JOURNAL OF ENGINEERING RESEARCH AND TECHNOLOGY, VOLUME 2, ISSUE 1, MARCH 2015

A Comparative Study Of The Thermal Comfort By Using Different Building Materials In Gaza City (JERT)

Husameddin M. Dawoud

College of Applied Engineering & Urban Planning, University of Palestine
Gaza strip, Palestine, hdawod@gmail.com

Abstract—This study compares between different alternatives of construction in Gaza city. This comes for proposing a new approach of using available construction materials to improve the thermal resistance of the building and to minimize energy losses. Using available materials with different detailed techniques, the focus was on three systems applied on the residential construction in Gaza city. Common materials used in building envelope such as stone, hollow block and plaster are combined together in different ways to form three systems of building envelope. After thorough on-site investigation and data collection, the information along with regional weather data, was input into the Ecotect energy simulation software for thermal performance evaluation. The breakdown analysis of passive gains indicates that the majority of heat losses occurs via conduction heat transfer (building fabric). This study found that using 5cm air gap in exterior walls saves 50% of energy required to maintain comfortable temperature inside the home. Current study demonstrates how a building envelope reacts significantly to outdoor conditions through graphic illustration. In addition, it shows ways for the research to be extended by the creation of simulations using Ecotect software. This research contributes to the promotion of passive and low energy architecture towards a sustainable future.

Index Terms— Thermal comfort, Envelope systems, Air gap, Wall cavity, Ecotect.

I INTRODUCTION

Construction and design of buildings in Palestinian areas have changed considerably over the last century. Flat roof and thin walled buildings of relatively low thermal insulation have replaced the old dome-roofed thick high walled houses, which were characterized by good thermal insulation and ventilation. However, new buildings are characterized by more efficient use of construction materials. Being in dire need of heating, cooling and ventilation systems, energy consumption in the new buildings has increased ever since. The building sectors account for about 40% of the total energy consumption and 38% of the CO_2 emission in the U.S. [1]. However, in Palestine, local homes still have an energy loss in winter that exceeds 6 times energy loss in buildings in the U.S. [2]. Therefore, this study mainly focuses on the thermal performance of available alternatives of materials and construction in Palestine comparing their environmental performance. This kind of buildings is expected to save energy and to be environment-friendly for long-term. Selection of suitable construction materials in buildings is sufficient to improve the thermal resistance dramatically, hence to minimize energy losses. The focus was on the envelop of the building for its vast effect on the thermal behaviour inside the building. In order to test their thermal properties, certain building materials have been investigated to construct walls of residential private house in Gaza city (Figure 1). This building actually exists at Gaza city and has two floors. The ground floor has an area of 190m², and the first floor has an area of 132m2 (Figure 2). The main elevation is facing south and it is not shaded by any vegetation or structure that could alter the results. This house is located in the middle part of Gaza strip. It has a warm steppe climate while it changes into a warm desert climate in the southern part [3]. Figure 3 displays the climate characteristics of the study area. They were adapted from El Arish city in Egypt because Gaza strip does not have weather data up to moment. El Arish city is located 70 Km far from Gaza strip and it carries the same climate characteristics and geographic conditions.

II WALL MATERIALS IN PALESTINE

Buildings in Palestine consist of concrete structure with flat roofs and hollow blocked walls. While stone is used for cladding with total thickness of the wall exceeding 25 cm. The usage of stone for cladding is not affordable all the time because of the cost and availability. Another common alternative is rendering the inner and outer sides of the building by cemented plaster only. In this case, thermal transmittance as well as energy loss will be high causing discomfort of the habitants. The need for comfortable indoor climate has lead to develop other construction techniques to overcome the drawback of scarcity or the high cost of insulation materials. These new techniques are based on using air gap or polystyrene boards 2to 5cm thick placed inside the hollow blocked concrete wall.

Figure 1 The case study of residential private house in Gaza city. (Image courtesy of Zawaya Co. [11])

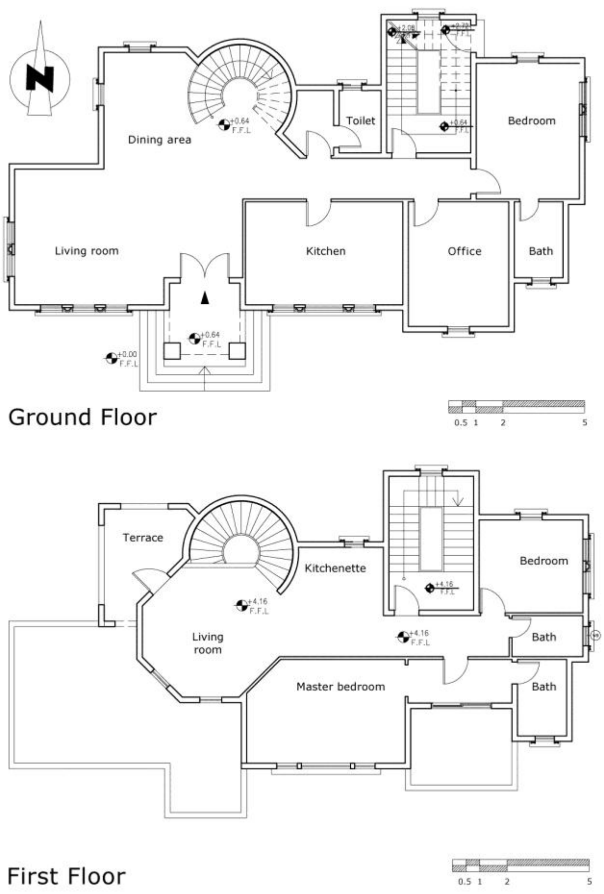


Figure 2 Analyzed building plans- ground and first floors. (Image courtesy of Zawaya Co. [11])

III Research Material

Exterior wall thermal insulation can effectively reduce both the annual energy consumption and peak loads of cooling and heating systems. It is well known that most of the Palestinian modern buildings consist of walls constructed from stones, concrete ,hollow block and plaster [2]. Stone is only used as a cover material because of its fancy appearance in facades rather than its thermal prosperities. Stone is obtained by taking rock from the earth and reducing it to the required shapes and sizes [4]. The majority of stone quarries in Palestine is concentrated in the West Bank area due to its rocky land. The limitations of stone industry as well as the obstacles in importation of stones to Gaza city make it costly to use. Therefore, hollow blocks made from cement and aggregates were used as main building materials plastered from both sides. Hollow block has standard dimension for height (20cm) , length (40cm) and width in different sizes (20cm, 15cm, and 10cm). External plaster is common choice for residential buildings in which they are made from cement, sand and lime. Colour is variable and it can be used to absorb or to reject solar radiation [5]. However, choosing colour of paintings in Palestine has no calculation or scientific methods. It is spontaneously known that light colours do reflect light around and they can help in reducing heat gain in summer [6]. Thermal performance of the selective materials was only evaluated on the basis of computer simulations. Colour of external materials was set to 4DE7D3, while internal colour was fixed to A3F8F8.

IV Simulation

The simulations were run on a computer model using Autodesk Ecotect® 2011. In order to ascertain the direct effect of wall materials on the thermal behaviour of the building, the material properties and details of the walls only were altered for each run. In other words, the materials and dimensions of the doors, windows, roof and floor constructions were still the same. Doors were set to solid core- Pine timber. Windows were single glassed timber frame. Roofs were flat made from concrete and hollow block with thickness of 25cm. Floors were 10 cm concrete slab. Simulation was analyzed for all zones of the house together. Active system for heating and cooling in all zones were placed to be mixed-mode system with efficiency 95%. Stairs, bathrooms and toilets were designed to have a natural ventilation. The scope is limited to three alternatives of the walls. The first alternative consists of a stone for cladding with 4cm as a thickness followed by 5cm mortar to process the paste of stone. Next layer is the hollow block with a thickness of 20cm covered by 1.5cm internal plaster as shown in Table 1a. Time lag for these layers is 2.41 hours; it can be calculated using Dynamic Thermal Properties Calculator (ver 1.0) [7] as Ecotect does not provide that directly. Simplified U-value for alternative A (based on admittance method) is 2.33 W/m^2K. U-value was calculated and assigned to relevant wall components in Ecotect.

The second alternative (B) consists of three layers. The first layer is the external plaster with a thickness of 1.5cm.

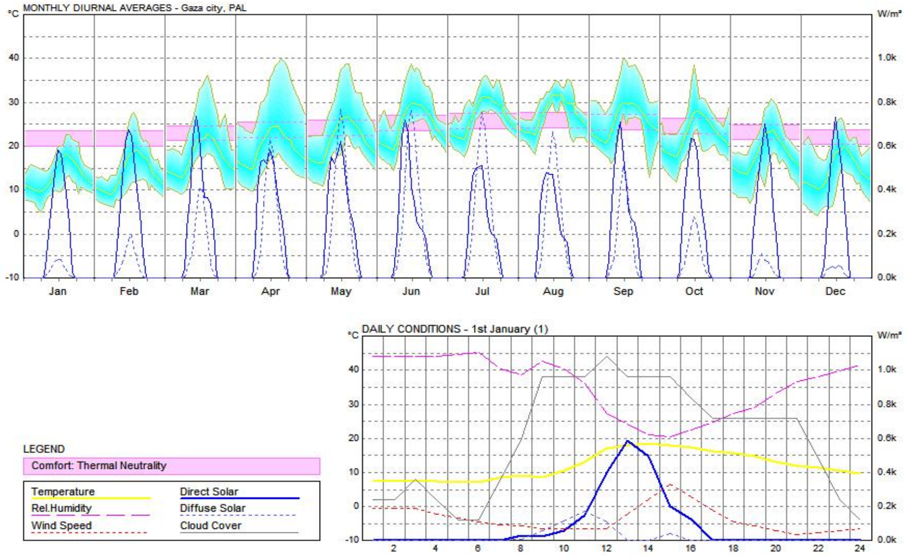


Figure 3 Diurnal averages of outdoor air temperature and solar radiation, for Gaza strip

The density of the external plaster is higher than that in the internal one to afford the fluctuations of the weather. The second layer is the hollow block with 20cm as a thickness. The internal layer is the plaster with a thickness of 1.5cm as shown in Table 2a. Time lag is 1.87 hours and simplified U-value for these three layers is 2.51 W/m²K.

The third alternative (C) consists of five layers which are 1.5cm external plaster, 15cm hollow block, 5cm air gap, 10cm hollow block and 1.5cm internal plaster (see Table 3a). Time lag is 2.02 hours and simplified U-value for these three layers is 1.6 W/m²K.

Computer simulations help to analyze conditions that are not tested yet in reality, moreover; to draw conclusions based on comparisons of different building systems. This comes before the beginning of the construction works. Although simulation studies with Ecotect were carried out for different months of the year, the results of the simulations for only average temperature are presented here for brevity. In order to compare the behaviour of the different materials, the simulation was firstly run on a computer model for the alternative A. Figure 4 shows the loads per month to maintain the temperature from 18.0 C to 26.0 C through the year. Red bars above the horizontal line in the middle are heating loads during the seasons, autumn and winter . While blue bars are the cooling loads during summer and spring seasons. When this house is enveloped by using alternative A, the energy consumption is 23381 kWh per year. The system for providing heating and cooling was fixed to mixed-mode system. This system is a combination of air-conditioning and natural ventilation where the HVAC system shuts down whenever outside conditions are within the defined thermostat range. Adaptive Methods were chosen in calculation because the adaptive comfort models add a little more human behaviour to the mix. They assume that if changes occur in the thermal environment to produce discomfort, then people will generally change their behaviour and act in a way that will restore it. Such actions could include taking off clothing, reducing activity levels or even opening the windows. The main effect of such models is to increase the range of conditions that designers can consider as comfortable, especially in naturally ventilated buildings where the occupants have a greater degree of control over their thermal environment.

V Results And Discussion

The simulations were run on a computer model for the three alternatives using Ecotect soft-ware. It is summarized in a graph for the entire year for the given building with all the conditions applied in the analysis. The three alternatives for the envelope materials are presented together in Table 4. The loads of Alternative B record the highest value (26737.334 kWh). While the loads of Alternative C is the lowest (19207.45 kWh). Alternative C saves 30% of the loads compared with Alternative B due to the efficiency of walls in reducing gains and losses.

Gains and losses occur via the various heat transfer mechanisms within a zone. These mecha-nisms include conduction, sol-air, direct solar, ventilation, internal and inter-zonal gains and losses. That is indicated by the colours shown in the legend below the figures 5,6 and 7. Values above the horizontal axis indicate heat gain; values below this axis indicate heat loss. To the left of these figures, the passive gains breakdown is measured in Watts per hour per square metre. While to the right of the graph, the gains are presented as percentage values.

Passive gains and losses breakdown analyses indicate that the majority of heat losses during winter or heat gains during summer occurs via Conduction heat transfer

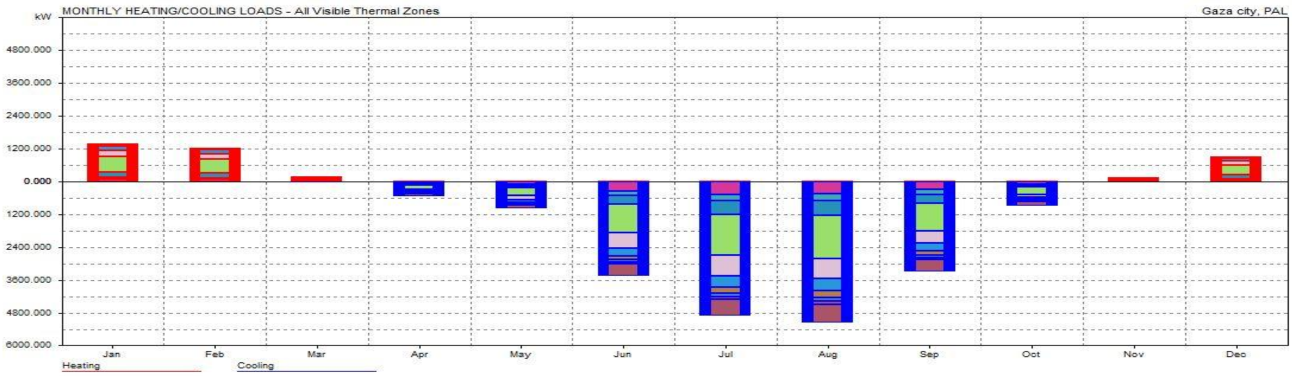


Figure 4 Alternative A monthly heating/cooling loads; heating load = 4112 kWh, cooling load = 19269 kWh; total loads = 23381 kWh.

(building envelope). Gains and losses analysis for alternative A shows the percentage of 54% caused by effect of using stone in exterior wall cladding (Figure 5a). The usage of stone cladding in exterior walls of the building could save energy better than using stone for cladding as shown in alternative A (Figure 5a), or even better than using plaster only for exterior walls as shown in alternative B (Figure 6a). As a result of the building conduction, the breakdown analysis for alternative A and B is respectively 54% and 60% of gains and losses. Alternative C is the most efficient option. It shows that 41% of heat gains and losses is due to the building conduction (Figure 7a). Therefore, this study suggests that building envelop in general, and more specifically, the walls of the building with low U -values should reduce heat gains and losses. Referring to Palestinian Code for thermal insulation, the overall heat transfer coefficients (“U” Factors) should not exceed 1.8 W/m^{2}K. Alternative C fulfilled this code and provided the lowest U-value of the walls (1.60 W/m^{2}K) compared with the other two alternatives A and B (2.33 and 2.51 W/m^{2}K respectively).

Table 4 Comparison between the three alternatives of wall materials

Month	Loads of Alternative A (kWh)	Loads of Alternative B (kWh)	Loads of Alternative C (kWh)
Jan	1395.981	1761.632	866.866
Feb	1238.777	1560.258	784.666
Mar	194.416	273.902	104.918
Apr	592.126	717.526	474.25
May	1015.314	1210.707	843.143
Jun	3474.519	3944.548	2930.56
Jul	4957.645	5466.524	4270.838
Aug	5189.35	5675.152	4539.039
Sep	3324.176	3635.027	2919.985
Oct	913.854	1068.838	853.13
Nov	166.602	227.688	92.497
Dec	917.779	1195.531	527.562
Total	**23380.537**	**26737.334**	**19207.45**

To conclude, conduction heat gains and losses are reduced from around 54% and 60% to around 41%. It should be noticed that the values are relative to the total amount of heat gains and losses. Figure 8 compares these values to the total amount and shows the significant difference between using exterior walls with air gap (alternative C) and other alternatives. The current study found that the peak measured values for heat gains and losses in alternative C with air gap for insulation has halved percentage.

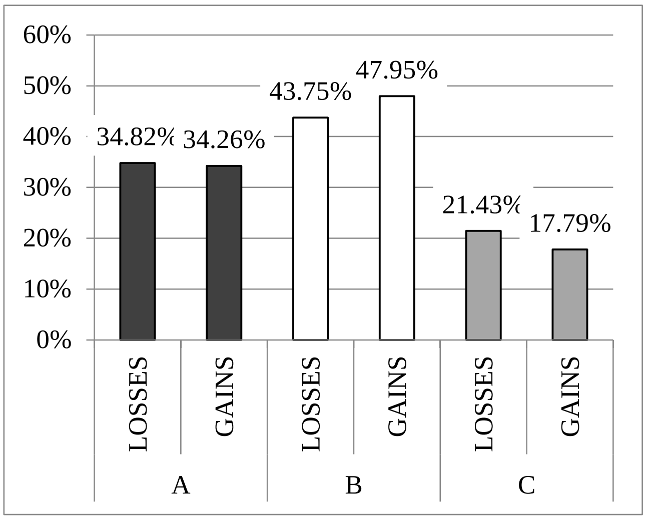


Figure 8 Passive gains and losses comparison for the three alternatives

In accordance with the present results, previous study for Ministry of Local Palestinian Gov-ernment [8] has demonstrated that homes with insulation save 50% of required energy to maintain comfortable temperature inside the home. It is true that the installation of insulation materials will cost more. Although the study of Ministry of Local Palestinian Government [8] shows that within maximum two years of running the system of heating or cooling, the saves of consumed energy will compensate the money was spent in installing insulation materials. This finding supports previous research into this brain area which links air gap for insulation and cost savings. Mahlia, Ng, Olofsson, and Andriyana [9] found that additional 0.64%/m2w all of life cycle cost savings can be achieved by applying 6 cm air gap at the selected insulation at optimal thickness. Moreover, Sadrzadehrafiei, Mat, Sopian and Lim [10] found that adding 2cm air gap in a brick walls decreases fuel consumed and emissions. Introducing optimal thicknesses insulation between 3 and 5cm and by adding air gap of 2cm, energy consumption cost was reduced to 24- 26% compared to a wall without insulation and air gap. Heat transfer through walls is minimized while economical and environmental advantages are also attained.

VI Conclusion

We conclude that building's envelop must have the priority in thermal insulation works, specially, in multi-storey bulding. This is because of its relativly wide area compared with the area of other building's elements such as roof and windows. Air gap inside the exterior walls works as a moderate. It also has the highest thermal resistivity compared to the other materials. It performs well in both hot and cold climate and it has the best R-value. It is the costliest when compared to the other materials and it is neither combustible nor perishable. External walls with air gap should be handled carefully to minimize the air flow and to stop any leaking that could ruin the insulation system.

The efficiency improvements provide a platform for the designers to include the thermal properties beforehand and to ensure the minimization of the loss of energy. The final results are interpreted from the total amount of heat gains and losses using the Ecotect software. The focus was on the envelop of the building, more specifically, the exterior walls for its significant effect. However, characteristics of other building elements are important factors to determine the energy efficiency of the buildings. The specific design which involves the orientation of individual buildings enhances the energy usage to a maximum extent. Moreover, it could be investigated in future studies putting in mind the crowdedness of Gaza strip and the expensive land price that hinder flexibility of choosing the best orientation of building to meet energy efficiency requirments.

References

[1] DOE (The United States Department of Energy), Buildings Energy Data Book. 2009.

[2] Ministry of Local Government, Construction materials & local market survey in Palestinian territories. 2002.

[3] The climate of Palestinian Territories. 2014 [cited 2014 24 Jun]; Available from: http://www.whatstheweatherlike.org/palestinian-territories/.

[4] Muhsen, H.L.A.-A., Decision Making in the Selection of the Exterior Walls Techniques in Affordable Housing Buildings in Palestine. 2012, National University.

[5] Palme, M., J. Guerra, and S. Alfaro, Thermal Performance of Traditional and New Concept Houses in the Ancient Village of San Pedro De Atacama and Surroundings. Sustainability, 2014. 6(6): p. 3321-3337.

[6] Hadid, M., Establishing, Adoption, and Implementation of Energy Codes for Building. Architectural Styles Survey in Palestinian Territories. 2002.

[7] MPA - The Concrete Centre. Dynamic Thermal Properties Calculator (ver 1.0). 2014; Available from: http://www.concretecentre.com/.

[8] Ministry of Local Government, Cost Efficiency Of Thermal Insulation. 2002.

[9] Mahlia, T., et al., Energy and cost savings of optimal thickness for selected insulation materials and air gaps for building walls in tropical climate. Energy Education Science and Technology, 2012. 29(1): p. 597-610.

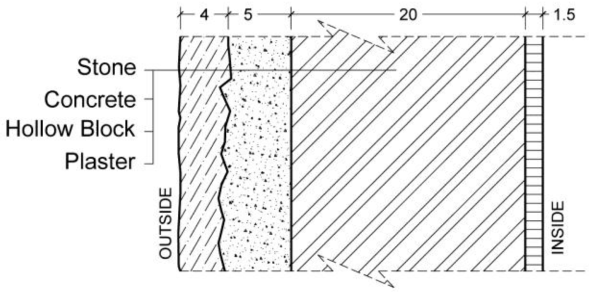
[10] Sadrzadehrafiei, S., K.S.S. Mat, and C. Lim, Determining the Cost Saving and Emission Reduction of Optimum Insulation Thickness and Air gap for Building Walls. Australian Journal of Basic and Applied Sciences, 2011. 5(12): p. 2287-2294.

[11] Zawaya company for design and consultation, Gaza strip, Palestine (2014). Private house design. Retrieved from http://www.zawaya.ps

Author Dr Husameddin Dawoud currently is an assistant professor in the College of Applied Engineering & Urban Planning at the University of Palestine in Gaza. He received his Ph.D in Theory in Design from University Science Malaysia in the year 2014. He occupied the posts of Director of Architectural Heritage in the Islamic University of Gaza in the year 2009, and Chief Engineer in Zawaya company for design and consultant since 2007. His research interest includes; CAD and AAD in architecture design, flow theory and creativity in design, rehabilitation of historic building, and green buildings. He is member of Association of Engineers (Gaza Governorates). He has published 6 scientific articles in his fields of interest. He can be contacted at hdawod@gmail.com.

APPENDIX

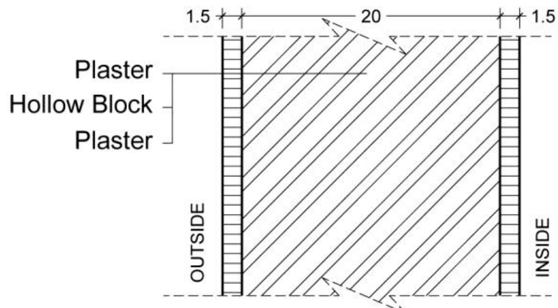
Table 1a Material prosperities for the Alternative A



Admittance [W/m2K]: 5.15, Time lead [hours]: 1.24 Time lag (Decrement delay) [hours]: 9.47
Time lag [hours]: 2.41
Simplified U-value (based on admittance method) [W/m²K]: 2.33

Material	Thickness [mm]	Density [kg/m³]	Specific heat capacity [J/kg/K]	Thermal conductivity [W/m/K]
Stone	40	2300	1000	1.8
Mortar	50	2300	1000	1.75
Hollow block	200	2000	836.8	1.1
Plaster	15	1300	1000	0.57

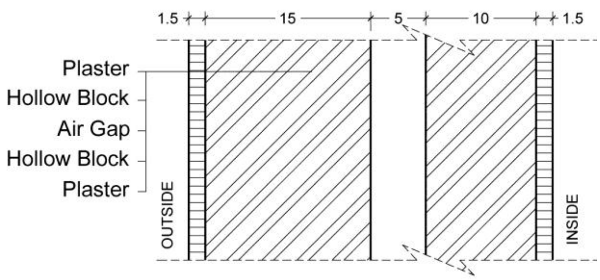
Table 2a Material prosperities for the Alternative B



Admittance [W/m²K]: 4.99, Time lead [hours]: 1.23 Time lag (Decrement delay) [hours]: 6.60Time lag [hours]: 1.87Simplified U-value (based on admittance method) [W/m²K]: 2.51

Material	Thickness [mm]	Density [kg/m³]	Specific heat capacity [J/kg/K]	Thermal conductivity [W/m/K]
External render (cement, sand)	15	1800	1000	1
Hollow block	200	2000	836.8	1.1
Plaster	15	1300	1000	0.57

Table 3a Material prosperities for the Alternative C



Admittance [W/m²K]: 5.15, Time lead [hours]: 1.24 Time lag (Decrement delay) [hours]: 9.47Time lag [hours]: 2.02Simplified U-value (based on admittance method) [W/m²K]: 1.60

Material	Thickness [mm]	Density [kg/m³]	Specific heat capacity [J/kg/K]	Thermal conductivity [W/m/K]
external render (cement, sand)	15	1800	1000	1
Hollow block	150	2000	836.8	1.1
Air Gap	50			
Hollow block	100	2000	836.8	1.1
Plaster	15	1300	1000	0.57

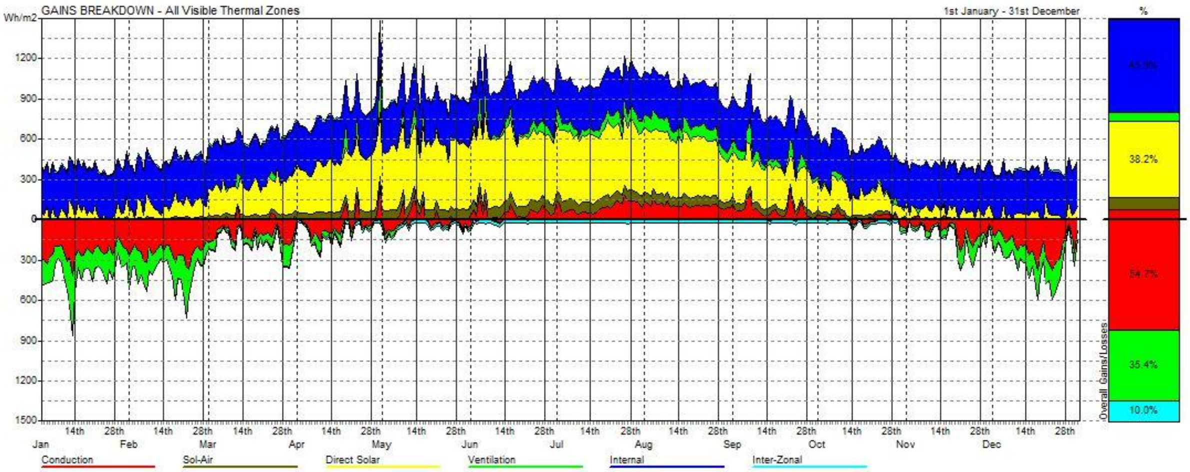


Figure 5a Passive gains and losses breakdown graph for alternative A

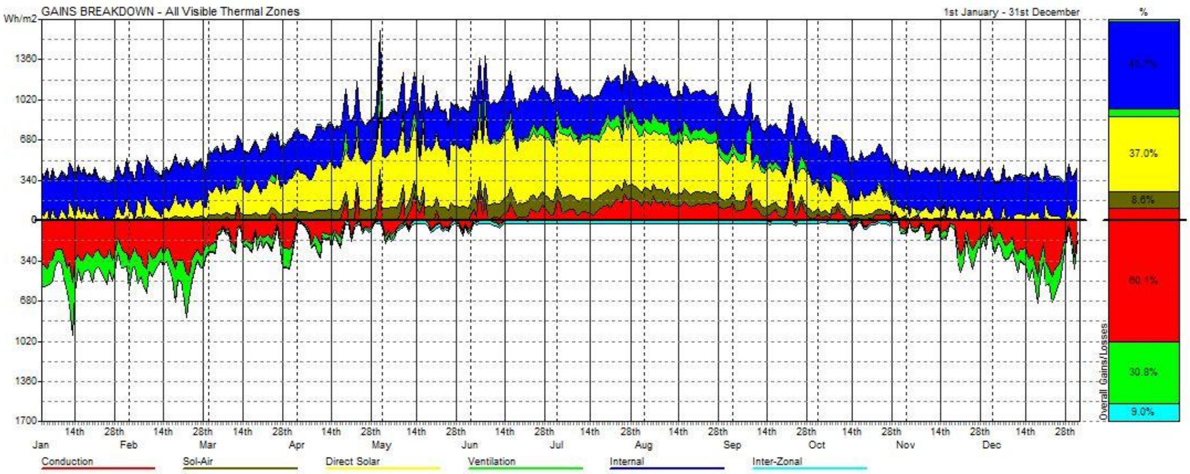


Figure 6a Passive gains and losses breakdown graph for alternative B

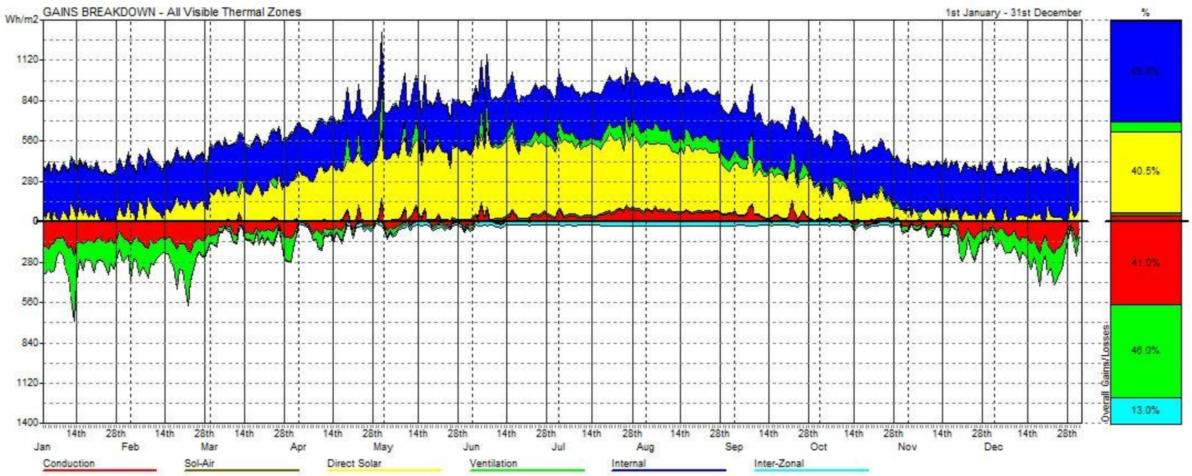


Figure 7a Passive gains and losses breakdown graph for alternative C