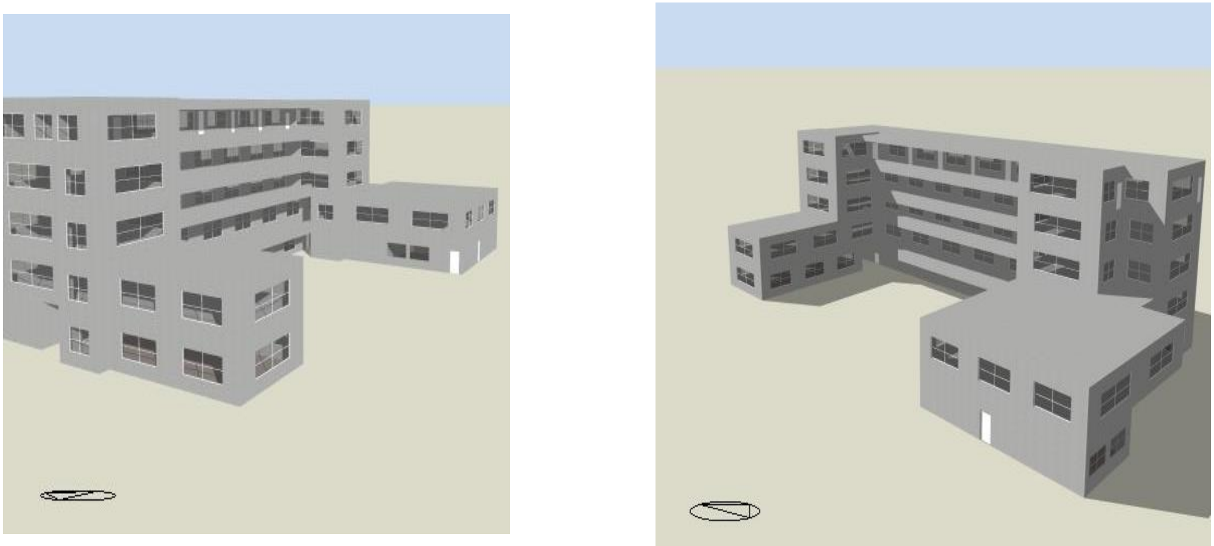


Figure (2): 3D shots of prototype primary schools at Cairo (Al sayedasomia at Shubra)

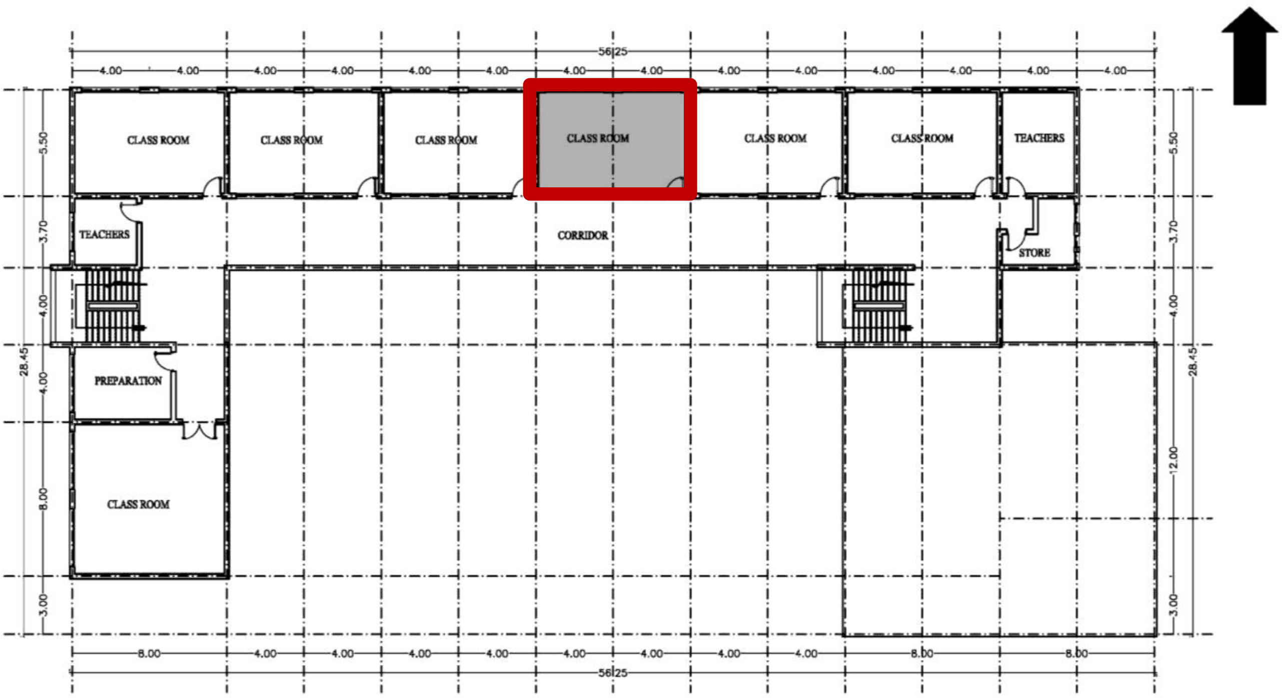


Figure (3): The class room at the Typical floor plan (From second to fourth)

Source: Educational Building Authority at Egypt

6-1 Climatic Context

The investigated school classroom is of a prototype to be applied in Cairo. Hence, the climate of Cairo is introduced in the following part: Cairo's climate is a desert climate, which remains mostly dry and arid year round. The hot weather in Cairo means that the humidity can rise at times, particularly during winter (December to February). At this time precipitation is more likely, and temperatures drop to 13 to 19 °C. Cairo weather in the summertime (May to August) sees temperatures up to 45 to 47 °C, As shown at figure (4).[1]

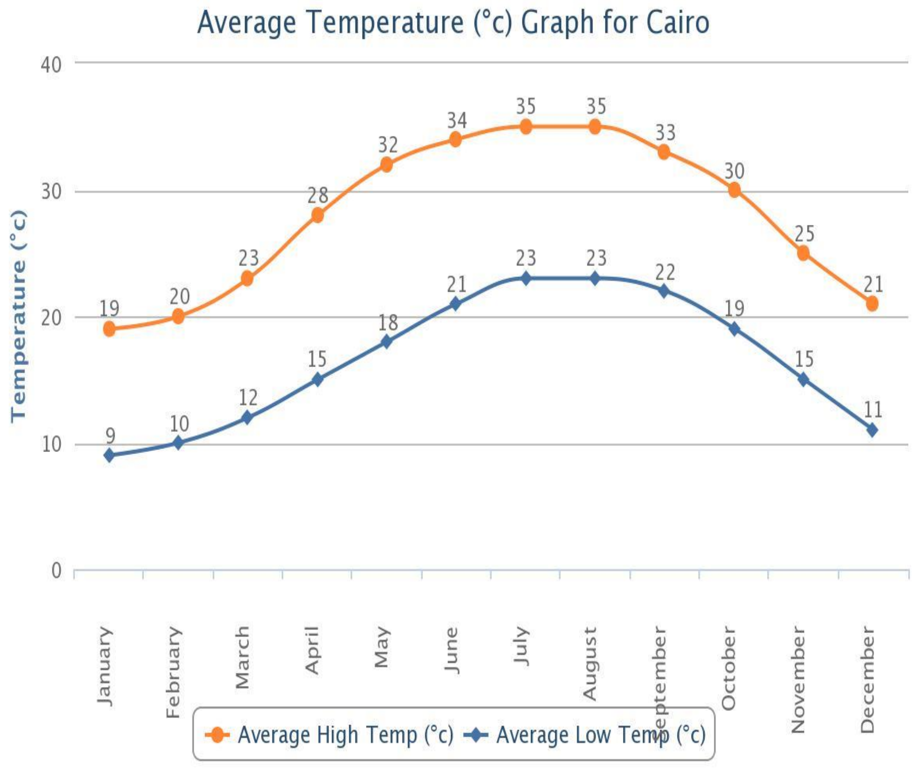


Figure (4): Cairo climate chart

Source: Cairo Egypt Weather Averages, http://www.worldweatheronline.com,last accesses 12/6/2014

1- Weather averages .http://www.worldweatheronline.com , last accsess 12-6-2014.

6-2 Classroom Characteristics:

6-2-1Geometry:

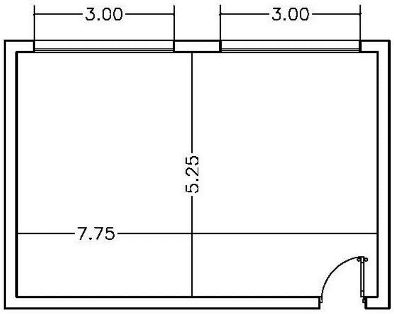


Figure (5): classroom SpaceDimensions

- **space Dimensions :** 5.25 *7.75, figure(5)
- **Height:** clear height is (2.8m)
- **Slab:** 150 mm concrete slab.
- **W.W.R (window to wall ratio):** (.445)
- **Area:** 38 m2
- **Orientation:** north

6-2-2 Operational conditions:

6-2-2-1Activity:

- **Occupied periods:**

  From 15 September up 15 June

  Days: starts from 8:00 a.m. to 2:00.p.m.

  Holidays: Friday & Saturday
- **Density**: 0.9 people /m2
- **Clothing** : Winter (clo)=1.0 , Summer(clo)=0.5
- **Metabolic for children (standing/walking)**=1.0
- **office equipment or computers** :off

6-2-2-2Lighting:

- **Target luminance** : (lux) :300
- **Artificial lighting** :on
- **lightning controller** :off

6-2-2-3HVAC:

- **Mechanical ventilation**: off
- **Heating & cooling** : off
- **Natural ventilation** :off

7-Base case Evaluation:

The class room thermal performance at the main four orientations(East-South-West-North) is simulated as a base case at occupied periods ,as the prototype school could be established at various plots with different orientations, so the thermal performance of the class room should be simulated at the four orientations to be evaluated as a base case, as shown at figure (6).

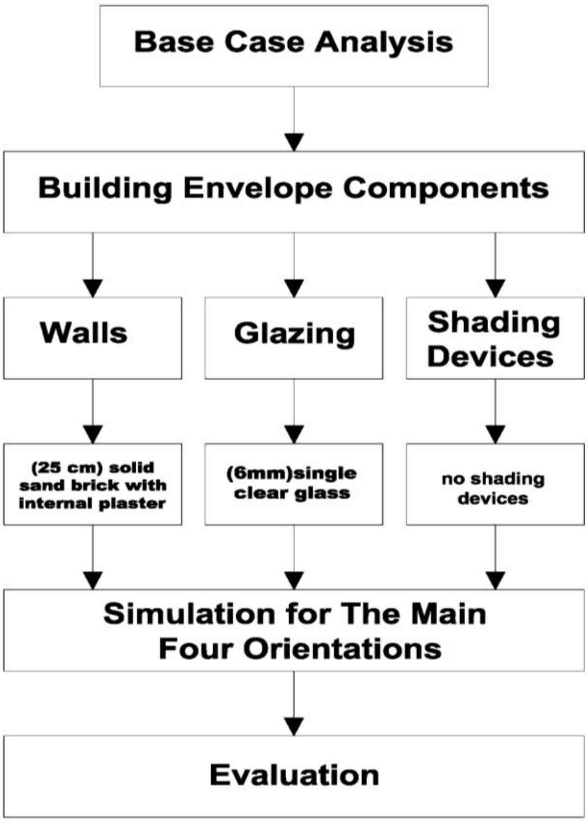
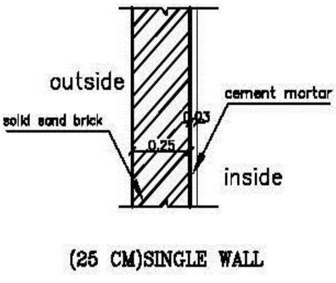
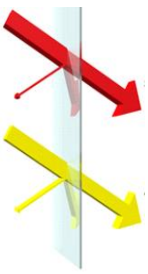


Figure (6): Base case analysis

7-1 Base Case Envelope Components:

The envelope is made up of all of the exterior components of the building, including walls, roofing, foundations, windows, and doors. Finish materials like siding and decorative items are not usually considered a part of the envelope. Insulation, and other components aimed at controlling temperature are typically included in the building envelope design. The base case envelope components are as shown at table(1).[1]

Table (1): Base case envelope components

COMPONENT	WALL	GLAZING
Type	(25 cm) solid sand brick	(6mm)single clear glass
Figure		
LAYERS	1-(25 cm) solid sand brick(base case) 2-(3cm) internal cement plaster	1-(6 mm) clear glass
U-VALUE(W/M^2-K)	1.827	6.121

1- what-is-a-building-envelope, http://www.wisegee.com ,last accsess 12-6-2014

7-2 Simulation Results of the Base Case:

Table (2)presents thermal difference above 28°c , no. of hours (above 28° c) and thermal difference (below 21° c), no. of hours (below 21° c); . Simulation results of the four main orientations (E-S-W-N) and the best one are shown at figures (7), (8).

Table (2): Base case Simulation results of the four main orientations (E-S-W-N)

ORIENTATION	NORTH	EAST	SOUTH	WEST
Temperature differences (above 28° c)	2927	3373	4296	3652
No. of hours (above 28°c)	861	889	1049	929
Rate of increase	3.4	3.8	4.1	3.9
Temperature l differences (below 21° c)	24	22	15	18
No. of hours (below 21° c)	40	30	20	20
Rate of decrease	0.6	0.73	0.75	0.9

1- What is abuilding envelope? ,http://www.wisegee.com, last accsess 12-6-2014.

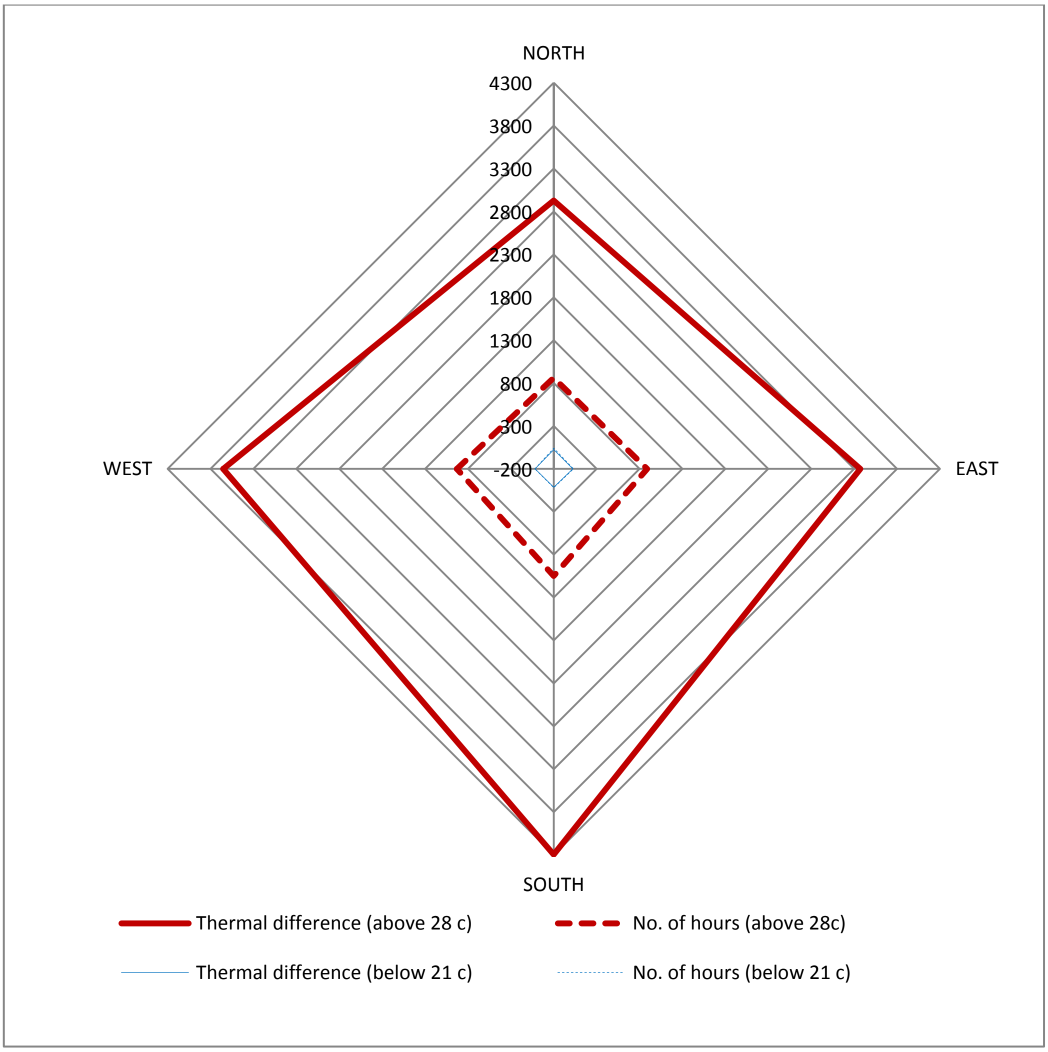


Figure (7): Simulation results of the four main orientations at base case

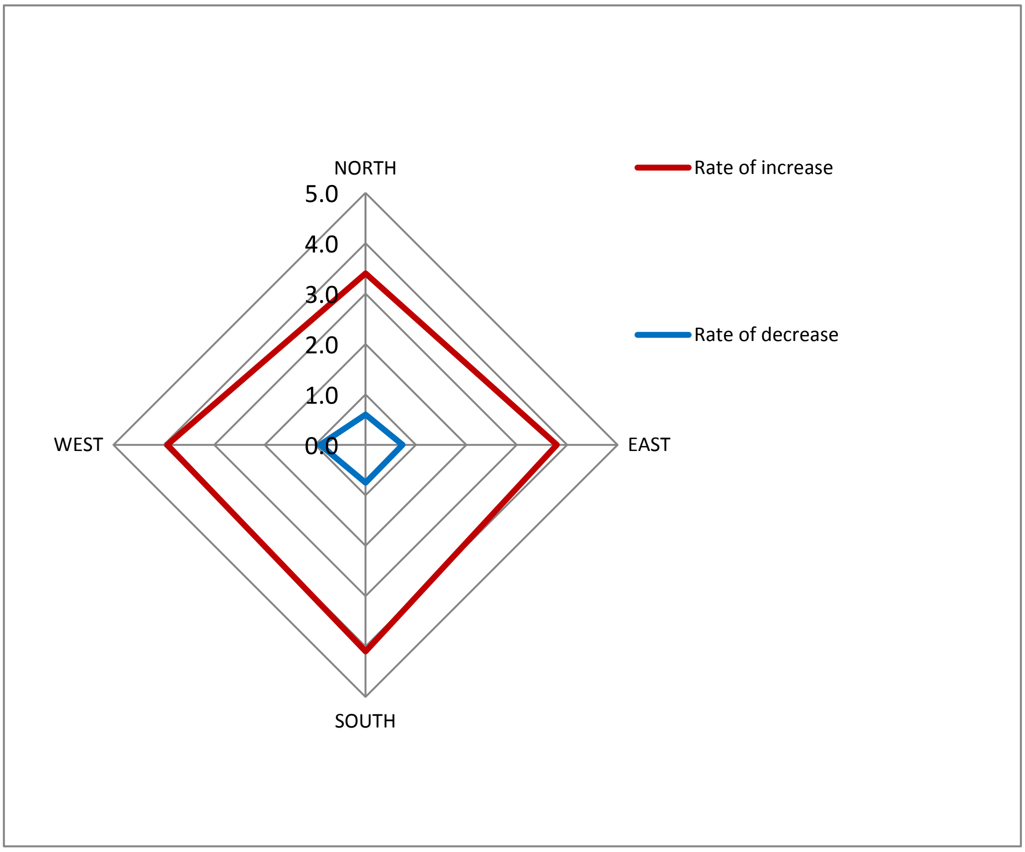


Figure (8): Rate of increase and decrease of four main orientations

7-2-1Simulation Results Analysis:

Thermal difference (above 28°c) is much greater than thermal difference (below 21° c),indicating the higher need for cooling as compared to the need for heating ,so design considerations should be taken at the summer period (above 28°c).

North is best orientation then east, west and south, respectively.

The highest difference (above 28°c) is the south orientation (4296)while the lowest difference(above 28°c)is the north orientation (2927).The highest difference (below 21° c) is the north orientation (240) while the lowest difference(below 21° c)is the south orientation (150).

That is because In the northern hemisphere summer the sun rises north of due east and sets north of due west, In the winter the sun rises south of due east and sets south of due west, So south orientation acts as a sun collector, thermal differences at east and west also high (above 28°c)due to low sun angle at morning and afternoon, as shown at figures (9), (10).

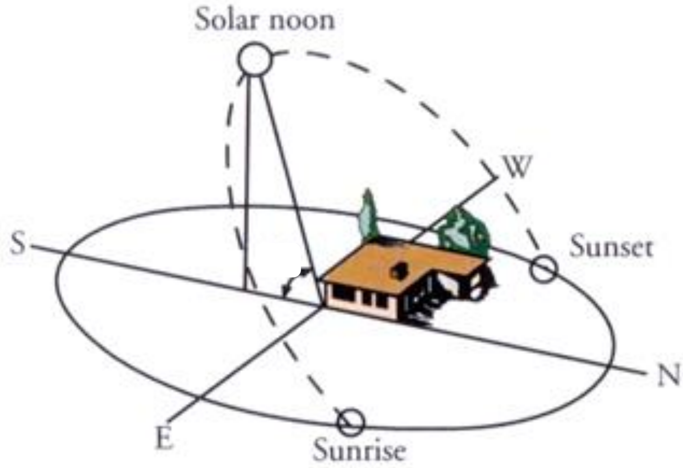


Figure (9): Sun path on summer

Source:homes window shading, http://www.fsec.ucf.edu., last accessed: 21-6-2014

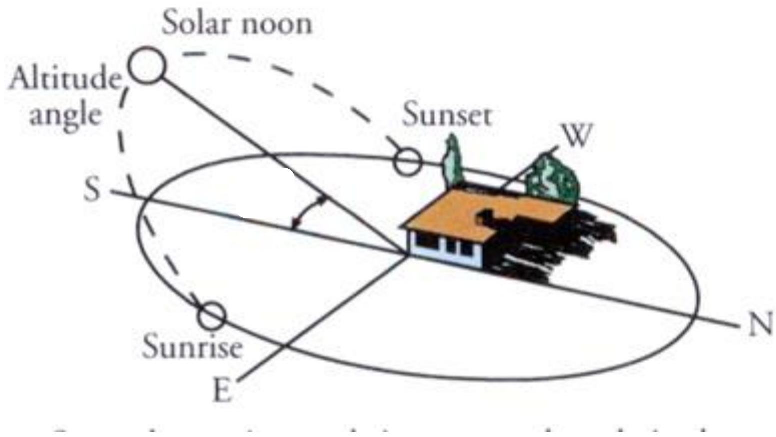


Figure (10): Sun path on winter

Source:homes window shading, http://www.fsec.ucf.edu., last accessed: 21-6-2014

Building envelope components should be modified to reduce the thermal differences and hours of discomfort.

8 – Alternatives Analysis:

Three parameters for each of the investigated components of classroom envelope (wall- glazing-shading devices) were studied; these alternatives are shown at figure (11).

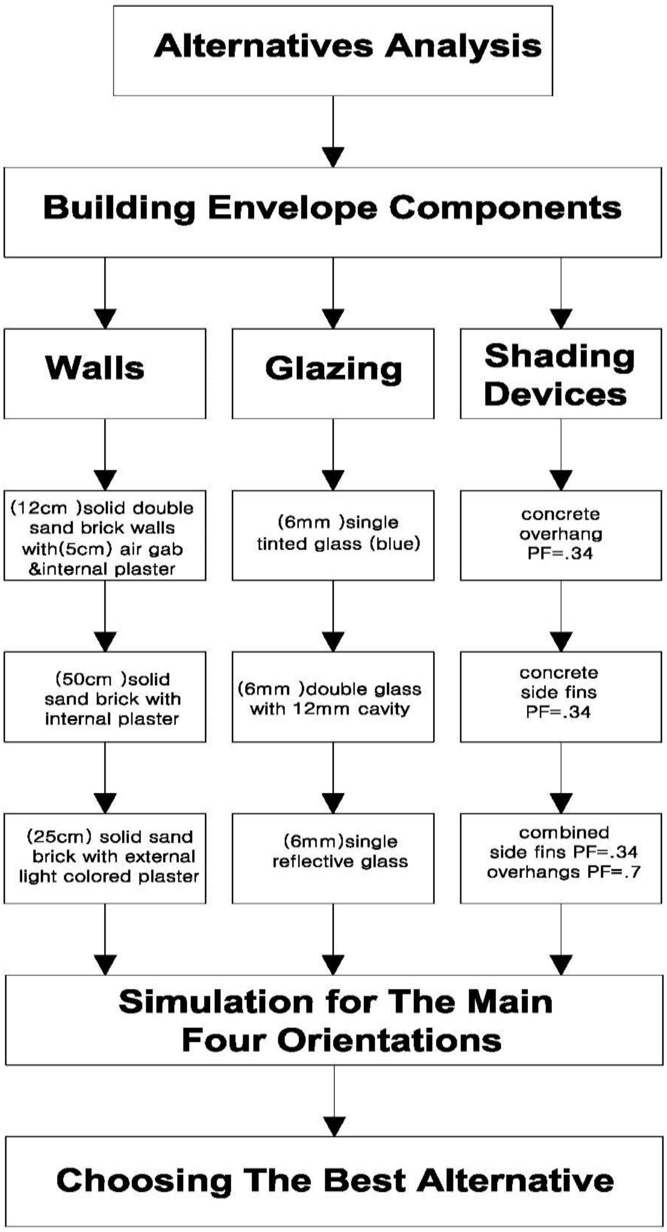


Figure (11): Alternatives analysis

9-Investigated Parameters:

9-1 Walls :

The effectiveness of a building in conserving energy is dependent upon the effectiveness of its walls, floor, roof, windows and doors in reducing the rate of heat escaping from the internal environment of the building to the outside. The ability of a wall, floor, roof, window or door to impede heat loss from a building is described in terms of its thermal transmittance (U-value), which is expressed as the transfer of heat in watts per square metre of area per degree difference in temperature. A wall, roof or floor that is well insulated will have a low U-value whereas one which is poorly insulated will have a high U-value. [1]

The heat transfer through building walls has been the subject of considerable investigation in the past, but the wide discrepancies in existing data seem to warrant further investigation, at least to the point where the heat transfer through the more common types of exterior walls can be estimated with a fair degree of approximation. This has been possible since the thermal transmittance (U- valu) of materials is either known or easily measured.[2]

Thermal Mass works on the principle that heat will always move towards cold. Thermal mass stores heat causing a lag between internal and external temperatures, as shown at figure (12).

This is unlike insulation which slows the transfer of heat. Most Thermal Mass has a low resistance (R Value) and therefore absorbs heat quickly. On a summer day the Thermal Mass can absorb the heat in the room and store it. When insulated from the exterior, the mass is prevented from also absorbing the unwanted heat from outside.[3]

1- Doran,S.,Carr.B.,Thermal transmittance of walls of dwellings before and after application of cavity wall insulation , Building Research Establishment Ltd,Scotlan, March 2008,p10

2- Op. cit. :what-is-a-building-envelope.

3- Thermal Mass Strategies ,http://www.mognot.com, last accessed 20-6-2014.

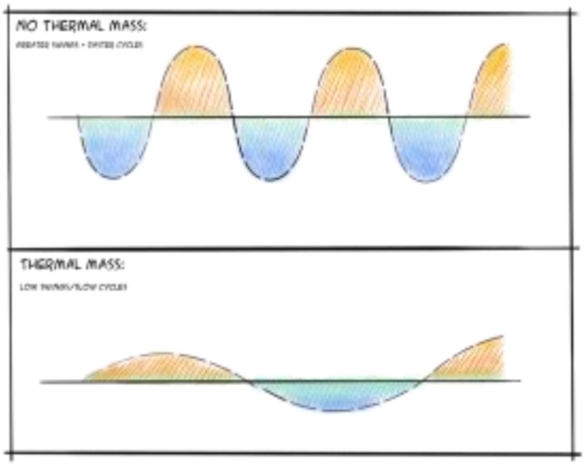


Figure (12): Thermal mass stores heat causing a lag
Source: Thermal Mass Strategies ,http://www.mognot.com, last accessed 20-6-2014.

The effect during the summer months is warmer nights and cooler days. Thermal mass works effectively where there are significant diurnal temperature swings. Once the mass has absorbed the excess heat in the room, it will store it until the air in the room becomes cooler than the mass. Once the heat is being released back into the room, Night Purge ventilation is used to evacuate it from the building, as shown at figures (13), (14).[1]

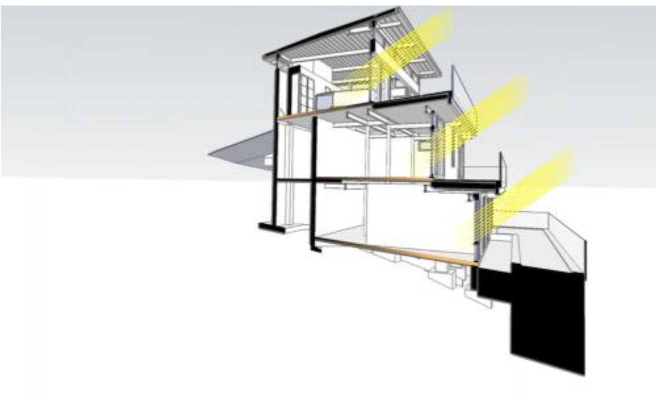


Figure (13): Thermal mass absorbing energy from sunlight

Source: Thermal Mass Strategies ,http://www.mognot.com, last accessed 20-6-2014.

1- Op. cit.: Thermal Mass Strategies.

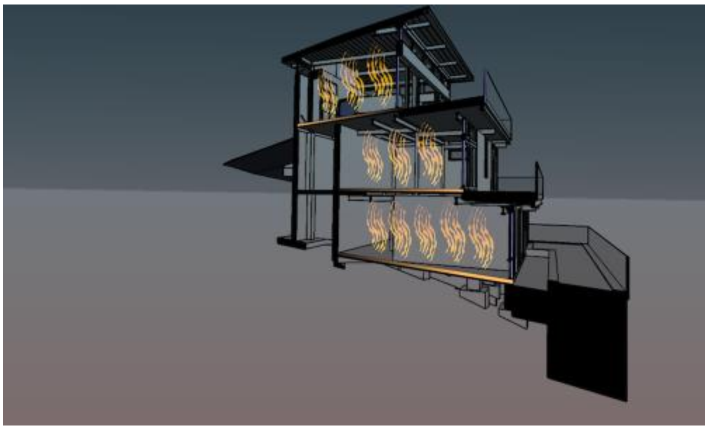


Figure (14): Thermal mass re-radiating heat at night

Source: Thermal Mass Strategies,http://www.mognot.com, last accessed 20-6-2014.

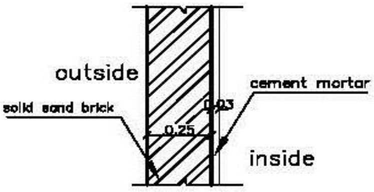
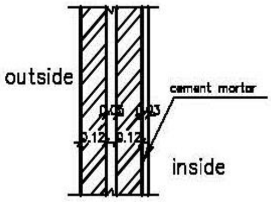
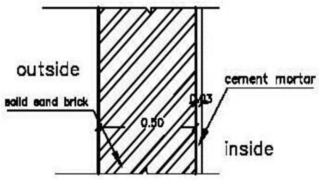
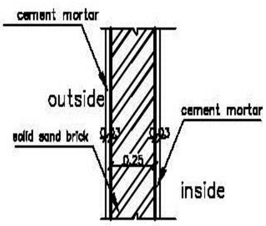
Specific methods to prevent heat gain include reflecting heat (i.e., sunlight) Dull, dark-colored building exteriors absorb 70% to90% of the radiant energy from the sun that strikes the surfaces. Some of this absorbed energy is then transferred into the building by way of conduction, resulting in heat gain. In contrast, light colored surfaces effectively reflect most of the heat away from building envelope. Wall color affects heat gain. White exterior walls absorb less heat than dark walls. And light, bright walls increase the longevity of siding, particularly on the east, west, and south sides of the building.[1]

So, There are Specific methods to prevent heat gain include reflecting heat (i.e., sunlight) away from building envelope , blocking the heat, removing built-up heat, and reducing or eliminating heat generating sources in the building .

These methods should be simulated to select the best one for the investigated school classroom; the selected alternatives for the wall alternatives according to (u-values) at the table (3)

1- Cooling Your Home Naturally,www.nrel.gov/docs/legosti/old/15771.pdf, last accessed 20-6-2014.

Table (3): The selected wall parameters

Type	Figure	LAYERS	U-VALUE(W/ M^2-K)
(25 cm) solid sand brick with internal painting(base case)	 (25 CM)SINGLE WALL	1-(25 cm) solid sand brick 2-(3cm) internal cement plaster.	1.827
(12cm) solid double sand brick walls with(5 cm) air gab in between	 (12 CM)DOUBLE WALL WITH (5CM) CAVITY	1-(12 cm) solid sand brick 2-(5 cm)air gap 3-(12 cm) solid sand brick 4- (3cm) internal cement plaster	0.942
(50 cm) solid sand brick	 (50CM)SINGLE WALL	1-(50 cm) solid sand brick(base case) 2-(3cm) internal cement plaster	1.738
(25 cm) solid sand brick walls with external light colored plaster	 (25 CM)SINGLE WALL WITH OUTER PAINTING	1-(3 cm) cement mortar 2-(25 cm) solid sand brick(base case) 3-(3 cm) cement plaster with light colored plaster	1.711

9-2 Glazing:

Windows are very important component of the building envelope, in addition to providing physical and visual connection to outside; it also allows heat and light in and adds beauty to the building. [1]

Glass windows are common used in many large offices, commercial and educational buildings. For a country located in the tropical zone (hot climate) like Egypt, glass windows installed in buildings act as a means of admitting large amounts of solar radiation into buildings, applied film to the glass window has become the easiest way to change building envelope properties in reducing the heat gain. Glass windows that are commonly used in buildings can be classified according to number of layers as single pane glass and double pane glass. Glass is also classified according to the type as clear, tinted, reflective and low-e glass. Clear glass and tinted glass are usually referred to the same group according to the manufacturing method. Reflective, low-e and glass applied with film are usually referred to another group.[2]

Double glazed windows are made from two panes of glass that are separated by a layer of air or gas and then sealed. They are designed to provide a better barrier against outside temperatures than single paned windows because the two layers of glass and the buffer layer act as insulators, Double glazing is now widely used in nearly all locations, both for new construction and as replacement windows.[3]

The amount of solar radiation that can pass through a window or skylight can be measured in terms of its solar heat-gain coefficient, or SHGC.

1- ECBC Envelope for Hot & dry Climate ,http:// high-performance buildings .org, last accessed 20-6-2014.

2- Chaiyapinunt.S ., Khamporn.N., SELECTINELECTING GLASS WINDOW WITH FILM FOR BUILDINGS IN A HOT CLIMATE, Chulalongkorn University, Thailand,p2.

3- Ibid: Envelope for Hot & dry Climate .

SHGC is best described as a ratio where 1 equals the maximum amount of solar heat allowed through a window, and 0 equals the least amount possible allowed through. An SHGC rating of 0.30 means that 30% of the available solar heat can pass through the window. the type of window, as well as the glass, affect the SHGC rating.[1]

The ability to quantify how much solar heat a particular type of glass can block is even more useful as manufacturers have recently begun to experiment with different treatments for window panes intended to influence SHGC. Tinted and reflective glass have been in use for some time now, Spectrally selective glass has recently gained in popularity, as well, utilizing tints and coatings, including special low- emittance coatings, to further affect how windows perform in relation to solar heat. The SHGC rating allows for easy comparison of these different products' attributes.[2]

The glass types selected for simulation to investigate thermal performance of the class room according to (SHGC) values are at the table (4).

Table (4): The selected glazing parameters

Type	**SHGC(Solar Heat Gain Coefficient)**
(6mm)single clear glass(base case)	0.82
(6mm)single Tinted glass(blue)	0.65
(6mm)double glass with 12mm cavity	0.7
(6mm)single reflective glass	0.39

1- Solar Heat-Gain Coefficient Ratings forWindows – InterNACHI , http://www.nachi.org ,last accessed 20-6-2014.

2- Ibid:Solar Heat-Gain Coefficient Ratings for Windows.

9-3Shading Devices:

Shading is a means of controlling radiation that may enter a building. Solar radiation through glazing areas is welcome during the winter but not desired during the summer. In order to control sun penetration to the interior of buildings it is important to provide exterior shading as a part of the architectural envelope design. Such shading devices can be attached to the building or can be achieved by the articulation and disposition of the building floors to create overhangs .Exterior shading is greatly preferred over interior shading as it is important to keep the solar radiation/heat from entering the building. Traditional interior blinds merely block the glare of the sun, but still allow the heat to enter the interior space, as figure shows (15).[1]

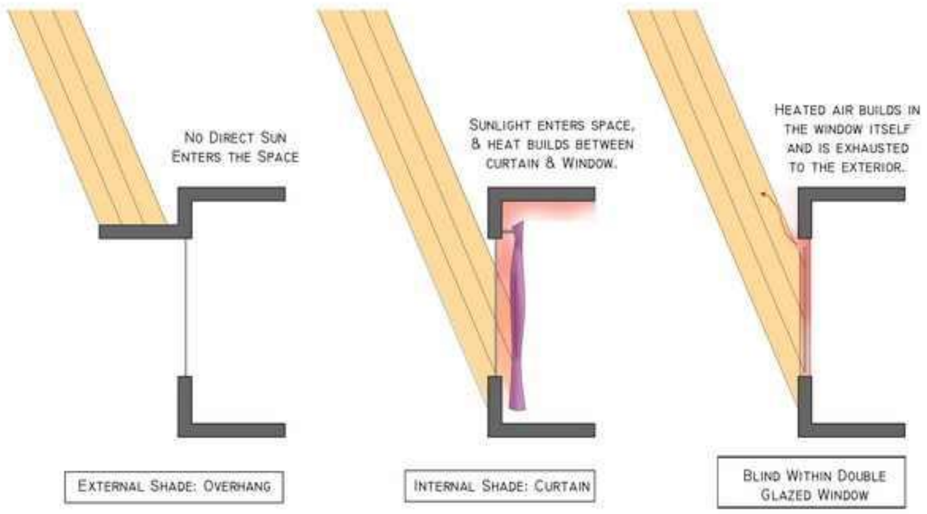


Figure (15):Shading devices locations

Source: shading, http://www.tboake.com/carbon-aia/strategies1b.html ,last accessed 20-6-2014..

9-3-1 Shading devices Types:

Two basic types of exterior shading device are horizontal and vertical, varies combination of those creates many configurations to accommodate different envelop shapes and orientations.[2]

1- Shading, http://www.tboake.com/carbon-aia/strategies1b.html,last accessed 20-6-2014.

2- Shading & Redirecting Sunlight,http://sustainabilityworkshop.autodesk.com ,last accessed 20-6-2014.

Both latitude and orientation contribute to the formulation of an effective shading device .Heat radiation is most effectively halted before it reaches the building envelope. Hence exterior shading devices are more effective. Given the wide variety of buildings and the range of climates in which they can be found, it is difficult to make sweeping generalizations about the design of shading devices. However, the following design considerations are true:

- Continuous horizontal overhangs adequate in the south.

- For east and west orientations The vertical exterior shading devices and a combination of vertical and horizontal shading devices are necessary as the sun subtends low altitude angles, as shown at figure (16).[1]

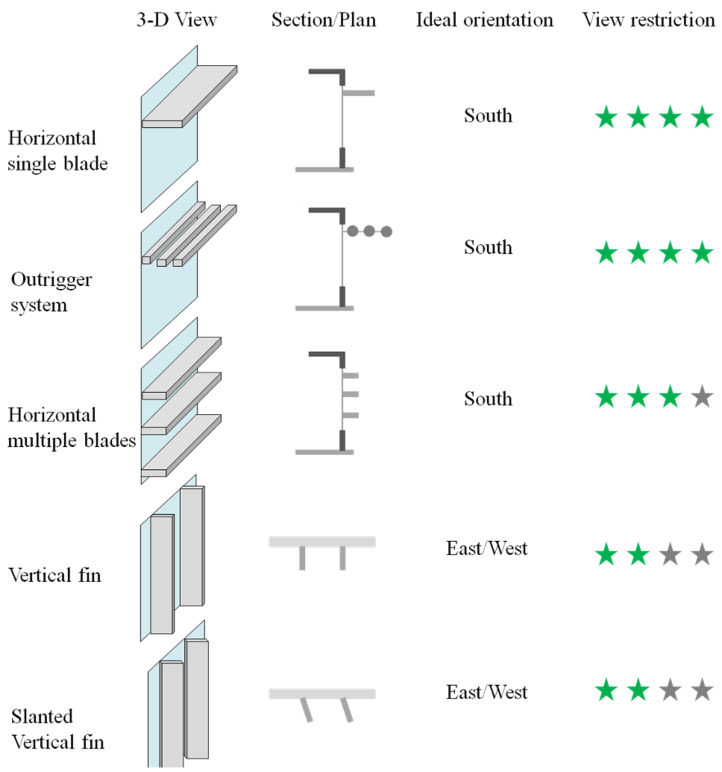
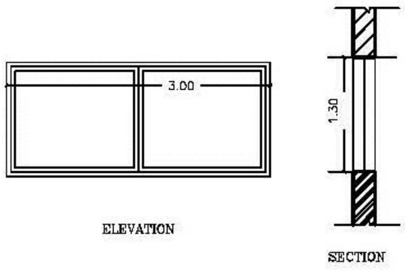
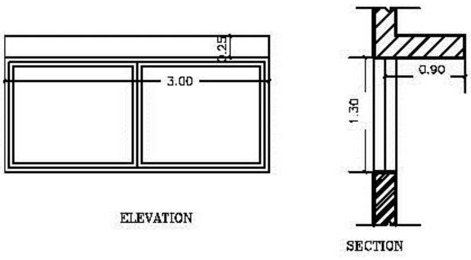
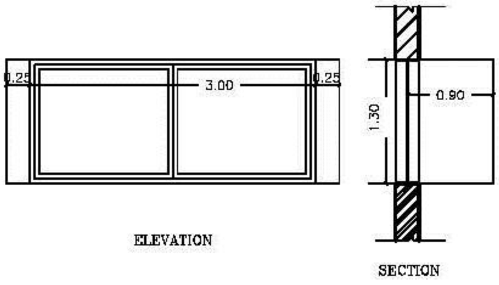
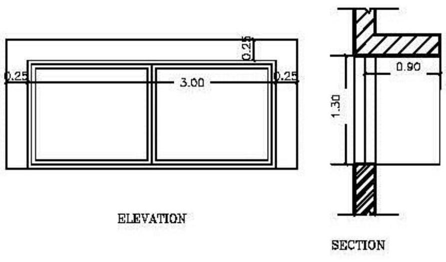


Figure (16) **:**Shading devicestypes
Source: Shading & Redirecting Sunlight, http://sustainabilityworkshop.autodesk.com,last

1- Po. cit.:Shading & Redirecting Sunlight

The shading types selected for simulation to investigate their influence on the four main orientations of the class room according to projection factor (PF) values are at the table (4).

Table (5): The selected shading devices parameters

type	Figure	Projection Factor(PF)
no shading device(base case)		
concrete over hang		0.34
concrete vertical side fins		0.34
combined(90 cm)projection side fins &(90 cm)projection over hang		Overhang, PF=.7 Side fin ,PF=.34

10- Simulation Results

10-1 North Orientation:

10-1-1 Wall Parameters:

Table (6)presents simulation results after testing wall alternatives on the north orientation . Figures (17), (18) present best wall alternatives compared to the base case.

Table (6): Simulation results of wall alternatives

number	1	2	3	4
Type	(25 cm) solid sand brick (base case)	(12cm) solid double sand brick walls with(5 cm) air gab in between	(50 cm) solid sand brick	(25 cm) solid sand brick walls s with external light colored plaster
Temperature differences (above 28 c)	2927	3114	2953	2767
No. of hours (above 28c)	861	898	870	844
Rate of increase	3.40	3.47	3.39	3.28
Temperature differences (below 21 c)	-24	-18	-18	-20
No. of hours (below 21 c)	40	20	30	30
Rate of decrease	-0.60	-0.90	-0.60	-0.67

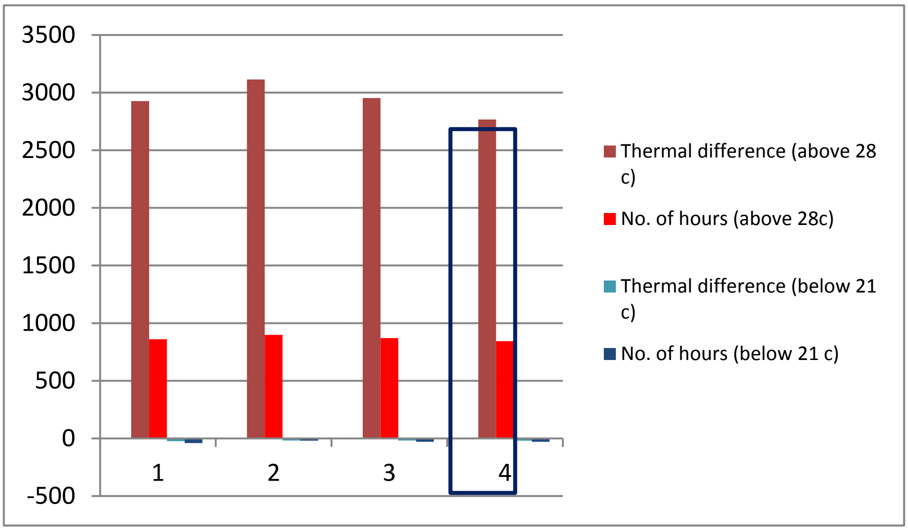


Figure (17): Simulation results of wall alternatives & the best one for north orientation

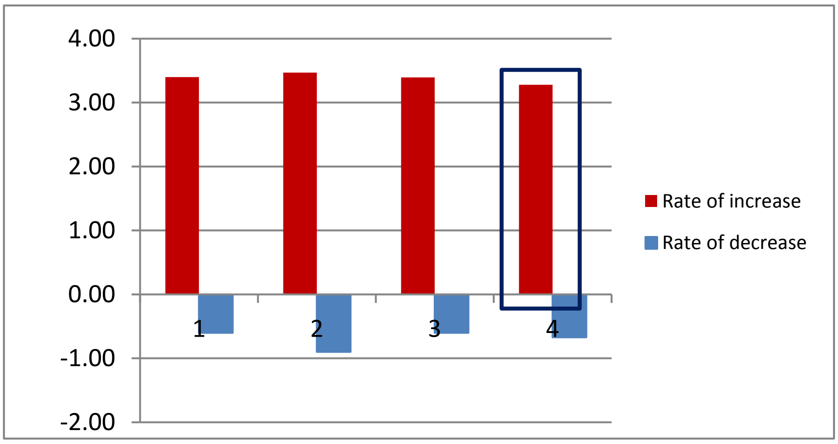


Figure (18): Rate of increase and decrease, showing the best wall alternative for north orientation

10-1-1-1 Simulation Results Analysis:

Thermal difference (above 28°c) is much greater than thermal difference (below 21° c),indicating the higher need for cooling as compared to the need for heating , so design considerations should be taken at the summer period (above 28°c).

The best wall alternatives are: (25 cm) solid sand brick walls with external light colored plaster (alternative 4) , (25cm) solid sand brick (base case),(50 cm) solid sand brick(alternative 3), (12cm) solid double sand brick walls with(5 cm) air gab in between respectively (alternative 3) .

The best and worst alternatives results are compared to the base case result(above 28°c) to show magnitude of improvement, by this method: Improvement percentage=[(base case result-alternative result)/base case result].For the best alternative(light colored),it was (5.4%) and for the worst alternative(double wall) it was (-6.3%).

Wall with external light colored plaster (alternative 4)is the best at the summer period as the light colored plaster reflects most of sun heat, In contrast, dark-colored (base case) absorbs radiant energy from the sun . Some of this absorbed energy is then transferred into the building by way of conduction, resulting in heat gain.

Double wall(alternative 2) was the worst during summer as the wall minimizes heat loss, it will be effective at air conditioned spaces and at winter ,as double wall is the lowest thermal difference (below 21°c).

Thermal mass (alternative 3),wasn't the best as the wall stores the heat until the air temperature of the room drops when the sun goes down, the heat is trapped by the walls during night, so it was needed night ventilation to evacuate heat.

10-1-2 Glazing Parameters:

Table (7)presents simulation results after testing glazing alternatives on the north orientation. Figures (19), (20) presents best glazing alternatives compared to the base case.

Table (7): Simulation results of glazing alternatives

number	1	2	3	4
Type	(6mm)single clear glass(base case)	(6mm) single Tinted glass(blue)	(6mm)double glass with 12mm cavity	(6mm)single reflective glass
Temperature differences (above 28 c)	2927	2904	3022	2752
No. of hours (above 28c)	861	861	881	851
Rate of increase	3.40	3.37	3.43	3.23
Temperature differences (below 21 c)	-24	-25	-18	-24
No. of hours (below 21 c)	40	40	30	40
Rate of decrease	-0.60	-0.63	-0.60	-0.60

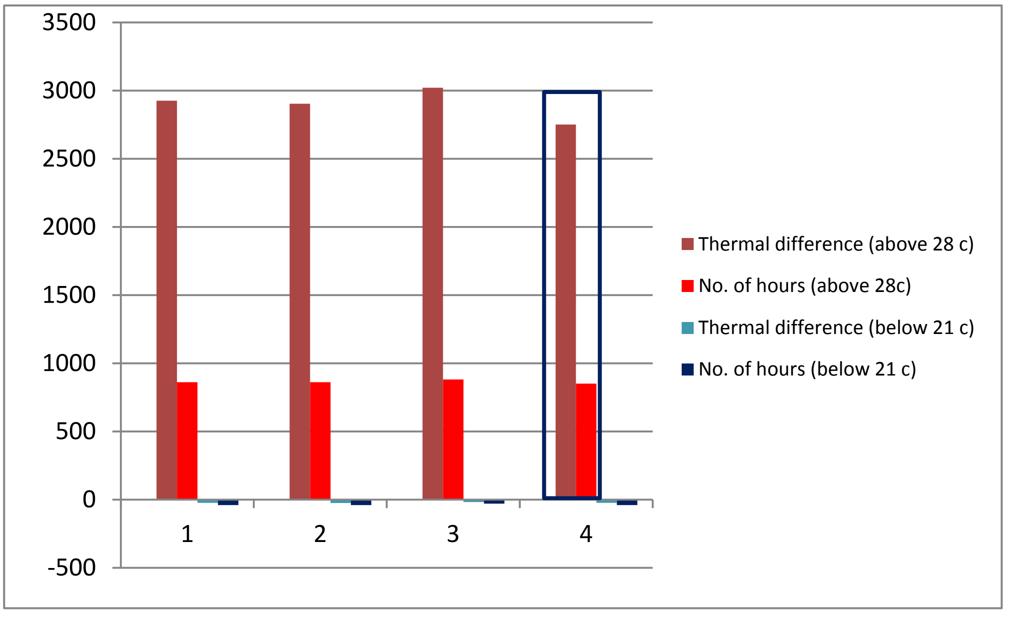


Figure (19): Simulation results of glazing alternatives & the best one for north orientation

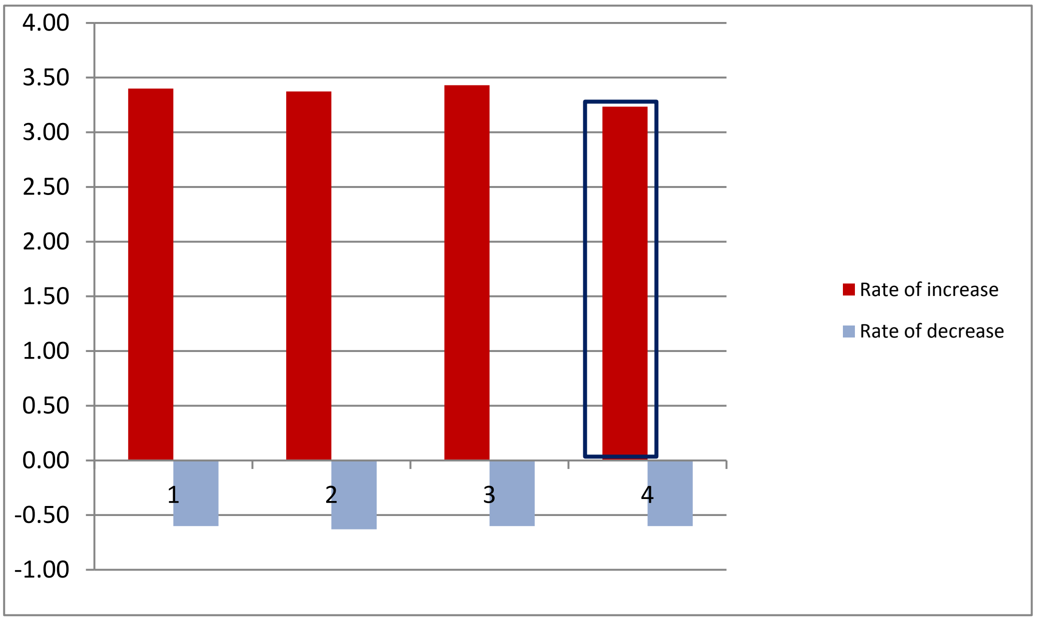


Figure (20): Rate of increase and decrease showing the best glazing alternative for north orientation

10-1-2-1 Simulation Results Analysis:

Thermal difference (above 28°c) is much greater than thermal difference (below 21° c),indicating the higher need for cooling as compared to the need for heating , so design considerations should be taken at the summer period (above 28°c).

The best glazing alternatives are: single reflective glass (alternative 4) , single Tinted glass (alternative 2) , single clear glass(base case) , double glass alternative(3) ,respectively.

The best and worst alternatives results are compared to the base case result (above 28°c) to show magnitude of improvement, by this method: Improvement percentage = [(base case result-alternative result)/base case result].For the best alternative (reflective glass),it was (6%) and for the worst alternative (double glass), it was (-3.2%).

Reflective glass (alternative 4), was effective and the best, as most of sun radiation will be reflected.

Single Tinted glass(alternative 2),was effective but wasn't the best, because some of received solar radiation absorbed in the glazing and indirectly admitted to the inside.

Base case (1) wasn't effective at summer because radiation is directly transmitted through the glazing to the building as the value of (SHGC) is too high.

Double glass (alternative 3) wasn't effective , as the two glass layers act as insulators and minimize heat loss so, heat is trapped inside the

classroom , it could be more effective at air conditioned spaces and at winter as double glass recorded the lowest thermal difference (below 21°c).

10-1-3 Shading Devices Parameters:

Table (8)presents simulation results after testing shading devices alternatives on the north orientation .Figures (21), (22) presents best shading devices alternatives compared to the base case.

Table (8): Simulation results of shading devices alternatives for north orientation

number	1	2	3	4
Type	no shading device(base case)	Concrete overhang(PF=.34)	concrete vertical side fins(PF=.34)	combined(90 cm)projection side fins &(90 cm)projection overhangs
Temperature differences (above 28 c)	2927	2894	2886	2831
No. of hours (above 28c)	861	860	858	858
Rate of increase	3.40	3.37	3.36	3.30
Temperature differences (below 21 c)	-24	-23	-23	-21
No. of hours (below 21 c)	40	40	40	30
Rate of decrease	-0.60	-0.58	-0.58	-0.70

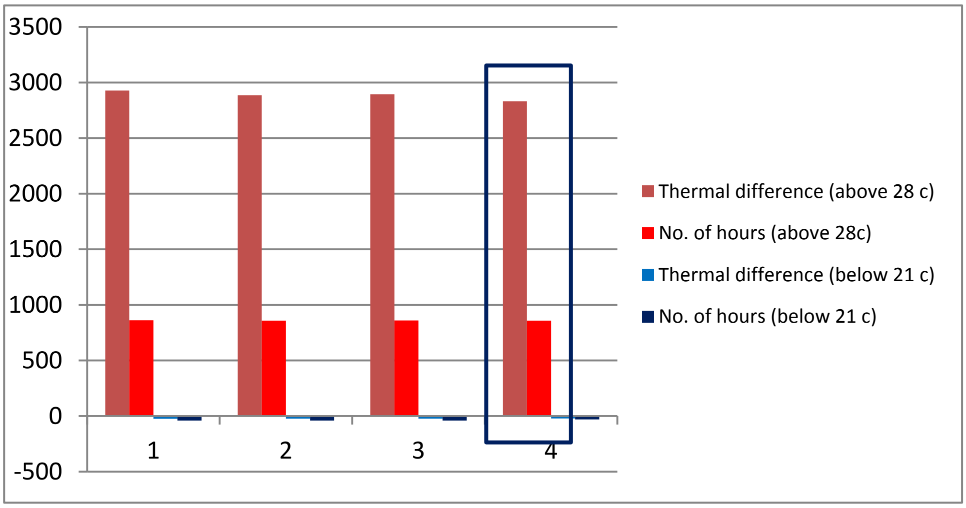


Figure (21): Simulation results of shading devices alternatives & the best one for north orientation

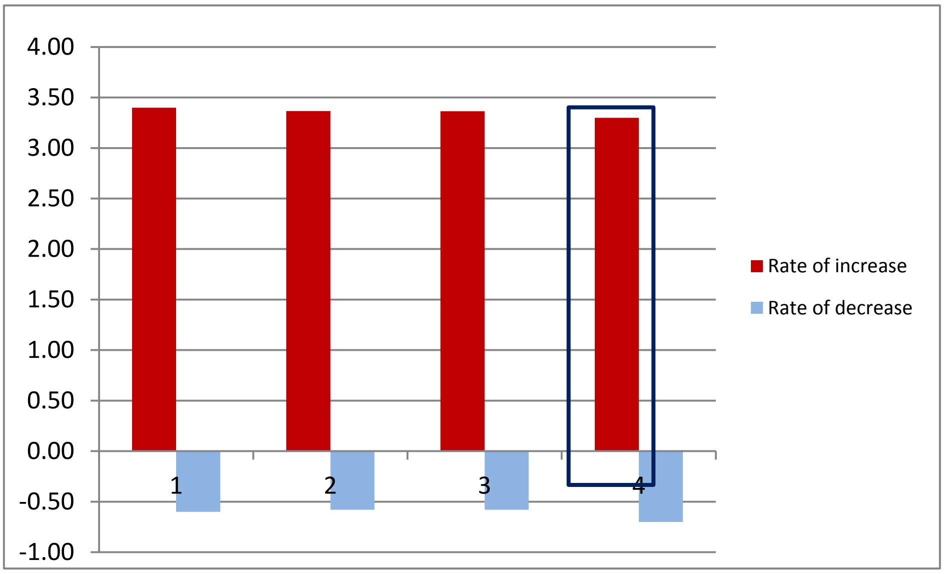


Figure (22): Rate of increase and decrease showing the best shading device alternative for north orientation

10-1-3 -1 Simulation Results Analysis:

Thermal difference (above 28°c) is much greater than thermal difference (below 21° c),indicating the higher need for cooling as compared to the need for heating , so design considerations should be taken at the summer period (above 28°c).

The best shading devices alternatives are: combined shading device (alternative 4),overhangs (alternative2),side fins (alternative 3),no shading (base case),respectively.

The best and worst alternatives results are compared to the base case result (above 28°c) to show magnitude of improvement, by this method: Improvement percentage = [(base case result-alternative result)/base case result].For the best alternative (combined shading device),it was (3.2%) and for the worst alternative (side fins), it was (1.1%), Improvement percentage is also calculated for (overhangs)and it was(1.4%) which means that overhang is near in its result to side fin, so overhangs and side fins are also effective during summer.

The combined shading device is the best alternative as it prevents solar radiation from reaching to the building envelope more than overhangs and side fins.

10-1-4North Orientation Combined Results:

Figure (23) shows that the best alternatives of building envelope for the north orientation are: wall with external light plaster, reflective glass and combined shading device.

The most effective alternative is **reflective glass** as it recorded the lowest thermal difference during summer.

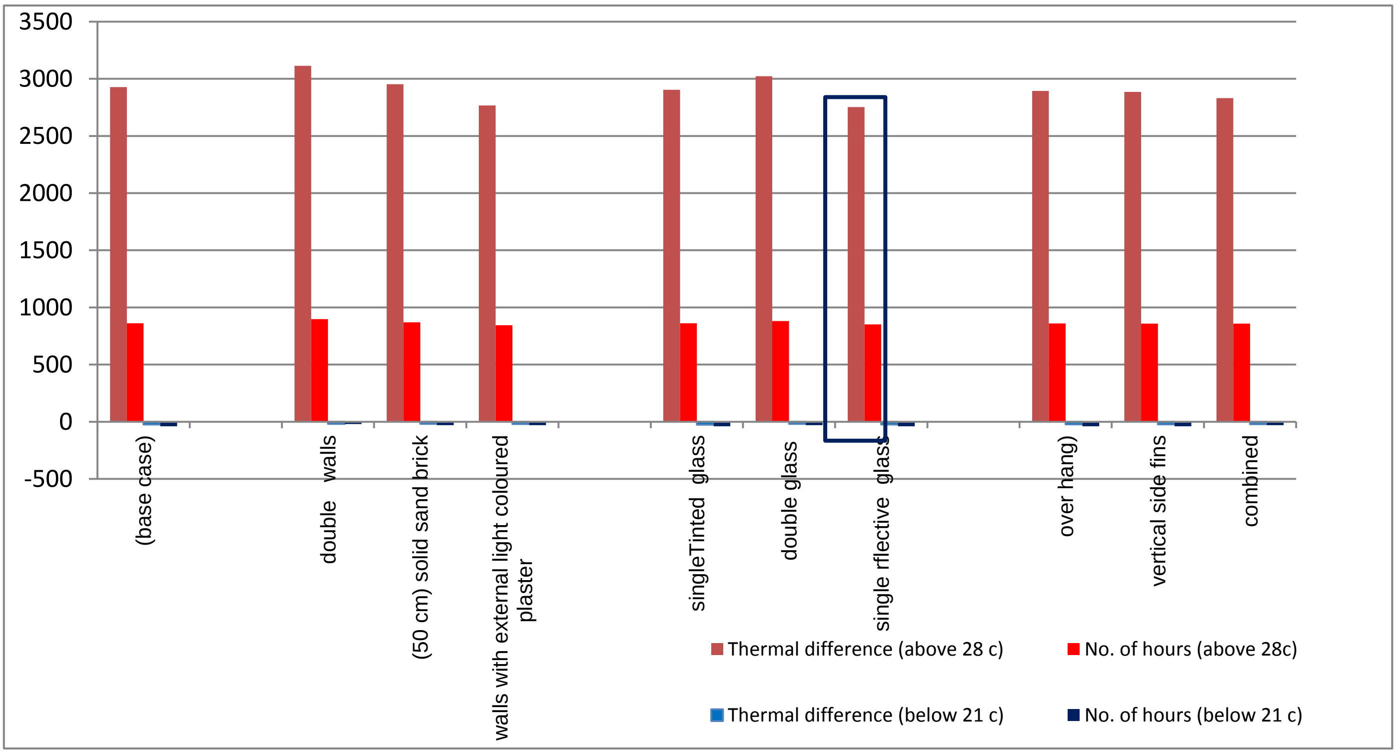


Figure (23): North orientation combined results

10-2EastOrientation:

10-2-1Wall Parameters:

Table (6)presents simulation results after testing wall alternatives on the east orientation. Figures (24), (25) present best wall alternatives compared to the base case.

Table (9): Simulation results of wall alternatives for east orientation

number	1	2	3	4
Type	(25 cm) solid sand brick(base case)	(12cm) solid double sand brick walls with(5 cm) air gab in between	(50 cm) solid sand brick	(25 cm) solid sand brick walls with external light colored plaster
Temperature differences (above 28 c)	3373	3537.6	3397	3162
No. of hours (above 28c)	889	922	895	872
Rate of increase	3.79	3.84	3.80	3.63
Temperature differences (below 21 c)	-23	-14	-17	-19
No. of hours (below 21 c)	30	20	30	30
Rate of decrease	-0.77	-0.70	-0.57	-0.63

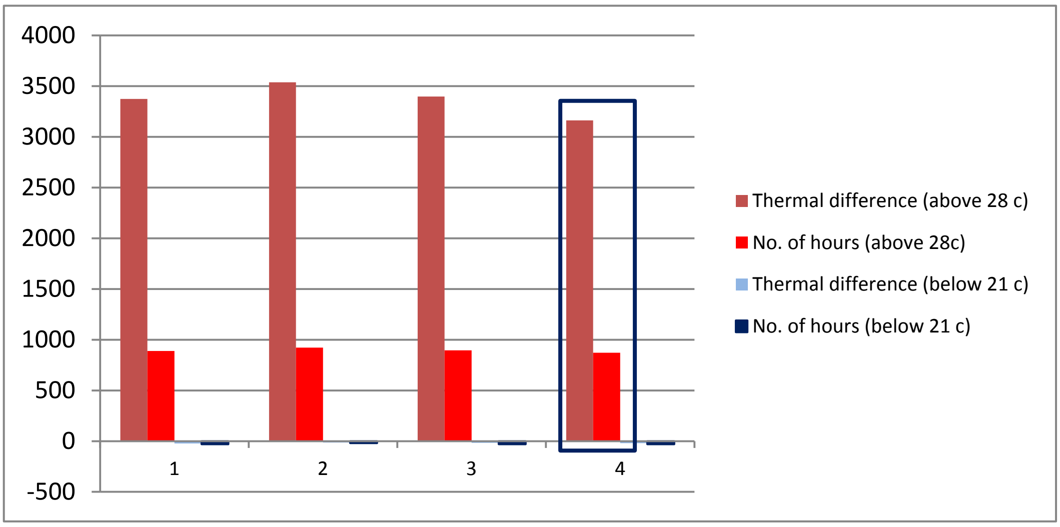


Figure (24): Simulation results of wall alternatives & the best one for east orientation

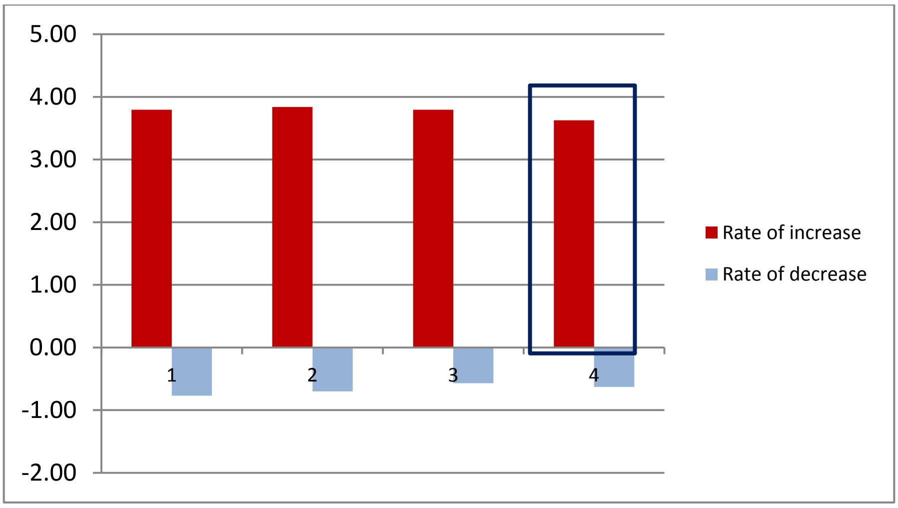


Figure (25): Rate of increase and decrease& the alternative wall al for east orientation

10-2-1-1 Simulation Results Analysis:

Thermal difference (above 28°c) is much greater than thermal difference (below 21° c),indicating the higher need for cooling as comparedto the need for heating , so design considerations should be taken at the summer period (above 28°c).

The best wall alternatives are: (25 cm) solid sand brick walls with external light colored plaster (alternative 4), (25cm) solid sand brick(base case),(50 cm) solid sand brick(alternative 3) ,(12cm) solid double sand brick walls with(5 cm) air gab in between (alternative 3) , respectively.

The best and worst alternatives results are compared to the base case result (above 28°c) to show magnitude of improvement, by this method: Improvement percentage = [(base case result-alternative result)/base case result].For the best alternative (light colored),it was (6.2%) and for the worst alternative (double wall) it was (-4.8%).

Wall with external light colored plaster (alternative 4)is the best at the summer period as the light colored plaster reflects most of sun heat, In contrast, dark-colored (base case) absorbs radiant energy from the sun .

Some of this absorbed energy is then transferred into the building by way of conduction, resulting in heat gain.

Double wall(alternative 2) was the worst during summer as the wall minimizes heat loss, it will be effective at air conditioned spaces and at winter ,as double wall is the lowest thermal difference (below 21°c).

Thermal mass (alternative 3),wasn't the best as the wall stores the heat until the air temperature of the room drops when the sun goes down, the heat is trapped by the walls during night, so it was needed night ventilation to evacuate heat.

10-2-2Glazing Parameters

Table (6)presents simulation results after testing wall alternatives on the east orientation. Figures (26), (27) present best wall alternatives compared to the base case.

number	1	2	3	4
Type	(6mm)single clear glass(base case)	(6mm)single Tinted glass(blue)	(6mm)double glass with 12mm cavity	(6mm)single reflective glass
Temperature differences (above 28 c)	3373	3297	3406	3012
No. of hours (above 28c)	889	886	902	865
Rate of increase	3.78	3.72	3.79	3.48
Temperature differences (below 21 c)	-23	-23	-17	-23
No. of hours (below 21 c)	30	30	30	30
Rate of decrease	-0.77	-0.77	-0.57	-0.77

Table (10): Simulation results of glazing alternatives for east orientation

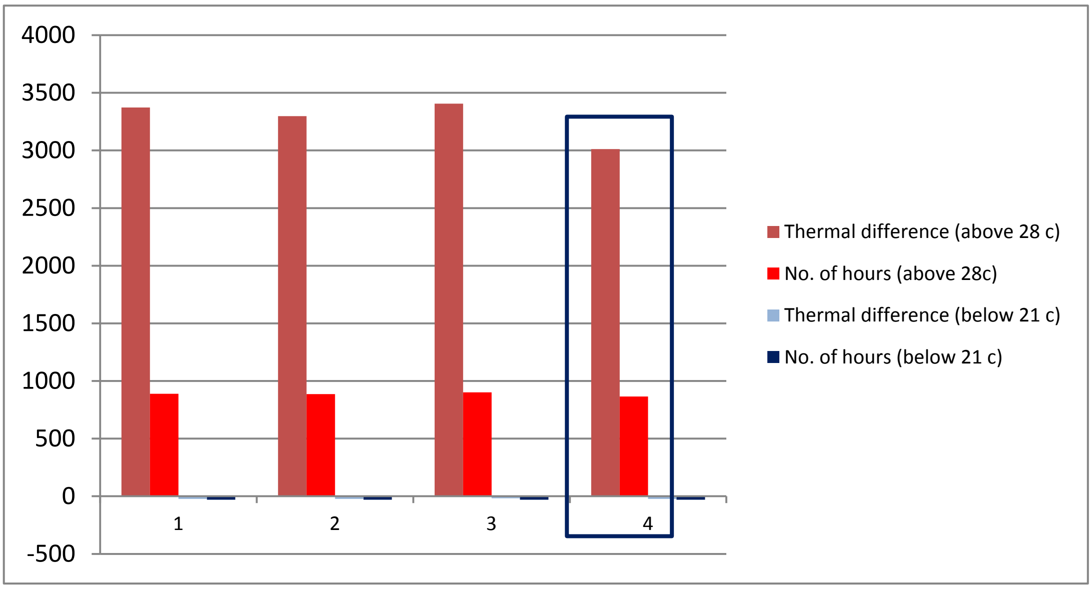


Figure (26): Simulation results of glazing & the best one for east orientation

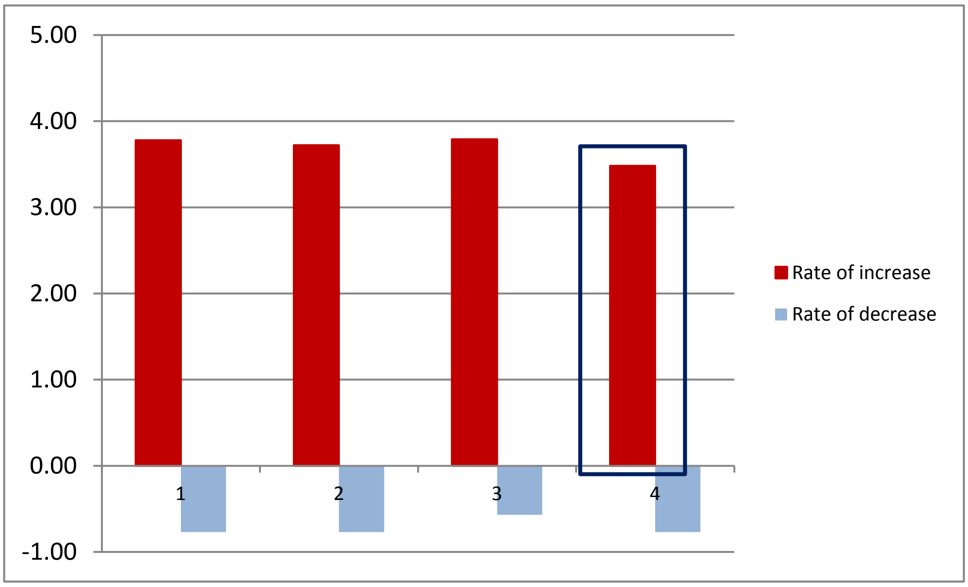


Figure (27): Rate of increase and decrease showing the best glazing alternative for east orientation

10-2-2-1 Simulation Results Analysis:

Thermal difference (above 28°c) is much greater than thermal difference (below 21° c),indicating the higher need for cooling as compared to the need for heating , so design considerations should be taken at the summer period (above 28°c).

The best glazing alternatives are: single reflective glass (alternative 4) , single Tinted glass (alternative 2) , single clear glass(base case) , double glass alternative(3) ,respectively.

The best and worst alternatives results are compared to the base case result (above 28°c) to show magnitude of improvement, by this method: Improvement percentage = [(base case result-alternative result)/base case result].For the best alternative (reflective glass),it was (10.7%) and for the worst alternative (double glass), it was (-.9%).

Reflective glass (alternative 4), was effective and the best, as most of sun radiation will be reflected.

Single Tinted glass (alternative 2), was effective but wasn't the best, because some of received solar radiation absorbed in the glazing and indirectly admitted to the inside.

Base case (1) wasn't effective at summer because radiation is directly transmitted through the glazing to the building as the value of (SHGC) is too high. But it will not reduce the transmitted light.

Double glass (alternative 3) wasn't effective , as the two glass layers act as insulators and minimize heat loss so, heat is trapped inside the classroom , it could be more effective at air conditioned spaces and at winter as double glass recorded the lowest thermal difference (below 21°c).

10-2-3Shading Devices Parameters:

Table (8)presents simulation results after testing shading devices alternatives on the north orientation .Figures (28), (29) presents best and worst shading devices alternatives compared to the base case.

Table (11): Simulation results of shading devices alternatives for east orientation

number	1	2	3	4
Type	no shading device (base case)	Concrete overhang (PF=.34)	concrete vertical side fins(PF=.34)	combined(90 cm)projection side fins &(90 cm)projection overhangs
Temperature differences (above 28 c)	3373	3291	3143	2934
No. of hours (above 28c)	889	876	873	855
Rate of increase	3.78	3.76	3.60	3.43
Temperature differences (below 21 c)	-23	-22	-22	-21
No. of hours (below 21 c)	30	30	30	30
Rate of decrease	-0.77	-0.58	-0.58	-0.70

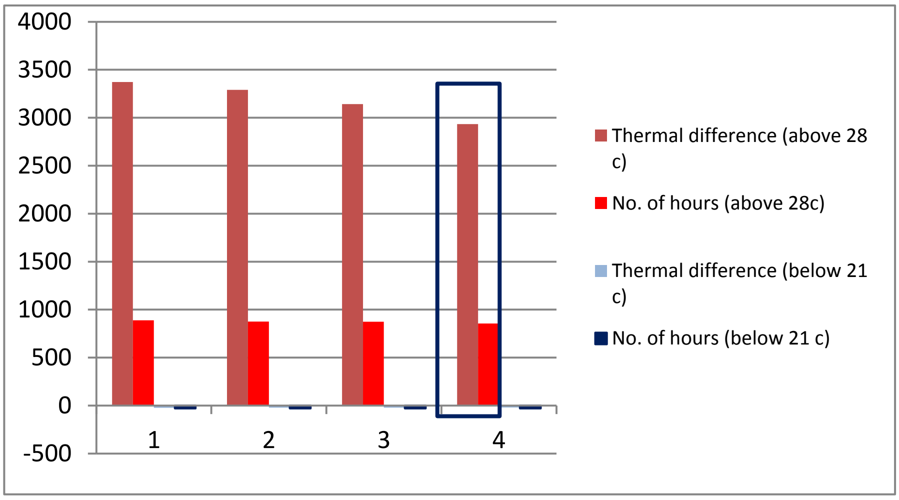


Figure (28): Simulation results of Shading devices & the best one for east orientation

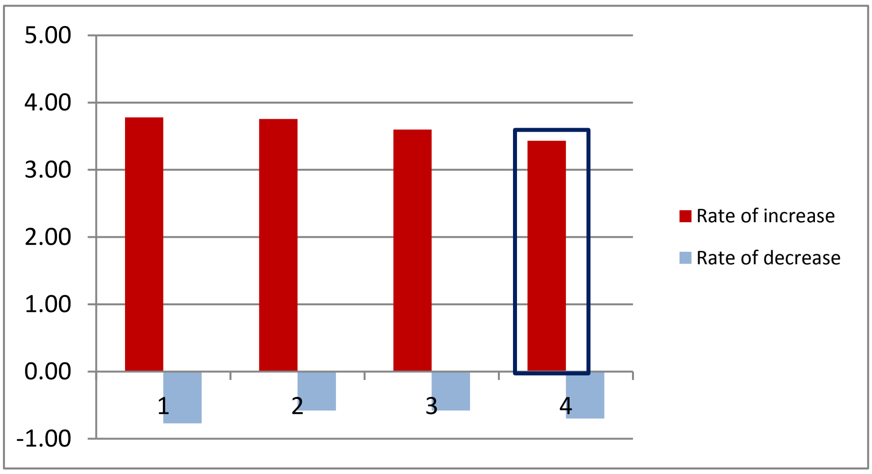


Figure (29): Rate of increase and decrease showing the best shading device alternative for east orientation

10-2-3-1 Simulation Results Analysis:

Thermal difference (above 28°c) is much greater than thermal difference (below 21° c),indicating the higher need for cooling as comparedto the need for heating , so design considerations should be taken at the summer period (above 28°c).

The best shading devices alternatives are: combined shading device(alternative 4), side fins (alternative 3),overhangs(alternative2), no shading (base case), respectively.

The best and worst alternatives results are compared to the base case result (above 28°c) to show magnitude of improvement, by this method: Improvement percentage = [(base case result-alternative result)/base case result].For the best alternative (combined shading device),it was (13%) and for the worst alternative (overhang), it was (2. 4%), Improvement percentage is also calculated for (overhangs)and it was(6.8%) which means that side fins is more effective than overhangs.

The combined shading device is the best alternative as it prevents solar radiation from reaching to the building envelope more than overhangs and side fins.

Side fins is more effective than overhangs because of the low sun angles at the morning.

10-2-4East Orientation Combined Results:

Figure (30) shows that the best alternatives of building envelope for the north orientation are: wall with external light plaster, reflective glass and combined shading device.

The most effective alternative is **combined shading device** as it recorded the lowest thermal difference during summer.

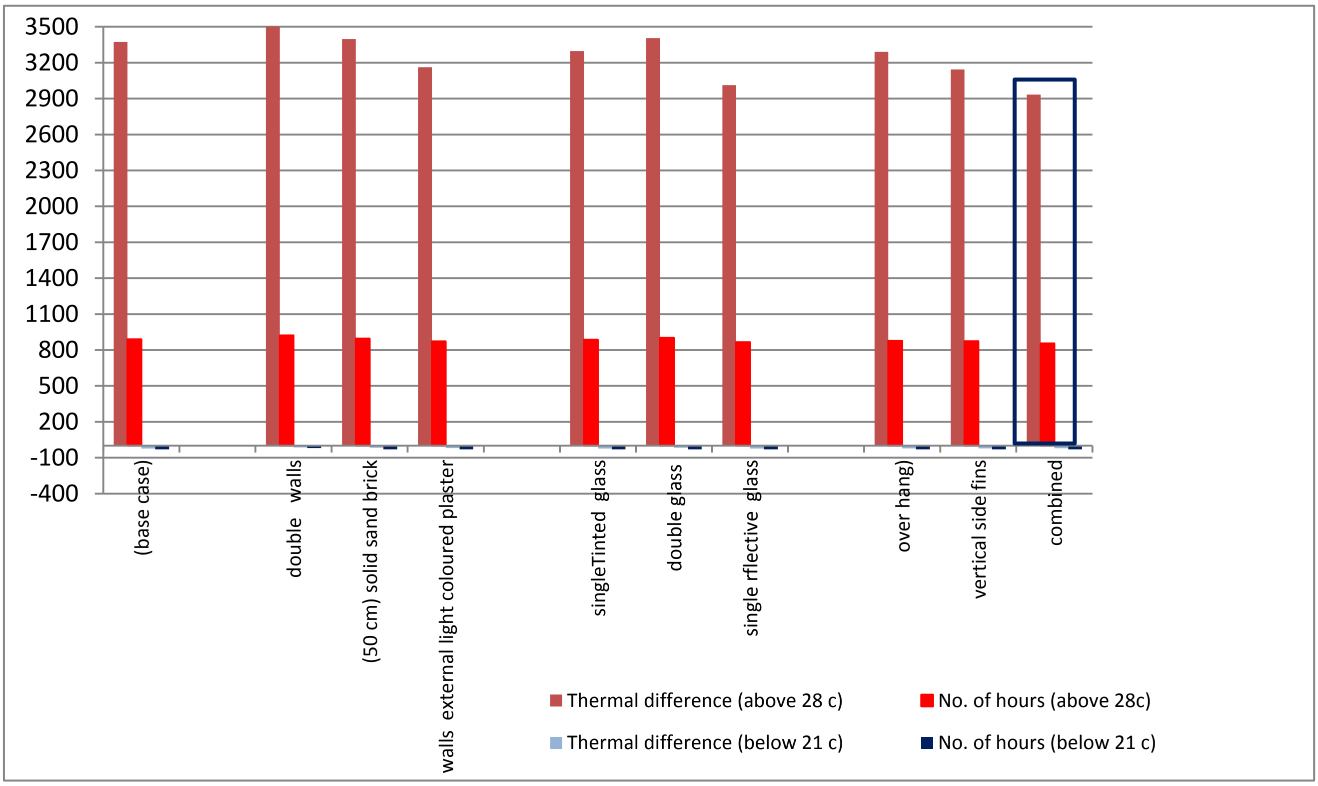


Figure (30): East orientation combined results

10-3 South Orientation:

10-3 -1 Wall Parameters:

Table (6)presents simulation results after testing wall alternatives on the east orientation. Figures (31), (32) present best wall alternatives compared to the base case.

Table (12): Simulation results of wall alternatives for the south orientation

number	1	2	3	4
Type	(25 cm) solid sand brick (base case)	(12cm) solid double sand brick walls with(5 cm) air gab in between	(50 cm) solid sand brick	(25 cm) solid sand brick walls with external light colored plaster
Temperature differences (above 28 c)	4296	4499	4331	3981
No. of hours (above 28c)	1049	1078	1056	1032
Rate of increase	4.10	4.17	4.10	3.86
Temperature differences (below 21 c)	-15	-9	-12.8	-12.4
No. of hours (below 21 c)	20	10	20	20
Rate of decrease	-0.75	-0.90	-0.64	-0.62

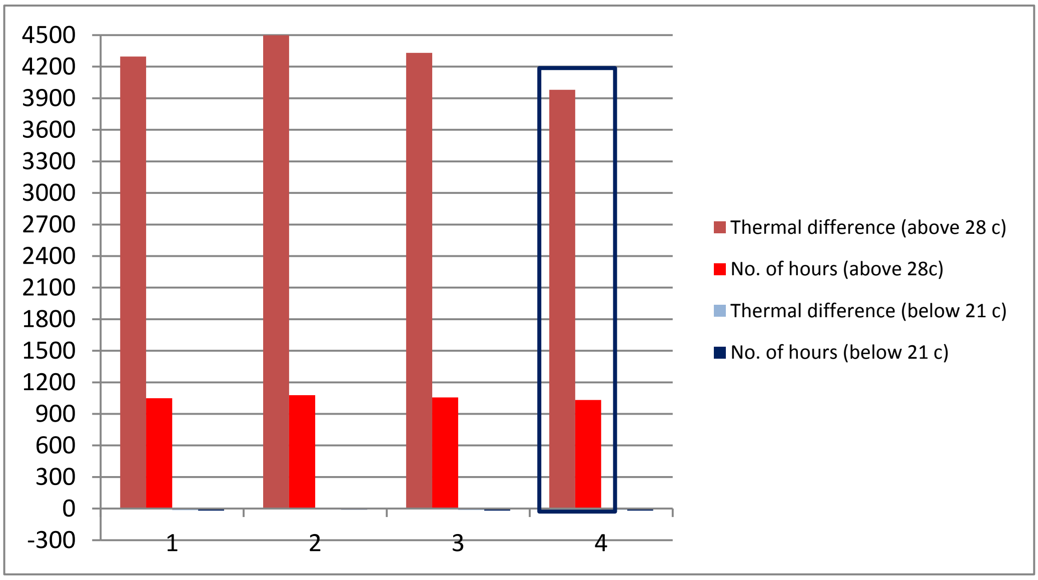


Figure (31) : Simulation results of wall alternatives & the best one for the south orientation

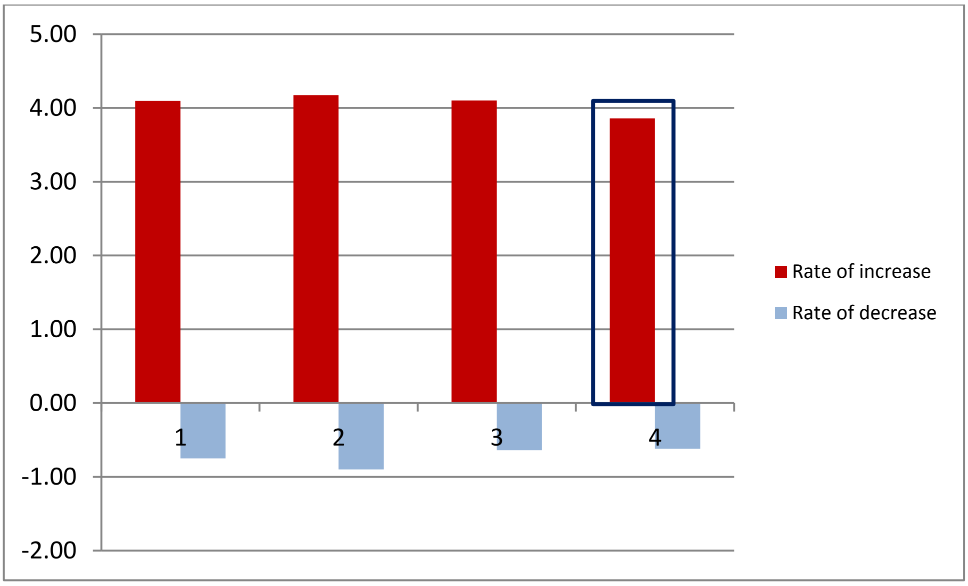


Figure (32): Rate of increase and decrease showing the best wall alternative for south orientation

10-3 -1 -1Simulation Results Analysis:

Thermal difference (above 28°c) is much greater than thermal difference (below 21° c),indicating the higher need for cooling as compared to the need for heating , so design considerations should be taken at the summer period (above 28°c).

The best wall alternatives are: (25 cm)solid sand brick walls with external light colored plaster (alternative 4),(25cm) solid sand brick(base case),(50 cm) solid sand brick(alternative 3) ,(12cm) solid double sand brick walls with(5 cm) air gab in between (alternative 3) , respectively.

The best and worst alternatives results are compared to the base case result (above 28°c) to show magnitude of improvement, by this method: Improvement percentage = [(base case result-alternative result)/base case result].For the best alternative (light colored),it was (10%) and for the worst alternative (double wall) it was (-4.7%).

Wall with external light colored plaster (alternative 4)is the best at the summer period as the light colored plaster reflects most of sun heat, In contrast, dark-colored (base case) absorbs radiant energy from the sun . Some of this absorbed energy is then transferred into the building by way of conduction, resulting in heat gain.

Double wall(alternative 2) was the worst during summer as the wall minimizes heat loss, it will be effective at air conditioned spaces and at winter ,as double wall recorded the lowest thermal difference (below 21°c).

Thermal mass (alternative 3),wasn't the best as the wall stores the heat until the air temperature of the room drops when the sun goes down, the heat is trapped by the walls during night, so it was needed night ventilation to evacuate heat.

10-3 -2 Glazing Parameters

Table (6)presents simulation results after testing wall alternatives on the east orientation. Figures (33), (34) present best wall alternatives compared to the base case.

Table (13): Simulation results of glazing alternatives for the south orientation

number	1	2	3	4
Type	(6mm)single clear glass(base case)	(6mm)single Tinted glass(blue)	(6mm)double glass with 12mm cavity	(6mm)single reflective glass
Temperature differences (above 28 c)	4296	4124	4236	3758
No. of hours (above 28c)	1049	1038	1048	1007
Rate of increase	4.10	3.97	4.04	3.73
Temperature differences (below 21 c)	-15	-17	-12	-18
No. of hours (below 21 c)	20	20	20	20
Rate of decrease	-0.75	-0.85	-0.60	-0.90

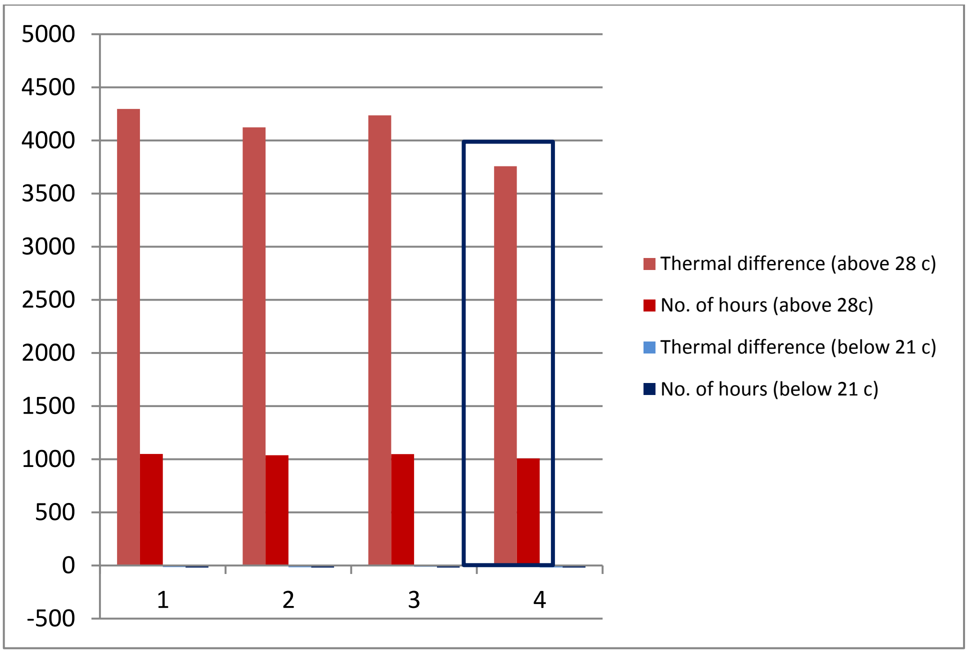


Figure (33): Simulation results of glazing & the best one for the south orientation

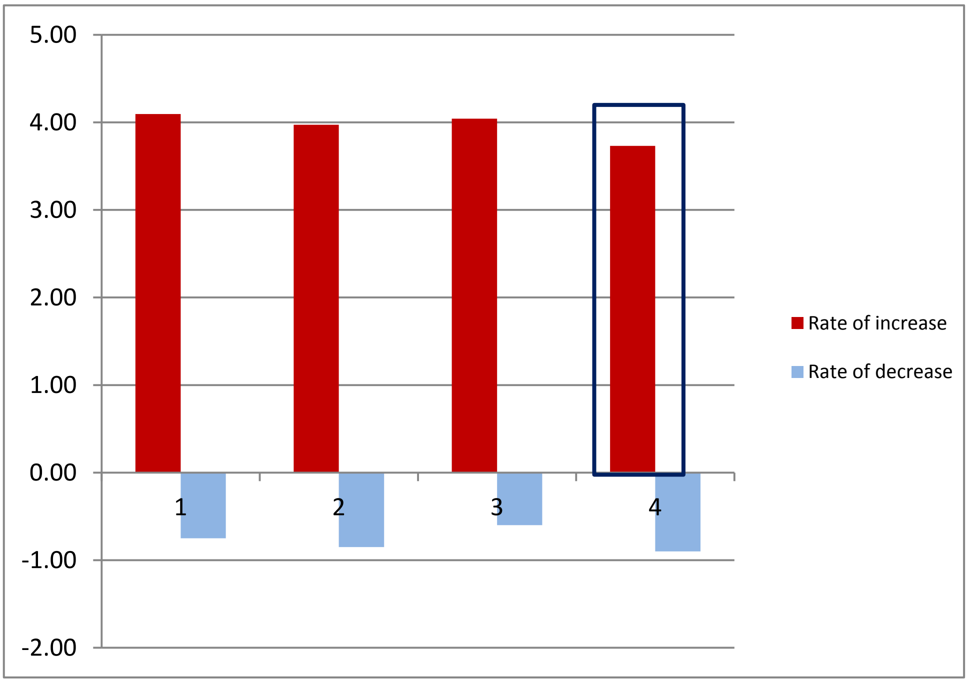


Figure (34): Rate of increase and decrease showing the best glazing alternative for south orientation

10-3 -2 -1Simulation Results Analysis:

Thermal difference (above 28°c) is much greater than thermal difference (below 21° c),indicating the higher need for cooling as compared to the need for heating , so design considerations should be taken at the summer period (above 28°c).

The best glazing alternatives are: single reflective glass (alternative 4), single Tinted glass(alternative2),double glass alternative (3),single clear glass(base case), respectively.

The best and worst alternatives results are compared to the base case result (above 28°c) to show magnitude of improvement, by this method: Improvement percentage = [(base case result-alternative result)/base case result].For the best alternative (reflective glass), it was (12.5%) and for the worst alternative (double glass), it was (1.4%).

Reflective glass (alternative 4), was effective and the best, as most of sun radiation will be reflected.

Single Tinted glass (alternative 2), was effective but wasn't the best, because some of received solar radiation absorbed in the glazing and indirectly admitted to the inside.

Base case (1) wasn't effective at summer because radiation is directly transmitted through the glazing to the building as the value of (SHGC) is too high.

Double glass (alternative 3) wasn't effective , as the two glass layers act as insulators and minimize heat loss so, heat is trapped inside the

Classroom , it could be more effective at air conditioned spaces and at winter as double glass recorded the lowest thermal difference (below 21°c).

10-3-3Shading Devices Parameters:

Table (8)presents simulation results after testing shading devices alternatives on the north orientation .Figures (35), (36) presents best shading devices alternatives compared to the base case.

Table (14): Simulation results of shading devices alternatives for the south orientation

number	1	2	3	4
Type	no shading device(base case)	concrete overhang(PF=.34)	concrete vertical side fins(PF=.34)	combined(90 cm)projection side fins &(90 cm)projection overhangs
Temperature differences (above 28 c)	4296	3734	4089	3176
No. of hours (above 28c)	1049	1016	1034	956
Rate of increase	4.10	3.68	3.95	3.32
Temperature differences (below 21 c)	-15	-16	-16	-17
No. of hours (below 21 c)	20	20	20	20
Rate of decrease	-0.75	-0.80	-0.80	-0.85

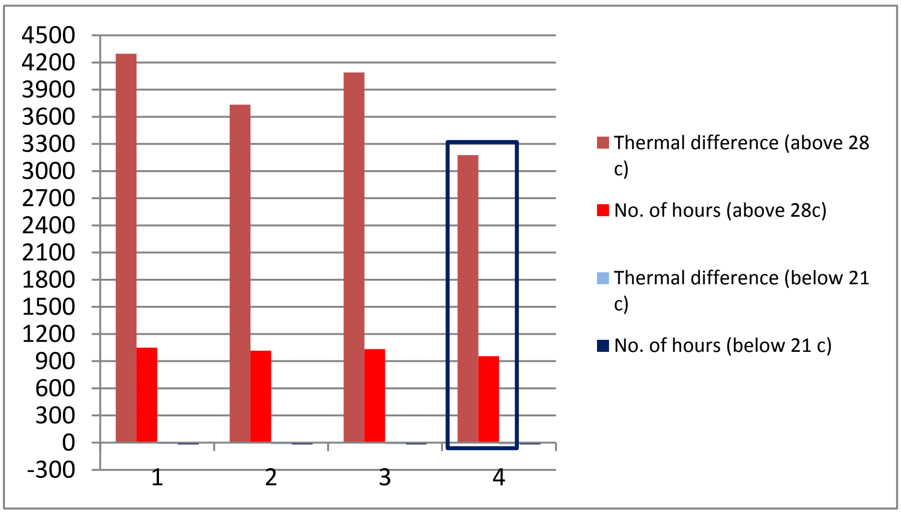


Figure (35): Simulation results of Shading devices & the best one for the south orientation

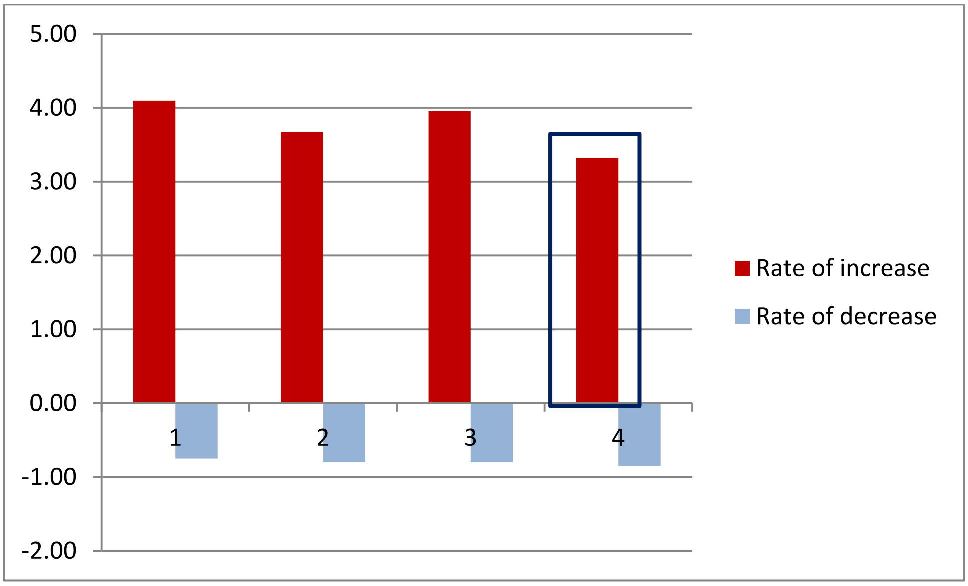


Figure (36): Rate of increase and decrease showing the best Shading devices alternative for south orientation

10-3 -3 -1Simulation Results Analysis:

Thermal difference (above 28°c) is much greater than thermal difference (below 21° c),indicating the higher need for cooling as compared to the need for heating , so design considerations should be taken at the summer period (above 28°c).

The best shading devices alternatives are: combined shading device (alternative 4), overhangs (alternative 2), side fins (alternative3),no shading (base case),respectively.

The best and worst alternatives results are compared to the base case result (above 28°c) to show magnitude of improvement, by this method: Improvement percentage = [(base case result-alternative result)/base case result].For the best alternative (combined shading device),it was (26%) and for the worst alternative (side fins), it was (4. 8%), Improvement percentage is also calculated for (overhang)and it was(13%) which means that overhangs is more effective than side fins for south orientation.

The combined shading device is the best alternative as it prevents solar radiation from reaching to the building envelope more than overhangs and side fins.

Over hangs is more effective than side fins because of the high sun angles.

10-3-4South Orientation Combined Results:

Figure (37) shows that the best alternatives of building envelope for the north orientation are: wall with external light plaster, reflective glass and combined shading device.

The most effective alternative is **combined shading device** as it recorded the lowest thermal difference during summer.

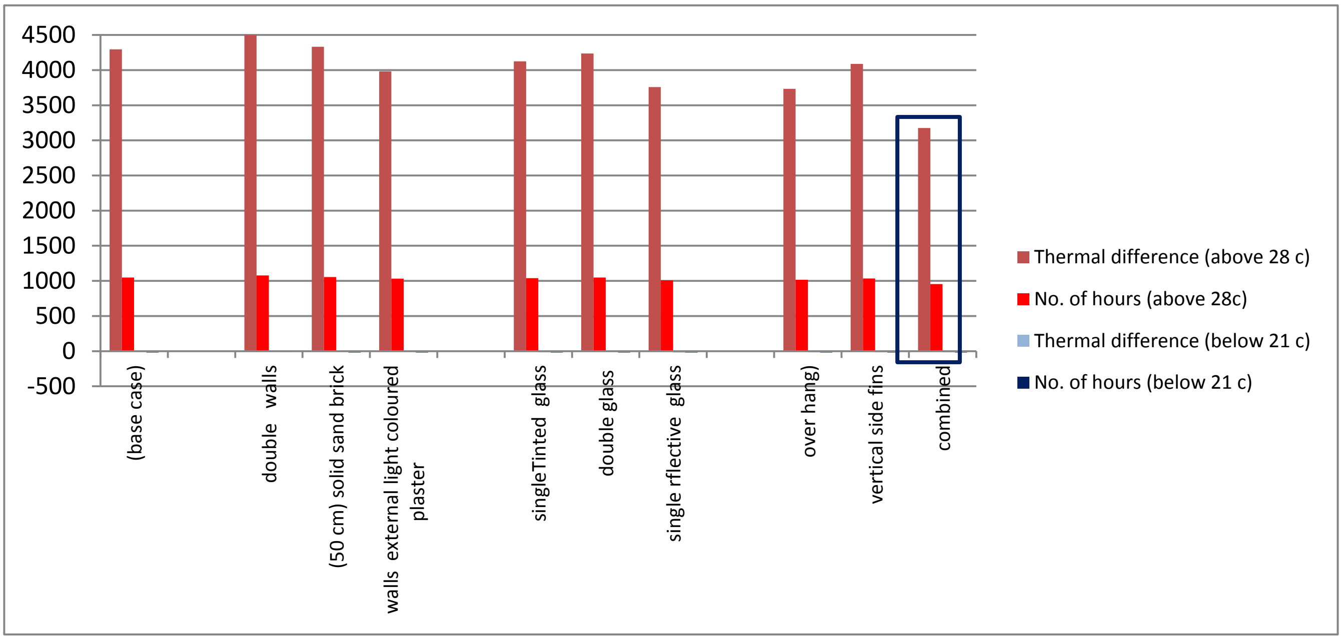


Figure (37): South orientation combined results

10-4 West Orientation:

10-4-1Wall Parameters:

Table (6)presents simulation results after testing wall alternatives on the east orientation. Figures (38), (39) present best wall alternatives compared to the base case.

Table (15): Simulation results of wall alternatives for west orientation

number	1	2	3	4
Type	(25 cm) solid sand brick(base case)	(12cm) solid double sand brick walls with(5 cm) air gab in between	(50 cm) solid sand brick	(25 cm) solid sand brick walls with external light colored plaster
Temperature differences (above 28 c)	3652	3892	3688	3451
No. of hours (above 28c)	929	968	939	912
Rate of increase	3.93	4.02	3.93	3.78
Temperature differences (below 21 c)	-18	-10	-14	-15
No. of hours (below 21 c)	20	20	20	20
Rate of decrease	-0.90	-0.50	-0.70	-0.75

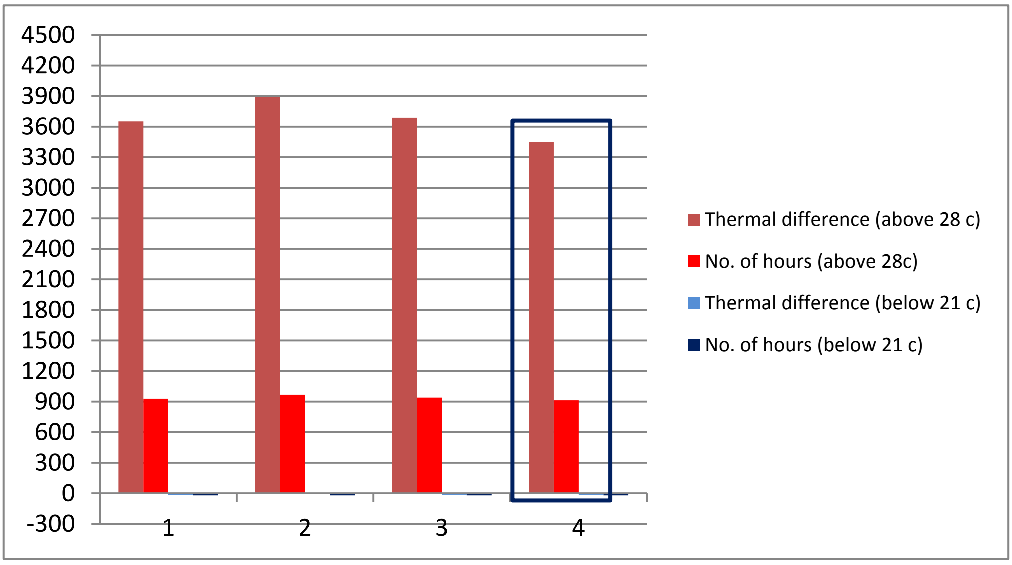


Figure (38) : Simulation results of wall alternatives & the best one for west

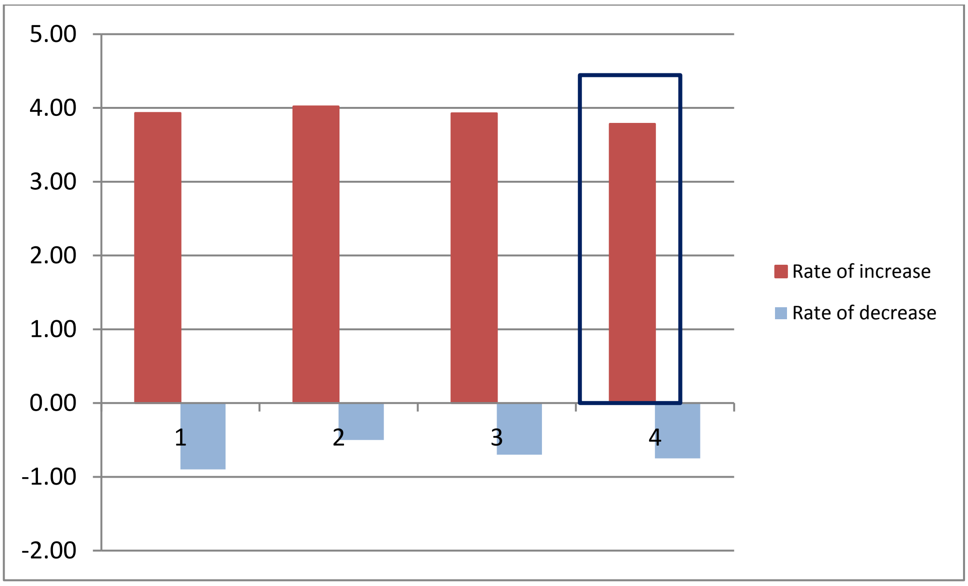


Figure (39): Rate of increase and decrease& bestwall alternative for west orientation

10-4-1-1 Simulation Results Analysis:

Thermal difference (above 28°c) is much greater than thermal difference (below 21° c),indicating the higher need for cooling as compared to the need for heating , so design considerations should be taken at the summer period (above 28°c).

The best wall alternatives are: (25 cm) solid sand brick walls with external light colored plaster (alternative 4), (25cm) solid sand brick(base case), (50 cm) solid sand brick(alternative 3),(12cm) solid double sand brick walls with(5 cm) air gab in between (alternative 3) , respectively.

The best and worst alternatives results are compared to the base case result (above 28°c) to show magnitude of improvement, by this method: Improvement percentage = [(base case result-alternative result)/base case result].For the best alternative (light colored),it was (5.5%) and for the worst alternative (double wall) it was (-6.5%).

Wall with external light colored plaster (alternative 4)is the best at the summer period as the light colored plaster reflects most of sun heat, In contrast, dark-colored (base case) absorb radiant energy from the sun . Some of this absorbed energy is then transferred into the building by way of conduction, resulting in heat gain.

Double wall(alternative 2) was the worst during summer as the wall minimizes heat loss, it will be effective at air conditioned spaces and at winter ,as double wall is the lowest thermal difference (below 21°c).

Thermal mass (alternative 3),wasn't the best as the wall stores the heat until the air temperature of the room drops when the sun goes down, the heat is trapped by the walls during night, so it was needed night ventilation to evacuate heat.

10-4-2Glazing Parameters

Table (6) presents simulation results after testing wall alternatives on the east orientation. Figures (40), (41) present best wall alternatives compared to the base case.

Table (16): Simulation results of glazing alternatives for west orientation

number	1	2	3	4
Type	(6mm)single clear glass (base case)	(6mm)single Tinted glass(blue)	(6mm)double glass with 12mm cavity	(6mm)single reflective glass
Temperature differences (above 28 c)	3652	3573	3689	3350
No. of hours (above 28c)	929	924	942	898
Rate of increase	3.93	3.87	3.92	3.73
Temperature differences (below 21 c)	-18	-19	-14	-21
No. of hours (below 21 c)	20	30	20	30
Rate of decrease	-0.90	-0.63	-0.70	-0.70

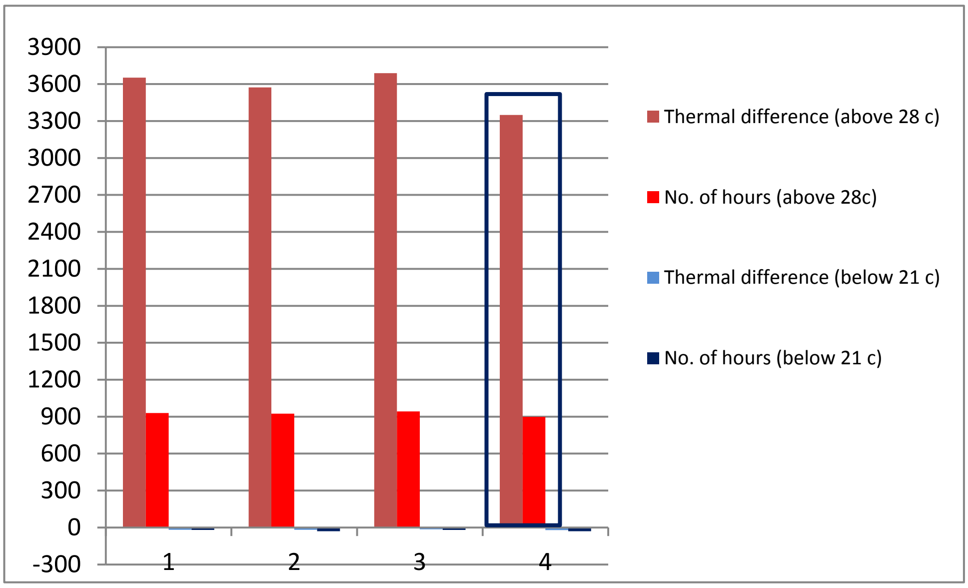


Figure (40): Simulation results of glazing & the best one for west orientation

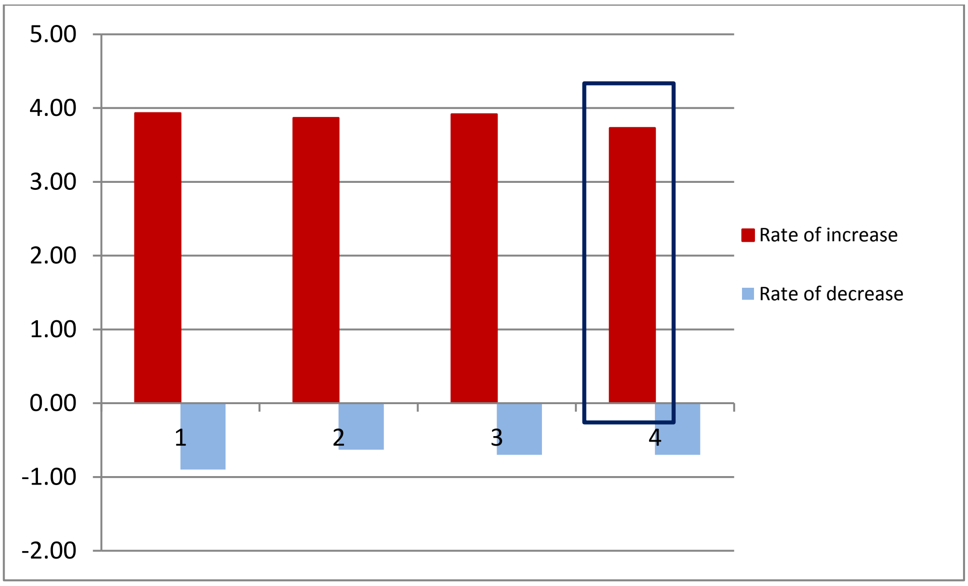


Figure (41): Rate of increase and decrease showing the best glazing alternative for west orientation

10-4-2-1 Simulation Results Analysis:

Thermal difference (above 28°c) is much greater than thermal difference (below 21° c),indicating the higher need for cooling as compared to the need for heating , so design considerations should be taken at the summer period (above 28°c).

The best glazing alternatives are: single reflective glass (alternative 4) , single Tinted glass (alternative 2) , single clear glass(base case) , double glass alternative(3) ,respectively.

The best and worst alternatives results are compared to the base case result (above 28°c) to show magnitude of improvement, by this method: Improvement percentage = [(base case result-alternative result)/base case result].For the best alternative (reflective glass),it was (8.2%) and for the worst alternative (double glass), it was (-.1%).

Reflective glass (alternative 4), was effective and the best, asmost of sun radiation will be reflected.

Single Tinted glass (alternative 2), was effective but wasn't the best, because some of received solar radiation absorbed in the glazing and indirectly admitted to the inside.

Base case (1) wasn't effective at summer because radiation is directly transmitted through the glazing to the building as the value of (SHGC) is too high. But it will not reduce the transmitted light.

Double glass (alternative 3) wasn't effective , as the two glass layers act as insulators and minimize heat loss so, heat is trapped inside the

classroom , it could be more effective at air conditioned spaces and at winter as double glass recorded the lowest thermal difference (below 21°c).

10-4-3Shading Devices Parameters:

Table (8)presents simulation results after testing shading devices alternatives on the north orientation .Figures (42), (43) presents best shading devices alternatives compared to the base case.

Table (17): Simulation results of shading devices alternatives for west orientation

number	1	2	3	4
Type	no shading device(base case)	concrete overhang(PF=.34)	concrete vertical side fins(PF=.34)	combined(90 cm)projection side fins &(90 cm)projection overhangs
Temperature differences (above 28 c)	3652	3528	3385	3119
No. of hours (above 28c)	929	915	913	884
Rate of increase	3.93	3.86	3.71	3.53
Temperature differences (below 21 c)	-18	-18	-18	-18
No. of hours (below 21 c)	20	30	20	30
Rate of decrease	-0.90	-0.60	-0.90	-0.60

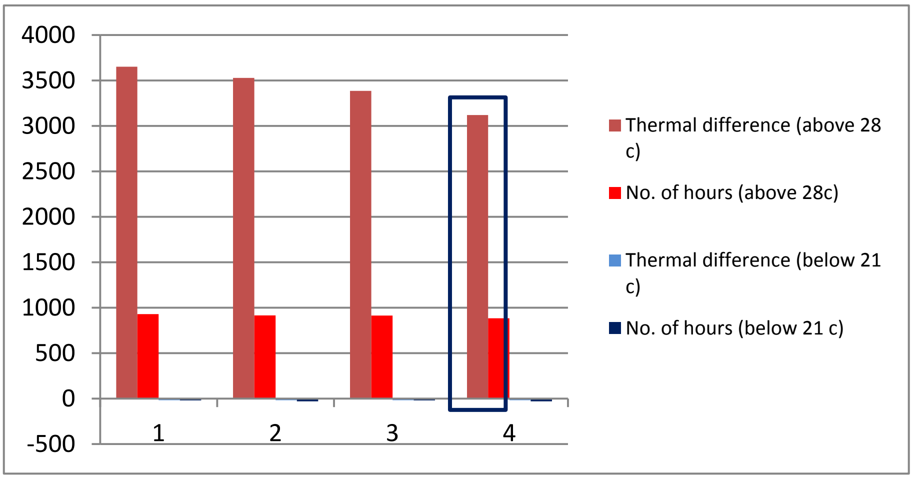


Figure (42): Simulation results of Shading devices & the best one for west orientation

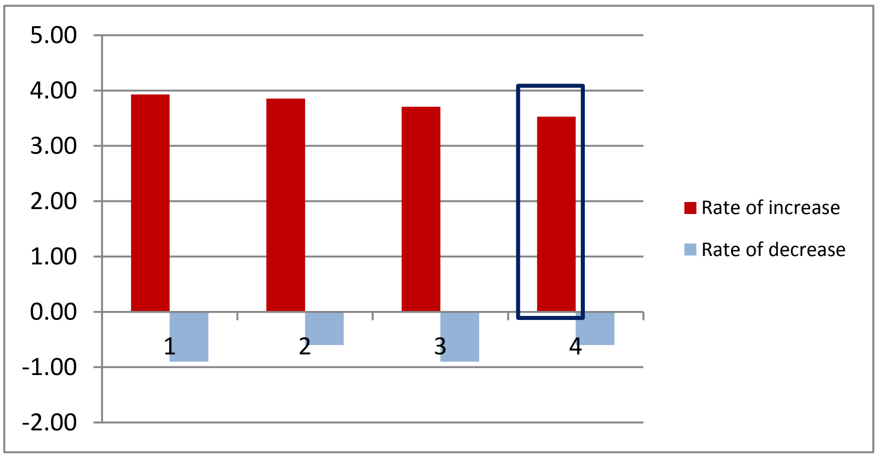


Figure (43): Rate of increase and decrease showing the best shading device alternative for west orientation

10-4-3-1Simulation Results Analysis:

Thermal difference (above 28°c) is much greater than thermal difference (below 21° c),indicating the higher need for cooling as compared to the need for heating , so design considerations should be taken at the summer period (above 28°c).

The best shading devices alternatives are: combined shading device (alternative 4), side fins (alternative 3),overhangs(alternative2), no shading (base case), respectively.

The best and worst alternatives results are compared to the base case result (above 28°c) to show magnitude of improvement, by this method: Improvement percentage = [(base case result-alternative result)/base case result].For the best alternative (combined shading device),it was (14.5%) and for the worst alternative (overhang), it was (3. 3%), Improvement percentage is also calculated for side fins and it was(7.3%) which means that side fins is more effective than overhangs.

The combined shading device is the best alternative as it prevents solar radiation from reaching to the building envelope more than overhangs and side fins, side fins is more effective than overhangs because of the low sun angles at the afternoon.

10-4-4 West Orientation Combined Results:

Figure (44) shows that the best alternatives of building envelope for the north orientation are: wall with external light plaster, reflective glass and combined shading device.

The most effective alternative is **combined shading device** as it recorded the lowest thermal difference during summer.

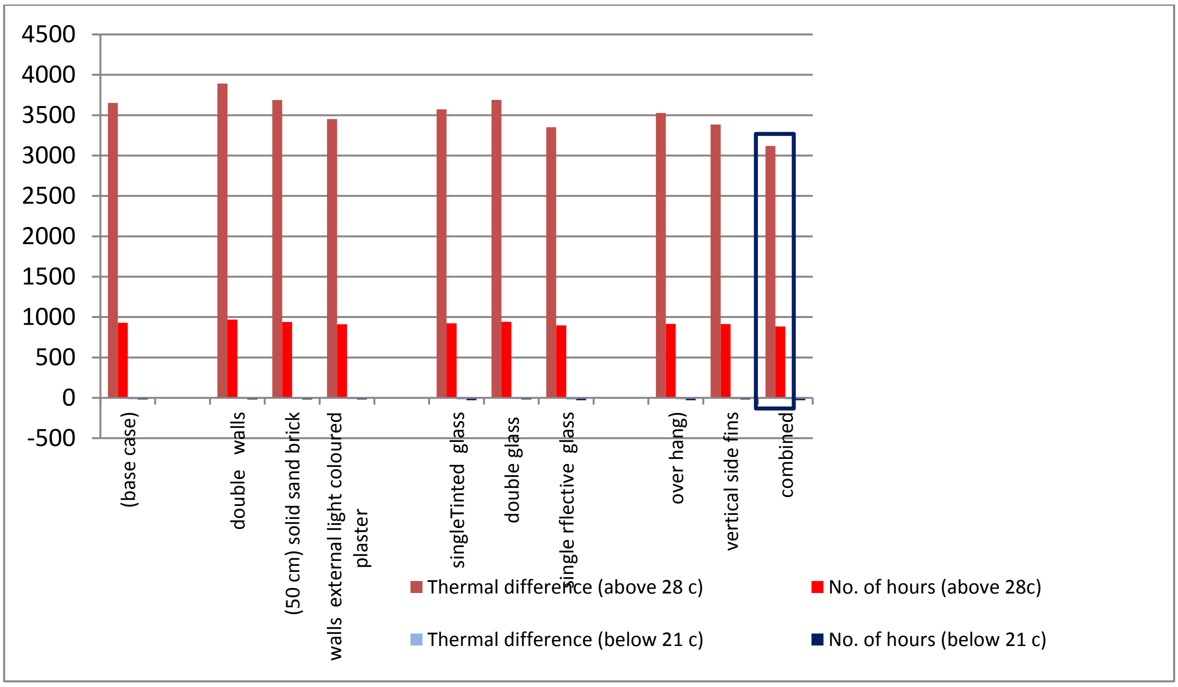


Figure (44): West orientation combined results

11- Simulation Results of Optimum Alternatives:

11-1 North Orientation:

The best alternatives for building envelope components were:

- Walls: 25 cm solid sand brick walls with external light colored plaster
- Glazing: (6mm)single reflective glass
- Shading devices: combined (90cm)projection side fins & (90 cm)projection overhangs.

Table (18), and figures (45), (46) shows Simulation results of best alternatives Compared to the base case .Improvement percentage is 11.5%.

Table (18): Simulation results of best alternatives compared to base case for north orientation

Type	base case	optimum alternatives
Temperature differences (above 28 c)	2927	2590
No. of hours (above 28c)	861	837
Rate of increase	3.40	3.09
Temperature differences (below 21 c)	-24	-17
No. of hours (below 21 c)	40	30
Rate of decrease	-0.60	-0.57

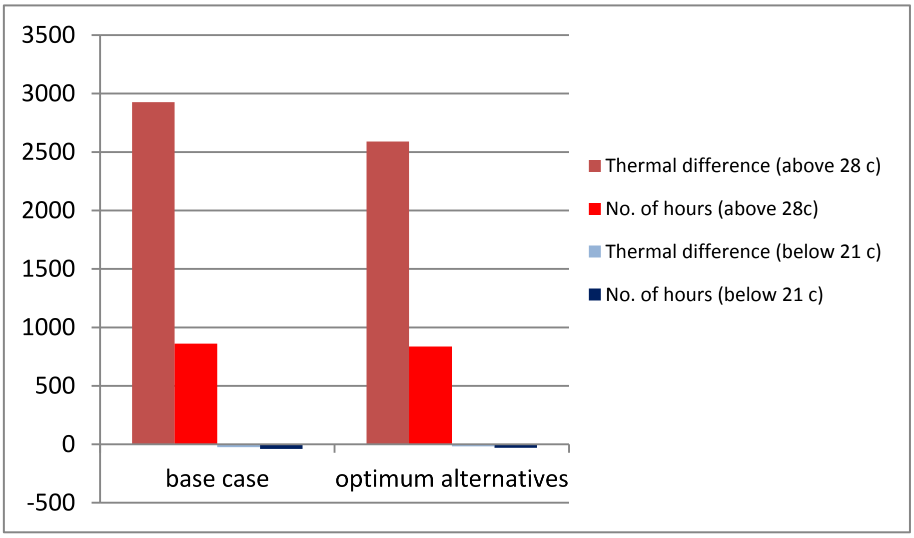


Figure (45): Simulation results of optimum alternatives compared to base case for north orientation

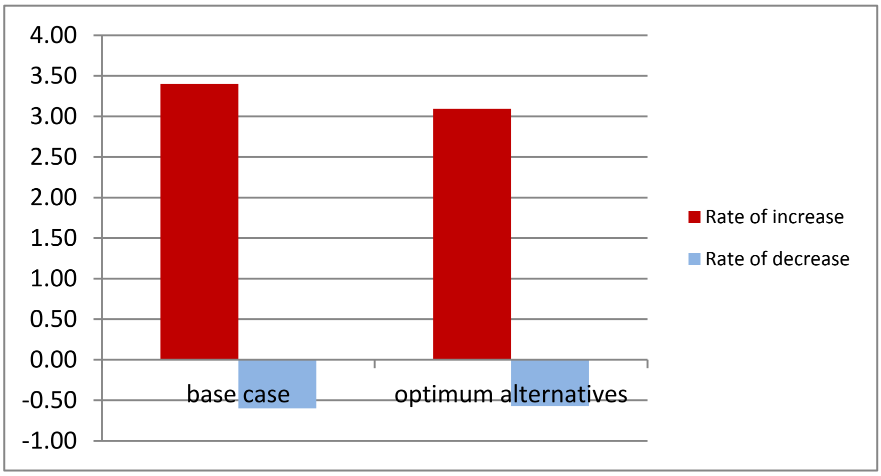


Figure (46): Rate of increase and decrease showing comparison between optimum alternatives and base case for north orientation

11-2 East Orientation:

The best alternatives for building envelope components were :

- Walls: 25 cm) solid sand brick walls with external s with external light colored plaster
- Glazing: (6mm)single reflective glass
- Shading devices: combined (90 cm) projection side fins & (90 cm) projection overhangs.

Table (19), and figures(47),(48) shows Simulation results of best alternatives Compared to the base case. Improvement percentage is 22%.

Table (19): Simulation results of best alternatives compared to base case for east orientation

Type	base case	optimum alternatives
Temperature differences (above 28 c)	3373	2670
No. of hours (above 28c)	889	827
Rate of increase	3.79	3.23
Temperature differences (below 21 c)	-23	-17
No. of hours (below 21 c)	-30	-30
Rate of decrease	-0.77	-0.57

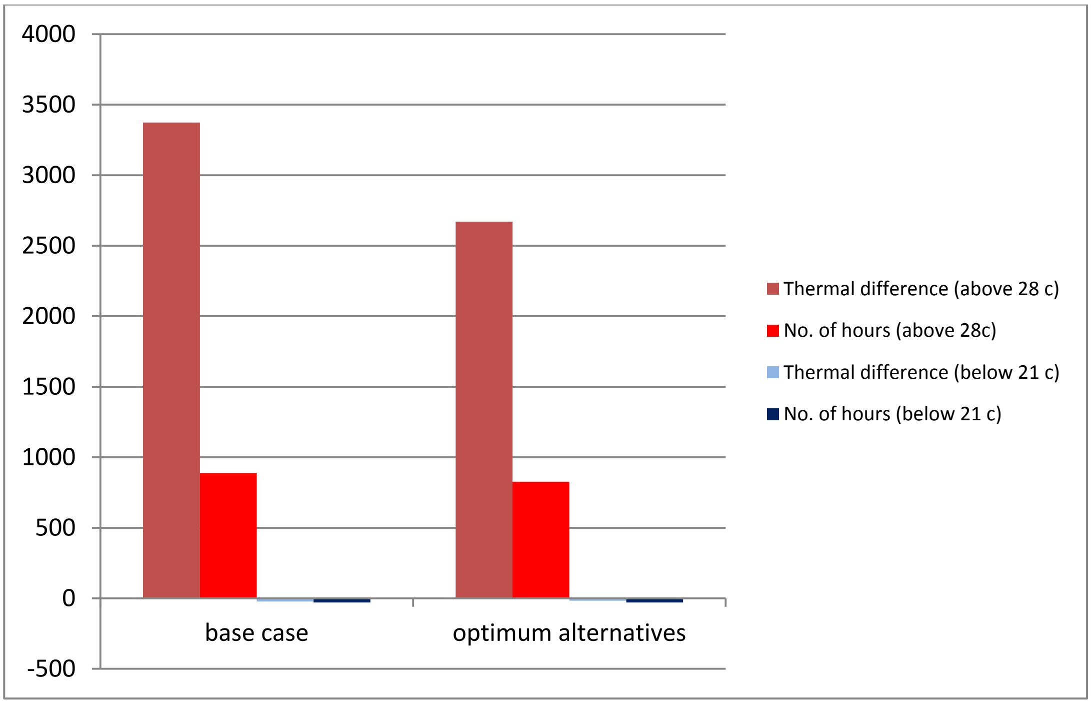


Figure (47): Simulation results of optimum alternatives compared to base case for east orientation

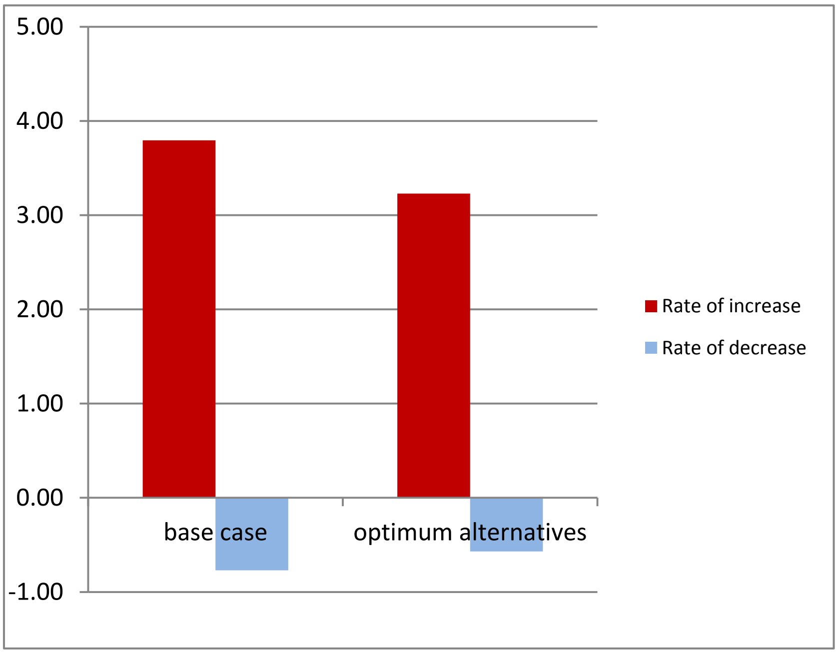


Figure (48): Rate of increase and decrease showing comparison between optimum alternatives and base case for east orientation

11-3 South Orientation:

The best alternatives for building envelope components were:

- Walls: 25 cm) solid sand brick walls with external s with external light colored plaster
- Glazing: (6mm)single reflective glass
- Shading devices: combined (90 cm) projection side fins & (90 cm) projection overhangs.

Table (20), and figure (49),(50) shows Simulation results of best alternatives Compared to the base case, Improvement percentage is 35% ,south orientation recorded the highest improvement after simulating best alternatives.

Table (20): Simulation results of shading devices alternatives compared to base case for south orientation

Type	base case	optimum alternatives
Temperature differences (above 28 c)	4296	2791
No. of hours (above 28c)	1049	891
Rate of increase	4.10	3.13
Temperature differences (below 21 c)	-15	-15
No. of hours (below 21 c)	20	20
Rate of decrease	-0.75	-0.75

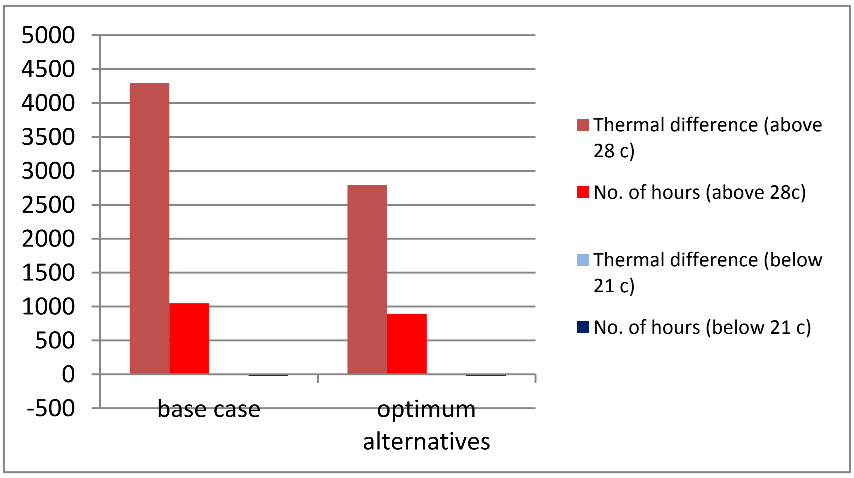


Figure (49) : Simulation results of optimum alternatives compared to base case for south orientation

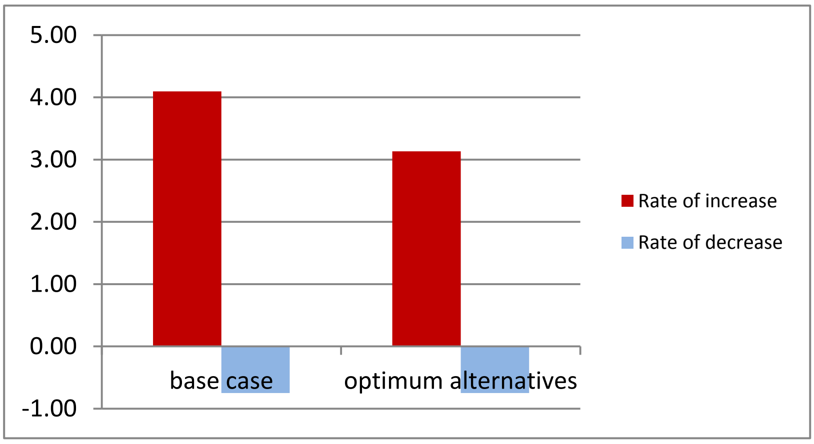


Figure (50): Rate of increase and decrease showing comparison between optimum alternatives and base case for south orientation

11-4 West Orientation:

The best alternatives for building envelope components were :

- Walls: 25 cm) solid sand brick walls with external s with external light colored plaster
- Glazing: (6mm)single reflective glass
- Shading devices: combined (90 cm)projection side fins &(90 cm) projection overhangs.

Table (21), and figures(51),(52) show Simulation results of best alternatives Compared to the base case. Improvement percentage is 23%

Table (21): Simulation results of shading devices alternatives compared to base case for west orientation

Type	base case	optimum alternatives
Temperature differences (above 28 c)	3652	2803
No. of hours (above 28c)	929	850
Rate of increase	3.93	3.30
Temperature differences (below 21 c)	-18	-15
No. of hours (below 21 c)	20	20
Rate of decrease	-0.90	-0.75

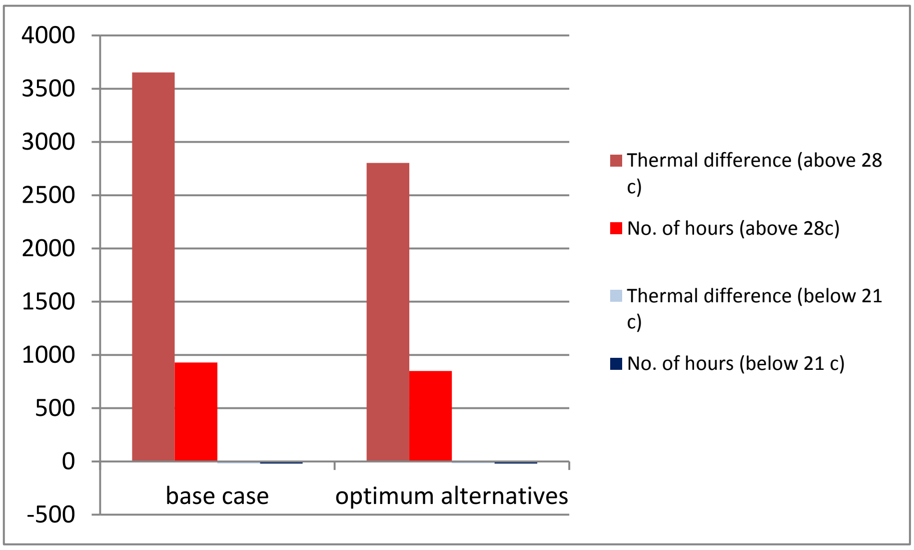


Figure (51) : Simulation results of optimum alternatives compared to base case of west orientation

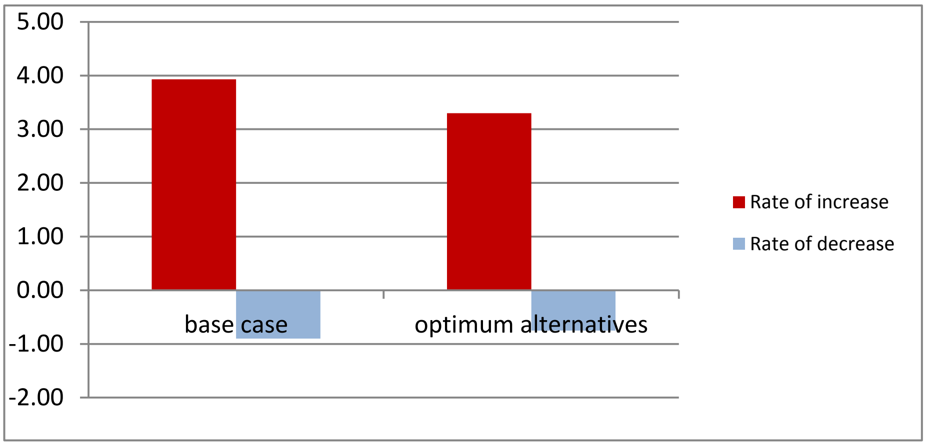


Figure (52): Rate of increase and decrease showing comparison between optimum alternatives and base case for west orientation

11-5 Main Orientations Combined Results :

Using passive design techniques are so effective at summer period ,The best orientations after using passive design techniques are north , then south and west, respectively , as shown at figure (53), (54).

South orientation recorded the highest improvement after simulating best alternative then west, east and north, respectively, according to the calculated improvement percentage.

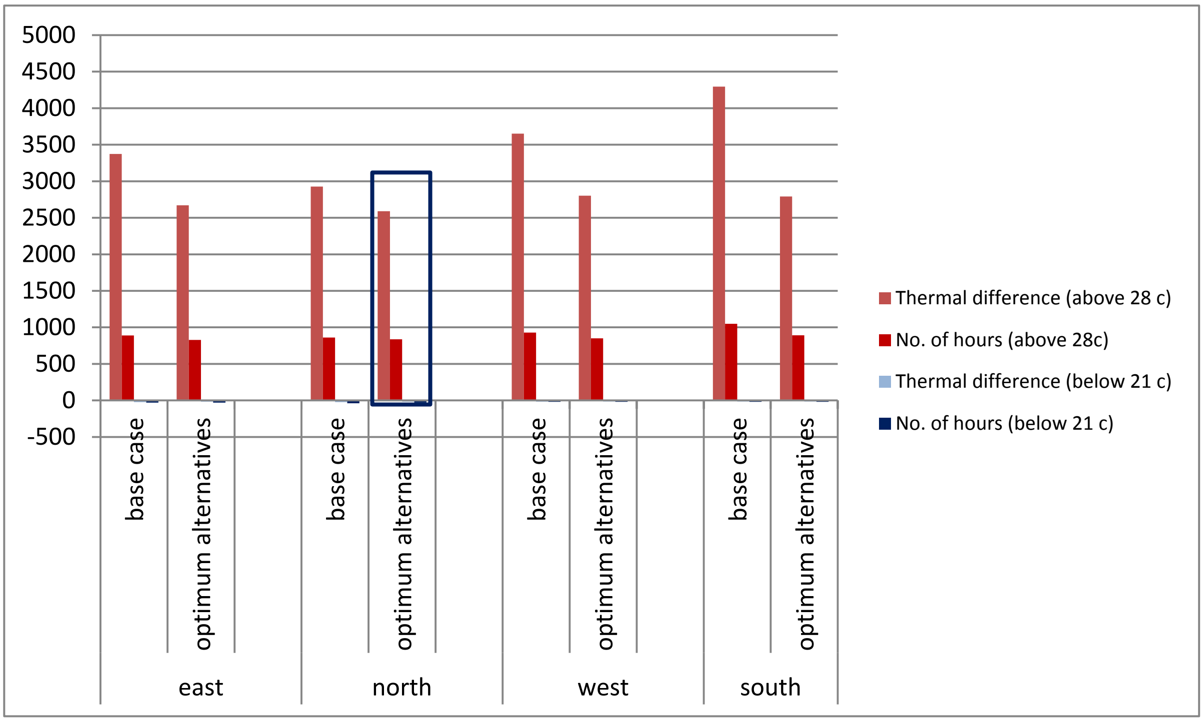


Figure (53): combined simulation results of the main orientations

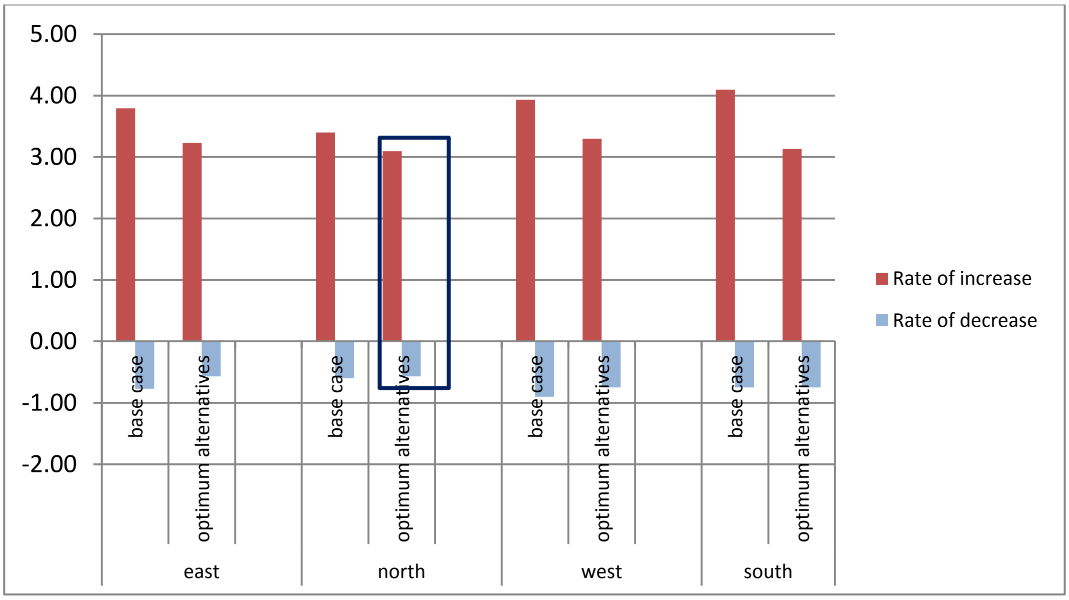


Figure (54): Rate of increase and decrease showing comparison between optimum alternatives and base case for four orientations

12-Conclusion & Recommendations:

Usage of the following alternatives: walls with external light plaster, reflective glass and combined shading devices, for the investigated classroom envelope recorded the lowest thermal differences during summer, so it recommended to be used in the prototype school classrooms at Cairo.

According to the research results, the demand for cooling was much greater than demand for heating, as thermal differences (below 21 °c) recorded neglected values compared to thermal differences (above 28 °c), so best alternatives for building envelope to reduce heat gain should be selected according to summer period .

North orientation recorded the lowest thermal difference during summer at the current state and before using passive design techniques, so north orientation is the best for the classroom then east, west and south, respectively.

After using passive design techniques, North orientation also recorded the lowest thermal difference during summer, so north orientation was the best for the class room then east, south and west, respectively.

South orientation recorded the highest improvement after simulating best alternative then west, east and north, respectively, according to the calculated improvement percentage.

Shading device is the most effective building envelope component for thermal comfort, then glazing and walls, respectively. Combined shading device was the most effective alternative; as it recorded the lowest thermal differences during summer for the four main orientations .Overhangs are more effective than side fins for north and south orientations. In contrast, side fins are more effective than overhangs for east and west orientations, so well selected and studied shading device will greatly improve thermal comfort inside classrooms.

The investigated school classroom could be established at various plots with different orientations at Cairo; as thermal comfort have been greatly enhanced after applying passive design techniques on the building envelope (wall- glazing – shading devices).Hence, to achieve thermal comfort for Egyptian classroom schools using passive design systems; several design considerations for building envelope components (walls, glazing , shading device) must be well studied in early design phase.

Optimum alternatives for building envelope could affect lightning quality, so design considerations about lighting quality at class should be studied.

Optimum alternatives for building envelope could affect cost so issues about cost and quality of the selected alternative should be taken into account.

Using simulation software in early design phase for different kinds of buildings is important in order to achieve a climatic responsive architecture for newly designed educational buildings and to observe the existing situation for retrofitting purposes.

According to the research, Simulation study can be applied on the prototype schools established by The Educational Building Authority at other Egyptian Provinces such as (Alexandria - Aswan - Damietta-….) as the climate differs from one region to another, So as to optimize thermal comfort there.

References:

1- Chaiyapinunt.S.,Khamporn.N., Selecting Glass Windowwith Film for Buildingsin a Hot Climatic , Engineering Journal: Volume 13 ISSUE 1 ISSN 0125-8281, Thailand, JAN. 2009 .

2- Dewidar .M.,Mahmoud. H., Moussa. R., EnhancingThe Human Thermal Comfortinside Educational Buildingsin Hot Arid Regions, British University, Cairo, 2009,

3- ANSI/ASHRAE Standard 55-2010American Society of Heating, Refrigerating and Air-Conditioning Engineers, International Organisation for Standardisation; 2010.

4- El-Deke .H. ,Hamdy. N.,Does Non-renewable Energy Utilization in Egypt Generate Net Gain or Net Loss?, National Society for Economic Policy (NSEP) ,August 2010.

5- Mediavilla. M., Miguel. L., Castro.C.,From fossil fuels to renewable energies, University of Valladolid, Spain, 2008.

6- Wargocki. P., Wyon .D., The Effects of Moderately Raised Classroom Temperatures Rate on the Performance of Schoolwork by Children (RP-1257),HVAC&R RESEARCH, June 2006.

7- Doran,S.,Carr.B.,Thermal transmittance of walls of dwellings before and after application of cavity wall insulation , Building Research Establishment Ltd,Scotlan, March 2008.

8- Chaiyapinunt.S ., Khamporn.N., SELECTINELECTING GLASS WINDOW WITH FILM FOR BUILDINGS IN A HOT CLIMATE, Chulalongkorn University, Thailand

9- Cairo climate, http://www.worldweatheronline.com, last accesses 12-6-2014.

10- Design Guidance for Schools in Washington,http://www.commercial windows.org,last accesses 12-6-2014.

11- Windows, http://www.wbdg.org, last accesses 12-6-2014.

12- Thermal Mass Strategies ,http://www.mognot.com, last accessed 20-6-2014.

13- Egypt Oil &Gas ,http://www.egyptoil-gas.com ,last accsess 12-6-2014.

14- weather- averages, http://www.worldweatheronline.com, last accsess 12-6-2014.

15- What is abuilding envelope?,http://www.wisegee.com, last accsess 12-6-2014.

16- Shading, http://www.tboake.com/carbon-aia/strategies1b.html,last accessed 20-6-2014.

17- Shading & Redirecting Sunlight, http:// sustainability workshop .autodesk.com,last accessed 20-6-2014.

18- Cooling Your Home Naturally,www.nrel.gov/docs/legosti/old/15771.pdf,last accessed 20-6-2014.

19- ECBC Envelope for Hot & dry Climate,http:// high-performancebuildings .org, last accessed 20-6-2014.

20- Solar Heat-Gain Coefficient Ratings forWindows, http://www nachi. org/shgc-ratings-windows.htm,last accessed 20-6-2014.