Local Traditional Building Materials in Reducing Energy Consuming in Residential Units

Comparison study of traditional and contemporary building material used residential units in Koya.

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ABSTRACT

Since 1972 with the release of the "Limits of Growth"; published by the Club of Rome, the world becomes aware of the serious concerns of consuming natural resources. That report; which was written by a team of the Massachusetts Institute of Technology (MIT) and was the start and motivation for many further studies, presented a forecast for 100 years addressing 5 major global concerns including dependence on nonrenewable resources and their accelerated depletion, and concluded that "if the growth trends in world population and industrialization continued unchanged, the model's limits to growth would be reached sometime within the following one hundred years (around 2072), with the most probable result being a rather sudden and uncontrollable decline in both population and industrial capacity to meets our needs." They then encouraged finding alternatives that "ensure the well-being of the human communities while being respectful of the life-sustaining ecological equilibriums". This paper considers the current global concern in saving energy and using renewable natural resources. The paper presents a comparison between the properties, advantages and disadvantages of traditional materials used in Koya residential units during the early 20th century represented by limestone and gypsum, and its currently common materials in building residential units represented by concrete blocks and plaster, in terms of heat gain and thermal consumption in Winter and Summer.

KEY WORDS: Energy Consumption, Traditional Materials, Limestone, Contemporary House

Research Significance and Objectives

The objective of the research is to assess the role of building materials in energy saving and accordingly compare between the traditional and contemporary materials that are used in Koya residential units. This comparison will provide information about the energy efficiency of these residential units during winter and summer.

1- INTRODUCTION

Architecture is a human creation. It is about people acting on their surroundings in building their shelters "culture, rituals, ways of life, and social organization, climates and landscapes, and materials and technology available, while the similarities are evidence not only of areas where some or all of these factors have coincided but also of some basic constancies in man's needs and desires" (Rapaport, 1969). In Kurdistan region, such patterns within rural settlements can reveal the clear variation in building styles and forms of houses which are imposed by the availability of local material, geographical location compared to a major regional center, or ease of access to major communication routes. (Rostam, 2017)

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This paper examines the energy consumption of selected old and modern local houses located in Bafra Qandi and Chwar-Bakhan which are two neighborhoods in Koya city by studying the building materials used in both houses.

1.1. Koya City

Koya City is located about 70 km southeast Erbil the capital of the Iraqi Kurdistan Region, its height is approximately between 625-700 m from the sea level. Koya is surrounded by the Mount Bawage which is 1260 m height and Mount Haibat Sultan with 1092 m height. The history of this city dates back to 2500 BC and is characterized by its ancient ruins. It contains about 80 archaeological sites like Kharabah, Klisheh, Qal'at Sheila and Aski Koya. In addition to its geographical and historical importance, Koya has a great cultural and scientific significance. The city has given birth to many writers and thinkers such as Malli Gawra, Haji Kader Koyi, Taher Tawfiq and others (Al-Saedi and Baban, 2017, p.37) It's also the birth city of the last three Iraqi presidents Jalal Talabni, Fuad Masum and Barham Salih.

Koya old town consisted originally of only four residential neighborhoods with a traditional character and organic planning includes a lot of winding alleys, these neighborhoods are Bafra Qandi, Qalat, Baizaga and Hawaw (Al-Qaisi, 2014, p.61) (Figure 1). New neighborhoods appeared later on and surrounded the old ones like the neighborhoods of Chwar-Bakhan, Kosrat, Haji Qadir and many others



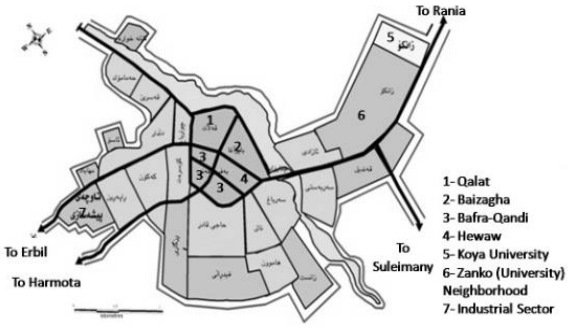


Figure 1: Koya old town location and neighborhoods, source: (Al-Saedi and Baban, 2017, p.37) and (Al-Qaisi, 2014, p.62)

1.2. Traditional building materials used in Koya:

Rostam (2017, p.12) notes in his study of the Kurdish vernacular architecture that "the materials used for the dwellings in the region differ depending on average annual temperature climate variations which range from +50°C to −10°C. Mudbrick, rubble stone, and timber were variously used. The modern Kurdish domestic vernacular settlements are not any different from those that were unearthed from archaeological sites, as mudbricks and domed roofing are employed in the drier zones, while rubble stone walls and wood beam roofs the dwellings observed in this study were mostly small houses with a couple of rooms with shared roofs which were built using traditional evolved engineering solutions such as stone arches and flat roofing, they all share a common link of being built by people following local customs using local materials".

The traditional building materials that were used in the construction of the 19th and early 20th century buildings in Koya include the locally available natural materials such as gypsum, stone, mud, soil, water resources, and reeds. The arches above doors are made of marble stone. The use of the lime in building which increase the strength of walls was a special characteristic that defines Koya local style, as well as the use of the clay jars that were used in the volts and in some walls to reduce the weight on the walls and increase thermal insulation due to the cavities within the empty jars. (Jelemordi, 2011, p.), (Sofi Bakir, 2018) (figures 2, 3)





Figure 2: The use of clay jars in Koya traditional houses, source: (Kawez, 2017)



Figure 3: The use of local materials in Koya

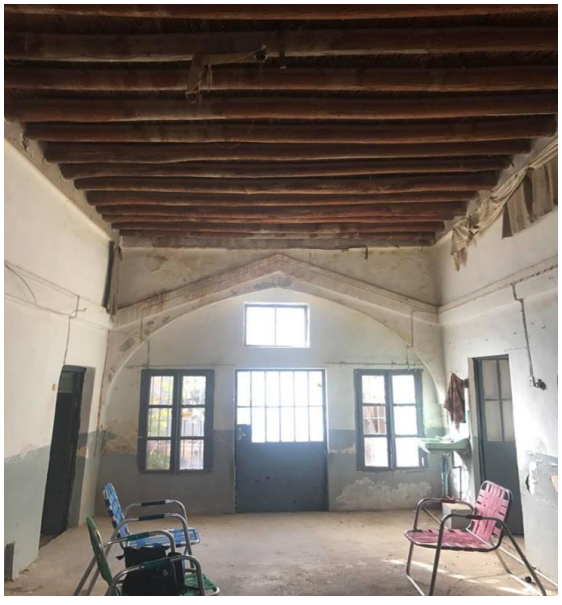




Figure 3: The use of local materials in Koya traditional houses, source: (Author, 2018)

1.3. Modern building materials used in Koya:

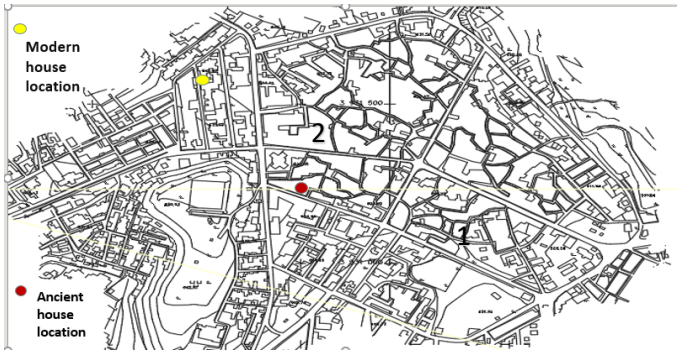
From the survey I've done to Koya old town, the building materials that were used for the houses since the 1950's were mainly concrete block, mortar, plaster.

2. METHODOLOGY

I will take a sample of the old traditional houses and compare it with another sample from the contemporary houses; are approximately within the same range of area. Both have the same orientation and environmental conditions, and will be examined via the (Design Builder) application to find out the amount of the zone sensible heating and cooling in both samples in order to compare between the old traditional building materials and modern building materials and conclude the amount of energy consumption in both cases.

3. CASE STUDY

Two houses were chosen in Koya city to be examined, an traditional house that uses the common local traditional building materials, and a contemporary house that uses common modern materials. both have approximately the same area which is around 240m². One of them in an old neighborhood in Koya old town which is Bafra-Qandi neighborhood, while the other one in a modern nearby neighborhood called Chwar-Bakhan. (Figure 4)



1- Old house in Bafra-qandi

2- New house in Chwar-Bakhan

Figure 4: The use of two houses in Koya, source: (Author, 2018)

3.1. The Traditional House:

The chosen house is known as the house of Bakri Haji kak Amin. This house is located in Bafra-Qandi. It was built in early 1928 with 253 m² area. Walls made of, plaster and stone with 0.45m thickness, the roof made of clay, straw and wood with 0.25m Thickness, and the floor made of clay, limestone and cement. Figures 5to 6 show the plans of the house and the materials of walls, roofs and floors.



Figure 5: Traditional house, ground floor, source: (Author, 2018)

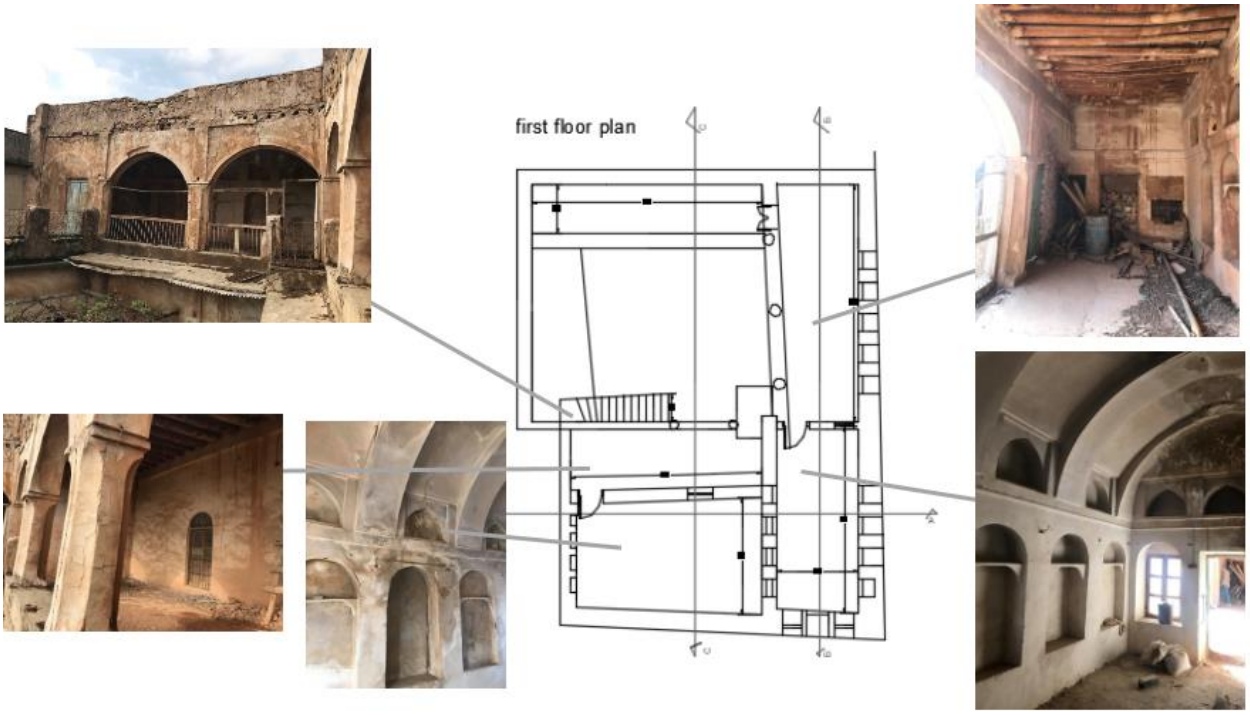


Figure 6: Traditional house, first floor, source: (Author, 2018)

3.2. The Contemporary House:

The chosen house belongs to Kak Dlsoz Ismaeel; it was built in 2010 in Chwar-Bakhan neighborhood with 250 m² area. Walls made of concrete block with 0.2m thickness, the roof made of concrete with 0.15 Thickness, and the floor made of concrete and Kashi Mosaik Figures 7 and 8 show the plans of the house and the materials of walls, roofs and floors.

3.3. Materials:

This section shows the main characteristics of the old and modern materials: (Table 1) (Figures 9, 10)

3.3.1. Characteristics Local Traditional Materials:

Limestone:

Mohammed Ali (2013, p.194) defines limestone as sedimentary rock like dolomite. It does not have division line in its structure, and its absorption is low. It is characterized by its high resistance for pressure and tightness. It is used for walls and floors.

According to Jassim (2015, p.132) limestone in Koya area within Pila-spi Formation could be used as construction material in accordance with national and international standard specification. A durable building stone is one which resists the weathering elements in the atmosphere, stone durability is closely related to both pore structure and strength, building material must be resist to physical and chemical weathering processes which are considered the main causes of building stone decay.

Wood

Wood is an organic material, a natural combination of cellulose fibers (that are strong in tension) embedded in a matrix that resists compression. It has a high caloric value (between 12.5 MJ/kg and 20.1 MJ/kg). Thermal re-utilization of untreated and uncoated wood is un-problematic. Re-utilization is possible if the wood is dismantled without damage. Untreated old wood conventionally can be used as raw material for a number of different applications. The conversion of wood into a sustainable, renewable resource to be used as a main building material could be beneficial in various areas of the world. (Almusaed and Almssad, 2015, P.45)



Figure 7: Contemporary house, ground floor, source: (Author, 2018)

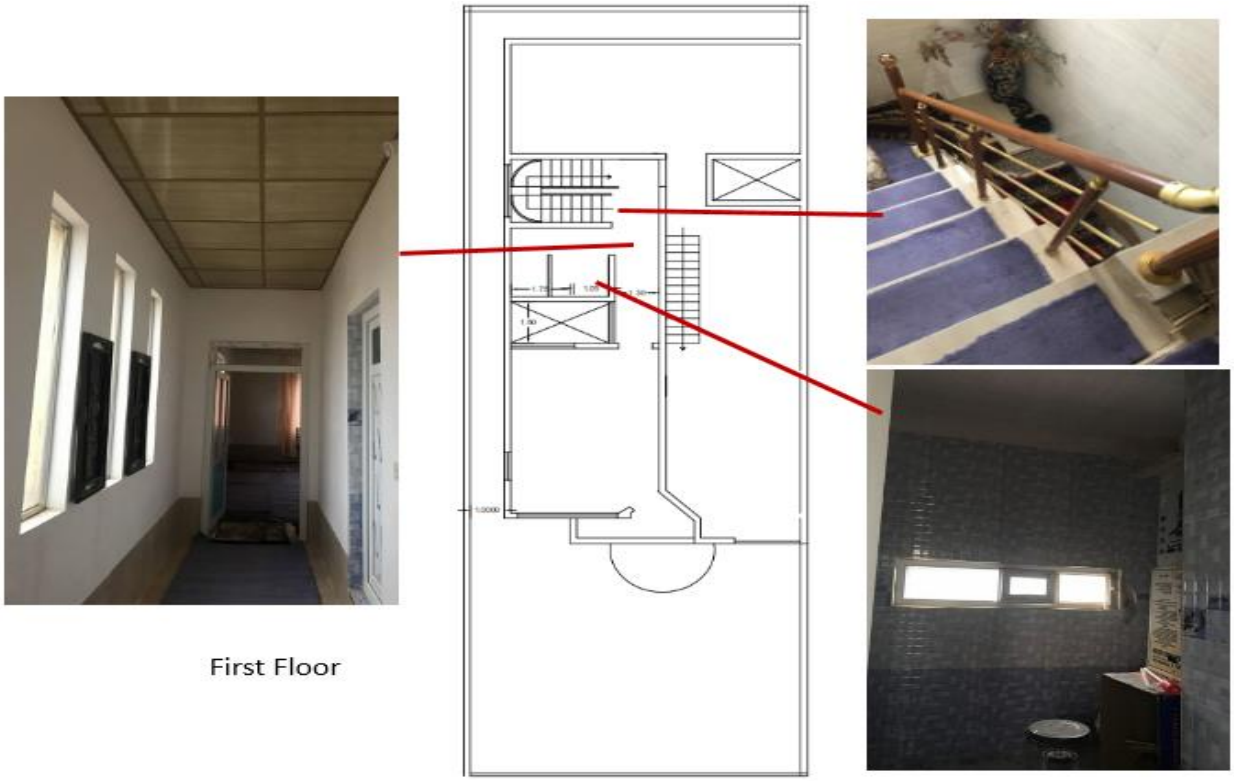


Figure 8: Contemporary house, first floor, source: (Author, 2018)

Straw:

Straw consists of 36% cellulose, 26% pentose's, 17% linen, wax, protein and ash – a composition very similar to wood. The straw has excellent insulation properties. Straw's biological functions include its axis for water. Therefore, straw bales are good at transporting moisture and thus regulate interior humidity, provided they bear the diffusion through open screen and coatings. Straw's weaknesses are risk of fire, insects or decay refraction caused by long-term, high moisture content (Gillv, 1970). Straw can provide greatly improved comfort, and dramatic energy savings compared to more expensive traditional building structures because they allow smaller heating or cooling systems in conventional homes because of the increased insulation. (Almusaed and Almssad, 2015, P.45)

Construction materials needs to be low energy consuming and mud construction system is less energy consuming and very successful in different weather conditions. Cob(Clay&straw) is an old earth building method passed down through the millennia, Cobis a sustainable earth building material with mud soil, coarse sand, straw and water are thoroughly mixed and beaten together (Ahmed,2017, p65)

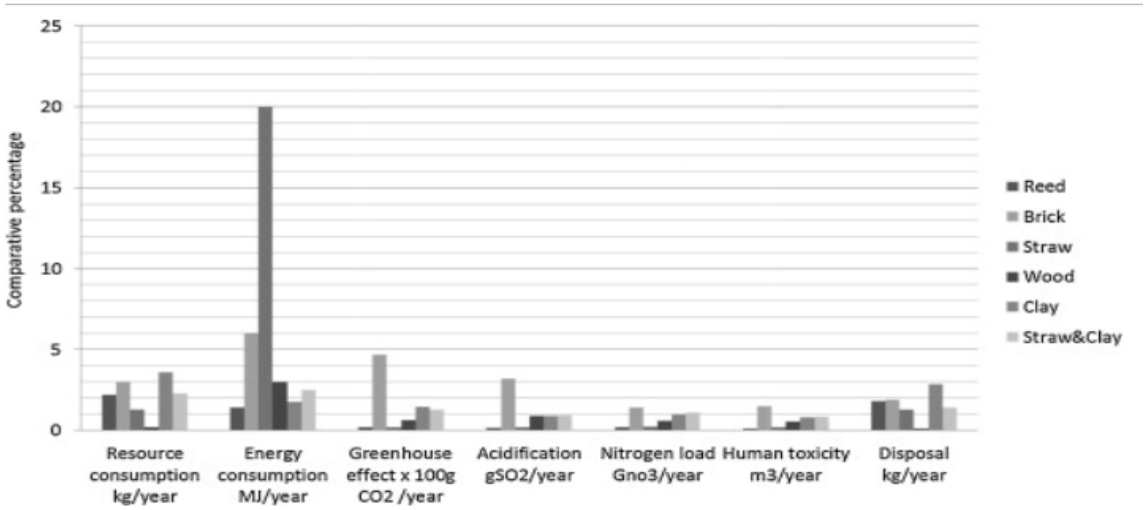


Figure 9: Building materials in eco-energy houses from Iraq and Iran. Source: (Almusaed and Almssad, 2015, P.46)

3.3.2. Modern Materials:

Thermostone:

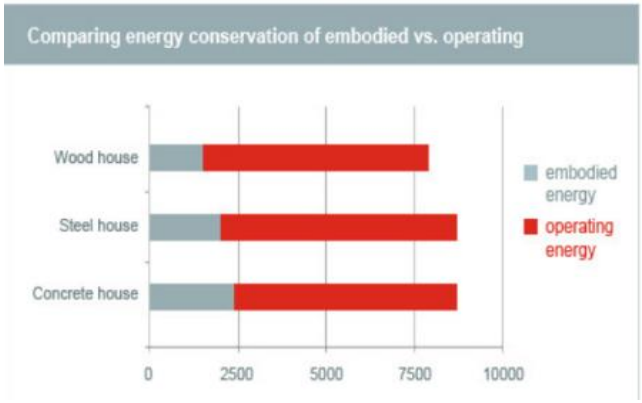
It is a modern construction material that has a white medium textured surface. It is a unique and excellent type of building material due to its super heat, fire and sound resistance; it is known as light weight concrete (LWC). It was invented in the mid-1920s by the Swedish architect and inventor Johan Axel Eriksson. The common raw materials used to manufacture thermostone blocks in Iraq are Portland cement, hydrated lime (calcium oxide), aluminum fine powder, water, and sand. Thermostone blocks offer ultimate workability, flexibility, durability, easy to handle, quickly to install and can be easily cut, chased and fixed into. (Ibraheem, 2013)

Concrete Block:

Normal weight blocks are made with cement, sand, gravel, crushed stone and air-cooled slag. Cellular concrete blocks are the major building materials in Kurdistan Region in Iraq. In a study about local concrete blocks, Rostam, Mohammed Ali and Atrushi (2016, p.1) examine 60 blocks from 10 local factories at Koya University Laboratory. The results showed that the products of all factories do not fulfil the requirements of the Iraqi and European specifications. The dimensions of specimens exhibited relatively high deviations with no recommended tolerances for dimensions of the blocks.

Table 1: Materials' Thermal Conductivity, source: (Improper, 1990)

Material	Thermal conductivity (W/m.K)
Brick(exposed)	0.77
Brick(protected)	0.56
Light Concrete Block	0.20
Dense Concrete Block	1.87
Mortar(exposed)	0.94
Mortar(protected)	0.88
Plaster (dense)	0.57
Plaster (light weight)	0.18
Exposed Polystyrene (EPS) Slab	0.040
Limestone or Marble	1.0
Sand	0.33
Wood	0.10-0.14
Steel (stainless)	15
Air	0.0262
straw	0.061



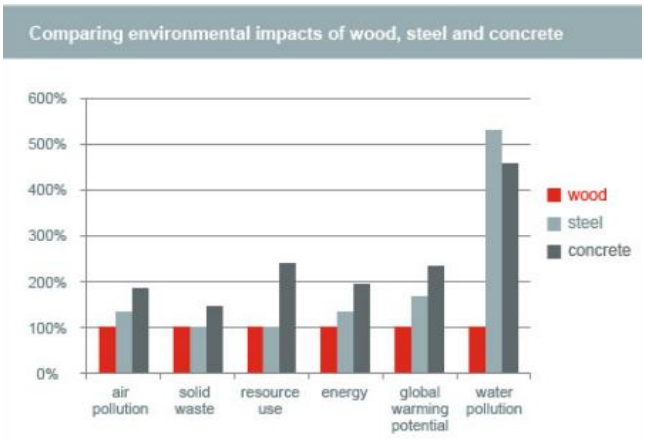


Figure 10: The environmental profile comparative analytical interpretation of 1 m² of different building materials. Source: (Sathre and Connor ,2010)

3.4. Design Builder Application Results:

I've used the design builder application to compare the old house with the new one.

Figures 11a and b show the data of the old house with stone walls of 0.45 m thickness, and the data of the new house with block walls of 0.2m thickness.

Now, the application enables us to reach the ideal heating/cooling design for each of those houses in Winter/Summer where the HVAC system should achieve in both cases the comfortable room temperature of 22 °C, the application therefore count the zone sensible heating and cooling for the two houses for winter and Summer.

Zone sensible heating is the heating effect of the HVAC system action on the zone heat balance, in particular the heating effect of introducing air that is warmer than the zone air. Likewise Zone Sensible Cooling is the cooling effect of the HVAC system on the zone. These are not always directly related to heating and cooling coil energy delivery, especially because of the effect of free cooling from outside air. So for example even if there is no cooling coil operational at a particular time, the Zone Sensible Cooling output on the Heat Balance graph can be high due to introduction of relatively cooler outside air into the space through mechanical ventilation. These

Zone Sensible Heating/Cooling outputs will also include a component due to fans (if operational) which will tend to warm air that moves through it (Tindale, 2019).

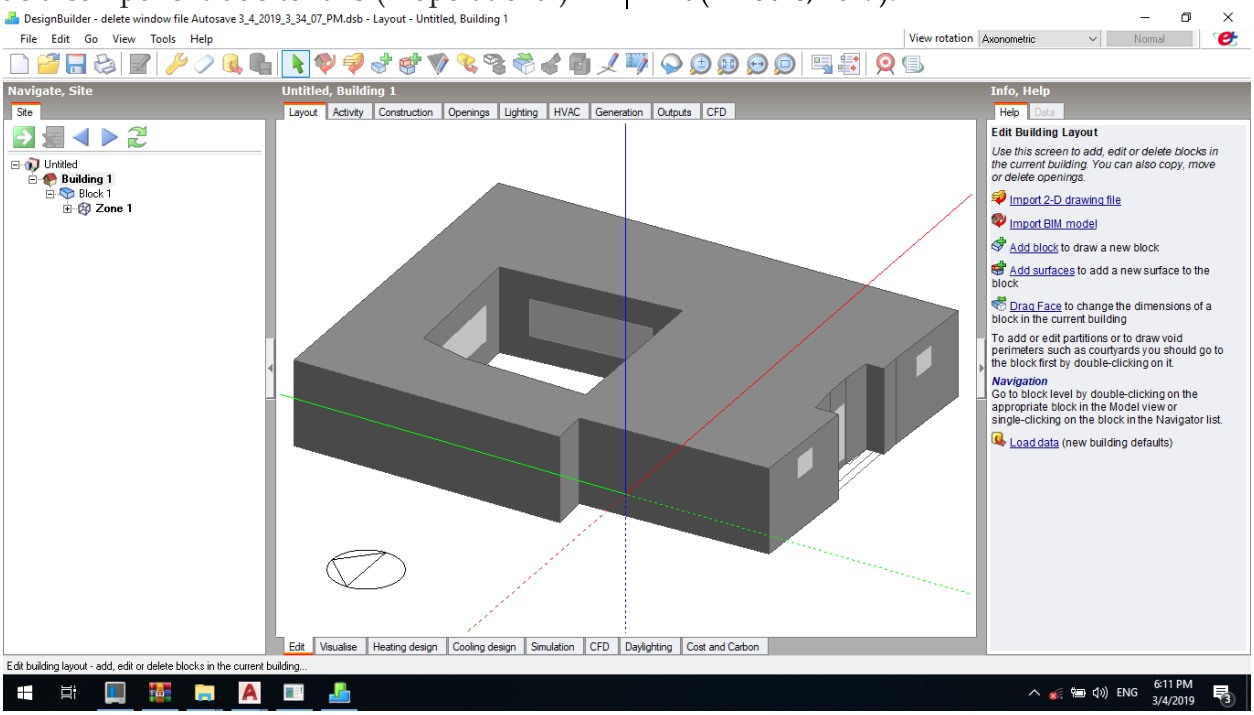


Figure 11a: The data of the old houses using the Design Builder interface.

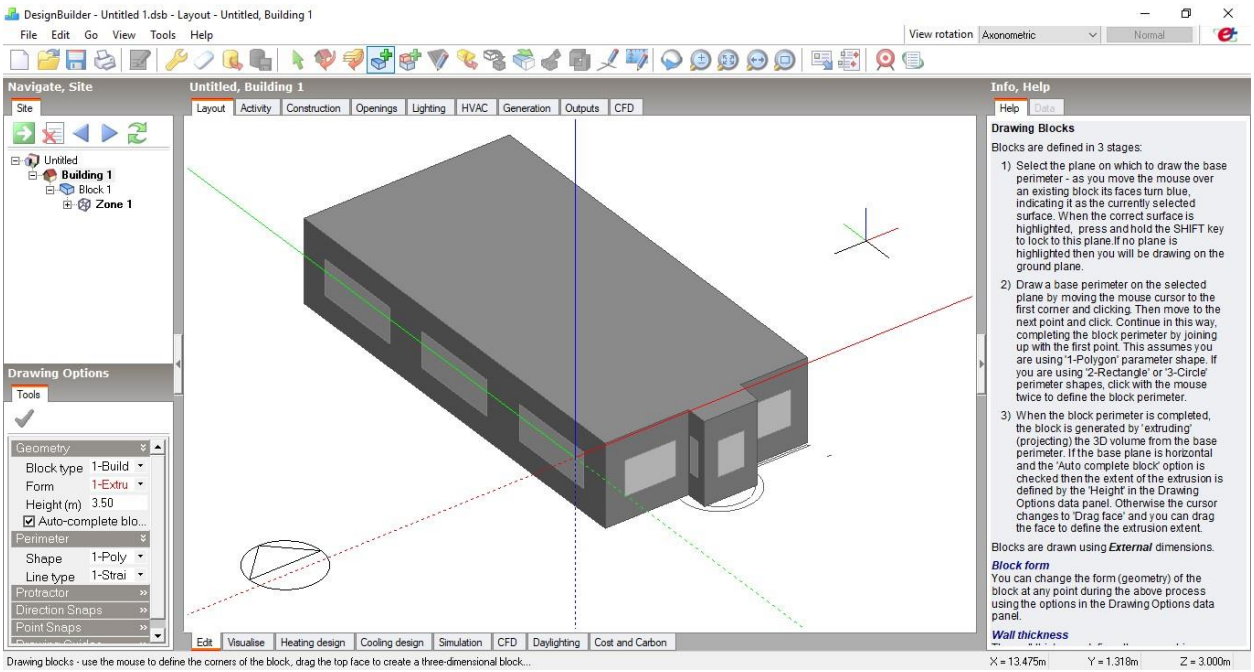


Figure 11b: The data of the new houses using the Design Builder interface.

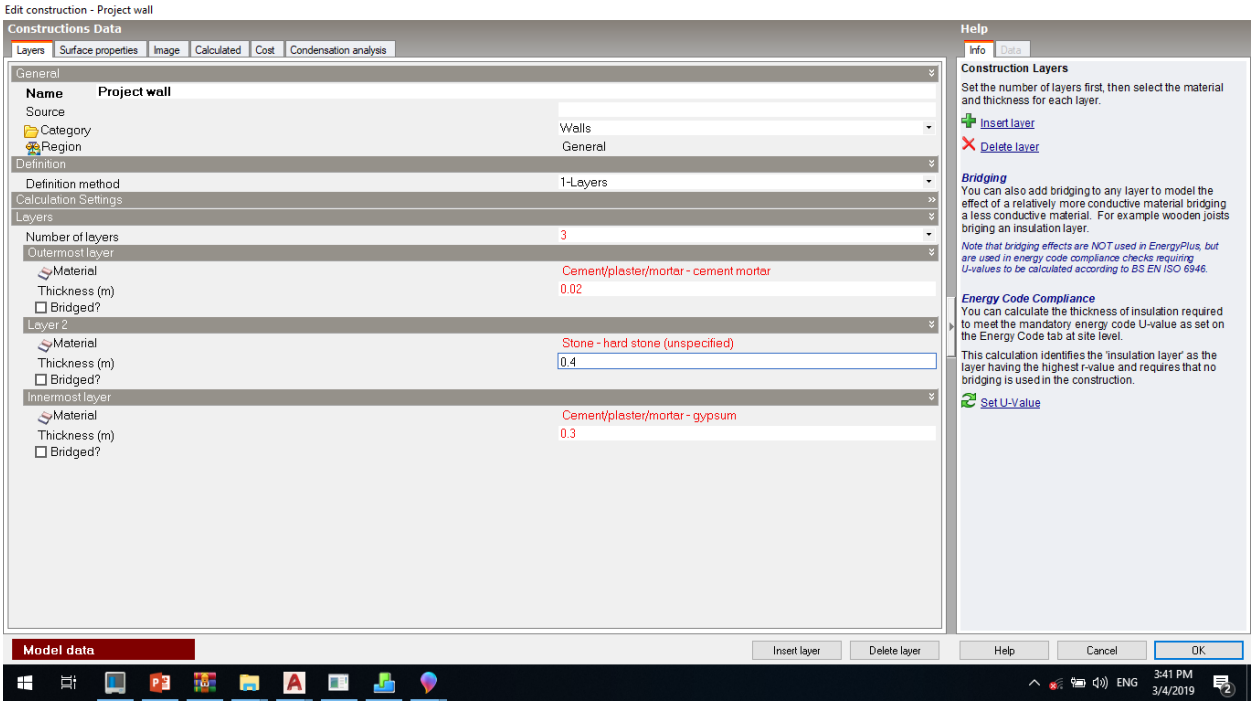


Figure 11c: The data of the old houses using the Design Builder interface.

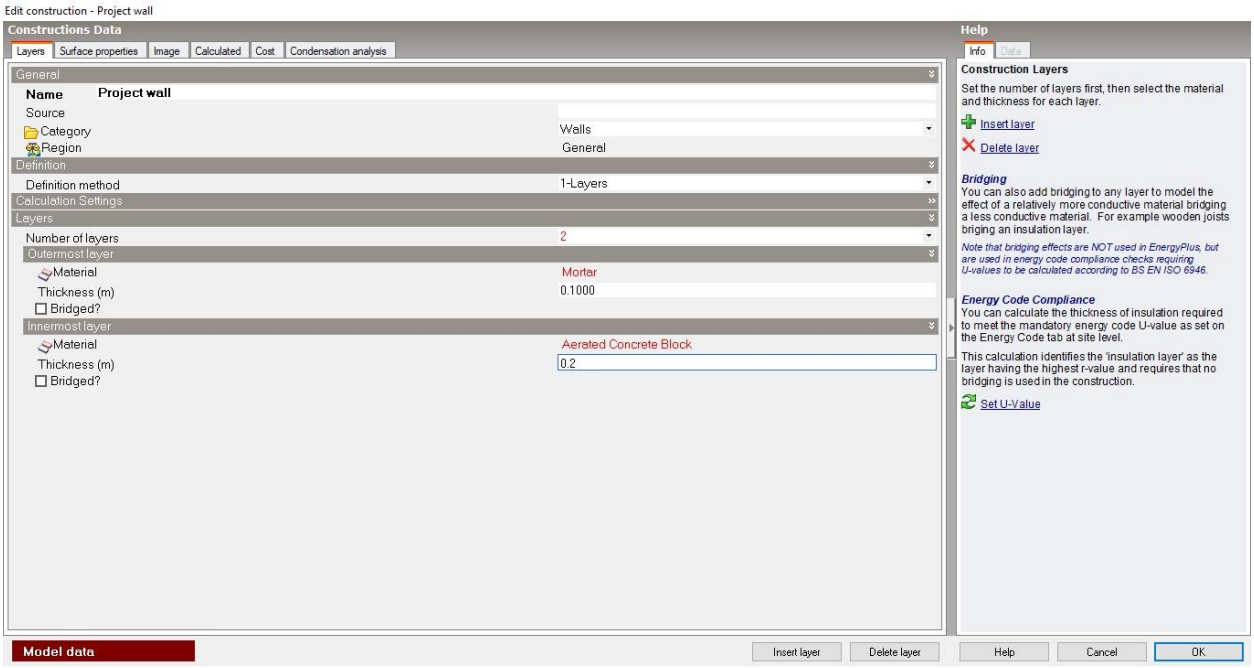


Figure 11d: The data of the new houses using the Design Builder interface.

Figure 12 shows the results of zone sensible heating of the old house which is 18.93 kW for Winter design caused mainly by the external ventilation -6.56 kW and external infiltration[i] -4.17 kW.[ii] Figure 13 shows the results of zone sensible heating of the new house which is 15.73 kW for Winter design caused mainly by the external ventilation -5.20 kW and external infiltration[iii] -3.30 kW. These results indicate that the new house was a little bit more efficient than the old house considering heating in Winter. The results show that the courtyard in the old house caused more

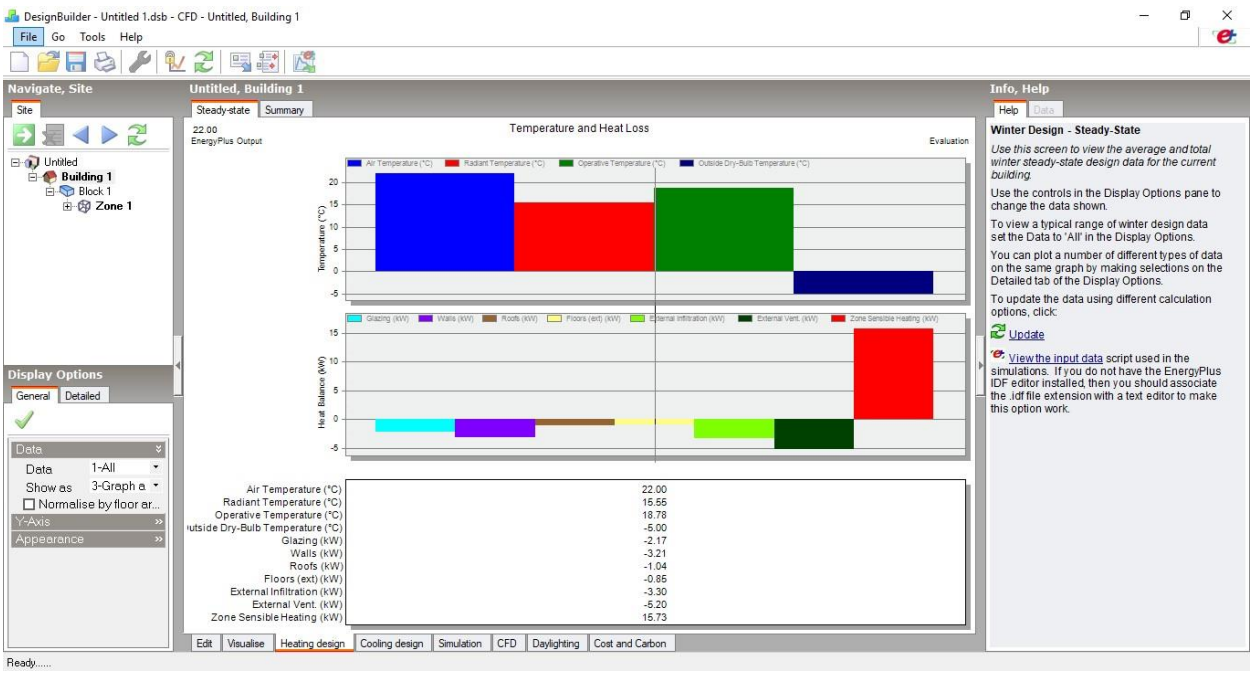


Figure 12: Zone sensible heating of the old house using the Design Builder

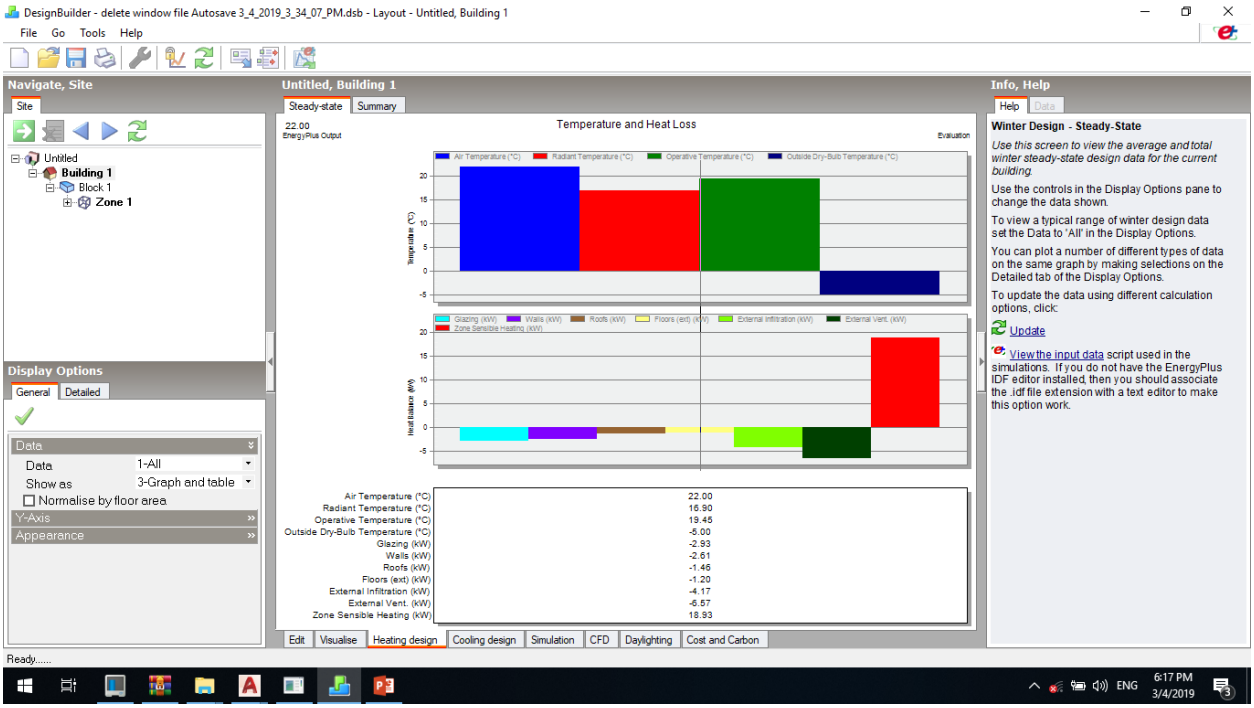


Figure 13: Zone sensible heating of the new house using the Design Builder.

The results of the heat gain of the old house in Summer show that the maximum indoor air temperature almost reaches 30°C in the first 4 hours (12-4 AM) of the day when the outdoor temperature goes down from 19°C to12°C, but the indoor air temperature settle down on 24°C for the next 14 hours (4 MA-6 PM) when the outdoor temperature starts increasing fast from 12°C to reach 30°C in the midday; the indoor air temperature goes up again to 26-28°C for the last six hours (6 PM-12 AM) when the outdoor temperature is going down from 27°C to 21°C. (Figure 14)

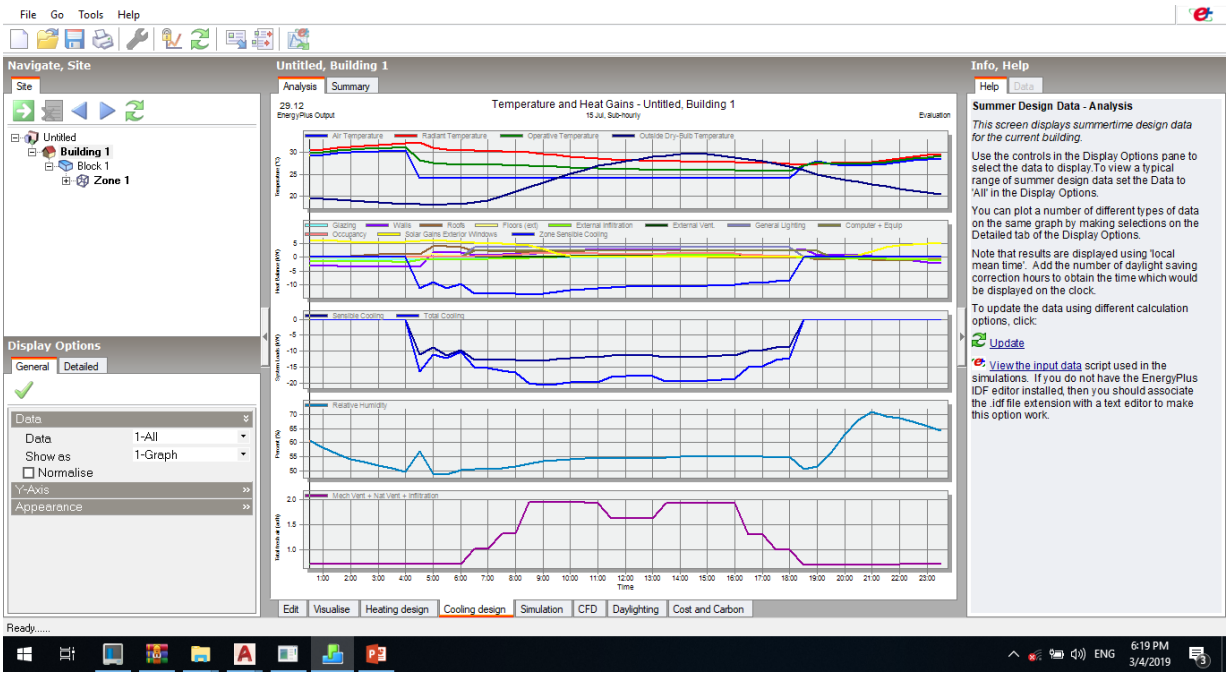


Figure 14: Heat gain of the old house using the Design Builder

Figure 14 shows also that the results of zone sensible energy for cooling of the old house reach its maximum -13 kW during 14.5 hours for Summer design.[iv]

In the other hand, the results of the heat gain of the new house in Summer show that the maximum indoor air temperature reaches 37°C in the first 4 hours (12-4 AM) of the day when the outdoor temperature goes down from 19°C to12°C, but the indoor air temperature settle down on 24.5°C for the next 14 hours (4 MA-6 PM) when the outdoor temperature starts increasing fast from 12°C to reach 30°C in the midday; the indoor air temperature goes up again to 26-35°C for the last six hours (6 PM-12 AM) when the outdoor temperature is going down from 27°C to 21°C. (Figure 15)

Figure 15 shows also that the results of zone sensible energy for cooling of the new house reach its maximum -19 kW during 14.5 hours for Summer design.

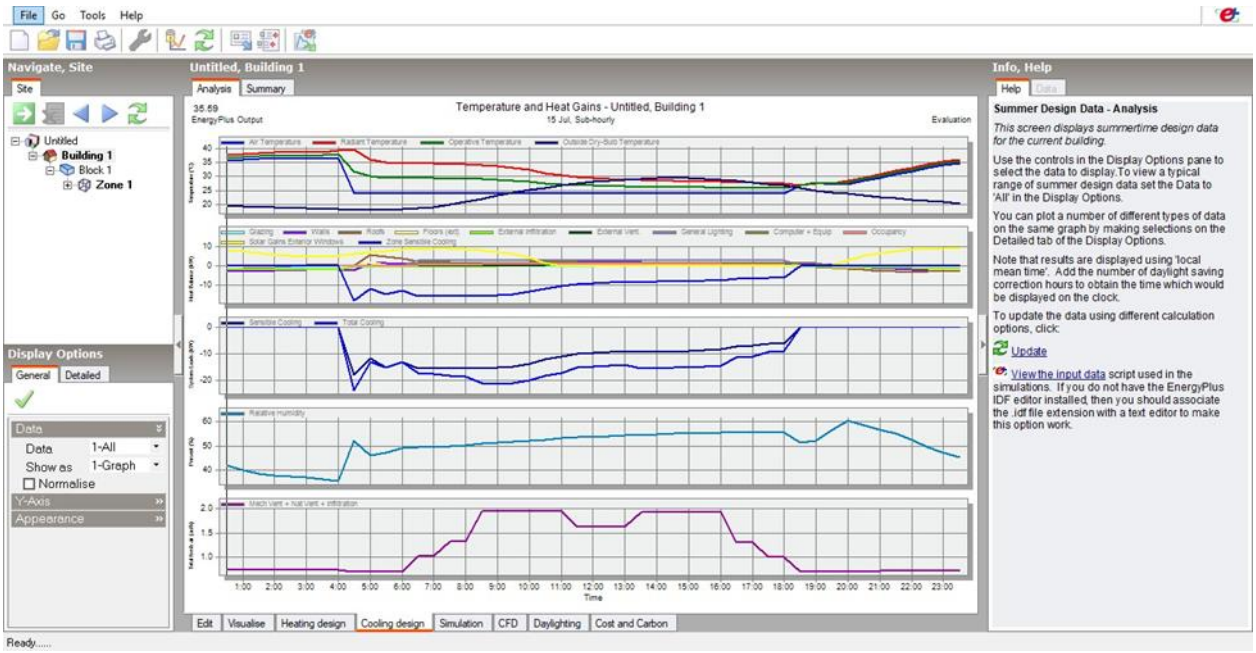


Figure 15: Heat gain of the new house using the Design Builder.

4. CONCLUSION

From the results above, the old house sounds slightly less efficient than the new house due to the existence of the courtyard in terms of zone sensible heating in Winter design, but the results also show that the stone walls in the old house caused only (2.61 kW) extra heat load, while the concrete block walls in the new house caused (3.21 kW) extra heat load. (Figures 12, 13)

The results show that the old house is remarkably more efficient than the new house in terms of heat gain and zone sensible cooling in Summer design. The stone walls of the old house helped enhancing the cooling activity better than the concrete block walls. (Figures 14, 15)

The study finds that the traditional local materials proved more efficiency in saving energy in both summer and winter and need to be taken in consideration when building new houses.

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[i] *infiltration is the unintentional or accidental introduction of outside air into a building, typically through cracks in the building envelope and through use of doors for passage, Infiltration is sometimes called air leakage. (American Society of Heating, 2005)*

[ii] *Negative values here refer to the extra heat load caused by each element.*

[iv] *Negative values here refer to the cooling load.*