A Study of Thermal Performance Analysis of Low-Income Housing in Jordan: Case of SOS Buildings

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ABSTRACT

Energy conservation and efficiency is an input-reduction method, and a way for achieving sustainable design. Its main roll is to reduce consumption of fossil fuels. Buildings consume energy in their operation for heating, lighting and cooling, and also in their construction. Aqaba's SOS village _ as energy efficient housing buildings_ gets the Aga Khan award in architecture 2001, for their friendly relation with environment.

This paper investigated, analyzed, evaluated and compared energy efficiency, thermal performance and envelope design for SOS buildings as energy efficient ones in three different locations in Jordan. The prime objective of this research was to understand the environmental conditions and to improve design practices, which aimed to help the ability to improve the quality of built environment and living conditions. Aimed also to determine the effective thermal strategies, to have the better thermal performance for energy efficient housing buildings, and to have these strategies as guidelines for architects.

Moreover, it evaluated energy performance of SOS village's buildings, through simulating the real environment by using computer simulation program, and monitoring the temperatures by using sensors and data loggers, in addition to that it used formal and informal interviews with house's occupants and its designer.

It concluded that Irbid's SOS village buildings was considered as a thermal comfort housing buildings that corresponded 60% of occupant's perceptions (according to ASHREA standards), regarding it as a comfort buildings. While Aqaba's ones were perceived as a totally comfort buildings in winter, and un-comfort environment in summer. A similar harsh environment needs a rational and conscious consideration of choosing envelope formers to get a good thermal mass that prevents heat gain in summer.

Definite strategies were defined to improve housing buildings thermal conditions and minimize energy consumption in the three villages, which can be generalized on similar housing buildings in the same cities, holding convergent characteristics.

These kinds of studies having a high grand, because it searches to minimize energy consumption and complies with human comfort as a main target. And also because housing projects having the greater portion in the built-up area all around the world and the highly energy consumers and the greater place to stay in daily, it deserves to have this interest.

A comprehensive understanding for energy efficient buildings will improve architects designs, and consequently human's lives and their interpretations. In total, the paper builds for setting up a base knowledge for thermal performance evaluation and investigation, and opens a way for future researches to take place.

1. INTRODUCTION

Jordan, as a developing country, has no significant oil resources with limited slow progress in energy sector, and natural gas reserve which is not able to support a substantial production increase. With the increase of electricity demand[1], and in parallel to the global tropism to renewable energy, and its different resources; solar, hydropower, wind, tide, geothermal, and the problem of climatic changes, its became a high challenge with Jordan's potential position to get benefit from the solar energy as one of the most important energy resources.

Energy consumption of Jordan is numerated as a high one especially that is the imported energy formed 96% of the total energy consumption in 2009[2] which is increasing daily, whereas the predicted energy need will increase in a percentage of 5.5% between 2008 -2020 as reported by the Jordanian ministry of energy and mineral resources[3]. These consumptions are divided into different sectors; industry, transportation, households and services. Whereas Household is in the second ascending order after transportation in energy consuming which reaches 22 -25% of energy use in Jordan[4].

Contemporary architectural design can't solve its problems of environmental control by means of artificial systems. Furthermore, in many other cultures buildings have been built with an acute awareness of the limitations imposed by the climate in which they are located. Builders with few technical resources are forced to design their buildings in close relation to their usefulness as a barrier against the climate. In our modern buildings, on the other hand, the unrealistic faith in artificial systems lead to design which disregard the climate and turn out buildings that are both physiologically and psychologically inhospitable.

One of the main tasks of environmental control systems is to provide thermally comfortable indoor conditions for the occupants. Mainly the sustainable buildings which are defined as "*the creation and responsible management of a healthy built environment based on resource efficient and ecological principles"*[5]. So the sustainable buildings are considered as buildings with a control on thermal indoor conditions that offers comfort for its occupants, through many strategies like; thermal mass, architectural and physical design and many other strategies to gain a healthy built environment.

Thermal comfort in buildings is perceived as one of the characteristic and difficult variables that architecture must address, for that a deep study for the idea of sustainable architecture, thermal comfort, thermal mass, orientation and the other physical architectural elements which are important in determining the rate of solar heat gain in addition to its architectural decorative function must be taken into consideration.

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[1] http://www.gasanodoil.com/goc/news/ntm24216.htm
[2] http://memr.gov.jo/LinkClick.aspx?fileticket=CMR4nbDhACQ%3d&tabid=36(28-10-2011)
[3] http://memr.gov.jo/LinkClick.aspx?fileticket=CMR4nbDhACQ%3d&tabid=36(28-10-2011)
[4] Ministry of energy and mineral resources reports at the end of year 2010.
[5] http://www1.arch.hku/research/BEER/sustain.htm

The main goal of the study was to investigate, analyze, evaluate and compare thermal performance for low income housing (SOS buildings) in three different locations in Jordan through different methods of inquiry.

2. GOALS AND OBJECTIVES:

Achieving this goal came through inquiring five objectives, there are:

- To evaluate energy performance of SOS villages buildings (as a case for low income housing), (through simulating the real environment by using a computer program), and to investigate thermal behavior of SOS villages buildings which should provide comfortable living conditions for its occupants without having to install an HVAC systems.
- To determine the effective thermal strategies and to have the best thermal performance for contemporary modern buildings. (To improve building design in order to provide comfortable living conditions with far lower purchased energy demand). In determining these strategies it will become as guidelines for architects while designing.
- To reduce energy levels due to artificial heating and cooling, while maintaining satisfactory comfort level for occupants. And to understand the effect of solar heat radiation on internal thermal comfort. And to create an environmental awareness.
- The study of buildings will lead to a better understanding of environmental conditions and to improve design practice that will help to study and improve the quality of the built environment & living conditions.

3. DESCREPTION OF SOS BUILDINGS AS A LOW INCOME HOUSING PROJECT IN JORDAN.

SOS Children's buildings, as community housing projects in Jordan, designed by architect. Jafar Tukan, was assumed as an energy efficient project. SOS children's village of Aqaba has received an award (*Aga Khan Award for Architecture 2001).* For creating a pleasant and attractive environment scaled to the needs of children,[6] in addition it is friendly with the environment.

The purpose of the design is to create an environment where orphaned children are able to enjoy living conditions that are as close as possible to normal family life. In Jordan, there are three villages that built in three different locations; Amman, Aqaba and Irbid. Each village consists of individual houses, usually include 8-15 houses, where built around a series of small-scale shaded open spaces which linked through pedestrian paths.(Assad). These houses are integrated with the nature of the site and a network of paved walkways, stairs and ramps connect the various parts of the villages. Informal landscaping and the use of rubble walls (the use of the local materials) enhance the integration of natural and built-up environment.). Another significant feature of the project is the use of local construction materials. Irregular rocks, which are naturally found on the site, were used, which emphasizes the integration between the buildings and the surrounded landscape.(see appendix.1.)

The shape of the buildings, which consist of one or two stories, is cubic and contains small openings in order to regulate the environmental conditions. The small area in the mean façade will limit heat exchange especially in Aqaba climate that categorized as hot-humid climate. This theme of environmental sensitivity is continued through the use of wind towers that provide ventilation and cooling, and also function as elements of architectural articulation. (Assad)).

Several passive techniques were employed in this project: First; the uses of traditional ventilation techniques such as wind towers were used. This system used a kind of large chimney vertically slit in its upper parts by several brick baffles. During night time the tower cools off; the air coming in contact with the tower also cool off, becomes a heavier and descends the interior of

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[6] http://www.akdn.org/agency/akaa/eighthcycle/page_06txt.htm

the tower, thereby penetrating the building (Cettina Gallo,1998..ren&Sus).second; the use of massive walls that used in these houses. The massive thickness of these walls is around 40 cm. Several materials were used such as concrete, irregular stones, lime, and timber. Third, the use of Mashrabiyas (screens), which filter the light of the harsh sun and consists of decorative wooden structure, implemented in most windows of the houses. Finally, the urban settings that has significant effect on thermal behavior of the building; the sensitivity

The selection of the envelop material, orientation, geometric shape, the openings and their orientation, and other designed elements working harmoniously with the climatic factors will lead simply to a thermal comfort in the designed building, but first of all there is the need to understand the performance of these elements with the different climatic factors.

2. CLIMATIC REGIONS IN JORDAN

Jordan is located 80 kilometers east of the eastern coast of the Mediterranean Sea. Its location between 29° 11'N and 33° 22'N, and between 34° 19' E and 39° 18'E with an area of 89329 km^2, more than 80% is classified as arid areas.(Jordan Meteorological Department,2003)

Badia lies at the eastern and most of the southern parts of the country and a range of mountains in the eastern side of Jordan River whose length is 330km in a valley of only 104km length. The mountains vary in elevation from 1250m in the North, to 900m in the middle and 1700m in the south. The Jordan rift valley which is also called the Ghor is totally below sea level varying from 200m in the north to 400m in the south. The Dead Sea is the absolute lowest area in the world (408m bellow MSL). (Jordan Meteorological Department, 2003)The rainy season is between October and May. 80% of the annual rainfall occurs through December to March. (With an average from 600mm/year in north to less than 50mm/year in south). Rainfall decreases from North to South, West to East and from higher elevation to lower ones. (Jordan metrological department,2003).

Climate in Jordan is predominantly of the Mediterranean type. Hot and dry summer and cool wet winter with two short transitional periods in autumn and Spring. (Ali H., 2001) and it is classified into four main climatic regions, (because of the topographical variety) (Ali H., 2001), they are as follows :(see appendix3)

<u>Jordan rift valley (The Ghor):as a low altitude region</u>: The climate of Ghor is classified as tropical. It is "*very hot in summer and warm in winter. The annual rainfall is 150-250mm. The elevation of the Ghor is below M.S.L. ranging from 200 to 400 meters. Its width is about 15 km In the North to 30 km in the South"* . (Jordan metrological department), the average daily temperature in summer is around 38C and in winter is around 18C. (Ali H. 2001)

<u>The Mountainous (Hilly) Region: as a high altitude region:</u> Lies to east of the Ghor extending from North to South. Its elevation varies from 750m to 1200m with some tops exceeding 1700m. The climate of these Regions is rather" *mild in summer and cold in winter, the amount of rainfall ranges from 300–600mm/year. Snowfall occurs over the mountains"*. [7]

<u>The Badia Region: as a medium altitude region:</u> It is a flat terrain that lies to the "*east of the high lands with elevation varies from 600-700m. Climate in this region varies widely between summer and winter and between day and night. It is characterized by dry hot summer and relatively cold dry winter the amount of rainfall 40-100 mm/year*". (Jordan metrological department) with an "*average daily temperature in summer is 35C. where it can exceed 40°C. In winter, it is cold and dry with an average daily temperature of 7C. The winter nights can be very cold, dry and windy"*. (Ali H. 2001)

(http://www.jmd.gov.jo/climate_intro.html)

The Aqaba Gulf***:*** Characterized by very hot summer and warm winter the amount of rainfall less than 50mm per year.

Weather conditions play significant role in energy consumption patterns and expenditures. These conditions include air temperature, wind speed and direction, precipitation, relative humidity, and sun radiations.

4. RESEARCH METHODOLOGY

According to the specific research context, a cross-sectional design strategy was adopted. In this study data were collected base on triangulation approach that uses of two or more methods of data collection procedures within a single study. (Duffy,1984). "Combining *quantitative and qualitative methods*". (Leedy, 1989). Its main principles that are the research question must be focused, the strengths and weaknesses of each method must complement the others, and the methods must be selected according to their relevance to the nature of the phenomenon being studied. Triangulation is used in order to reach verification for the results and also reliability and to reach the internal validity. (E.S.Mitchell ,1986).

Data collection procedures used in this study included:

1. Building Simulation
2. Monitoring and Calculations of Heat Flow and Building Balance Point.
3. Field Observation and Occupants Interview

4.1 Building Simulation

Simulation is a technique that uses a computer programs to analyze, synthesis, formulate and evaluate sequence of design activity. Modeling strategy is concerned in how the various sub-systems in building energy simulation are integrated. In most simulation tools, the building and its energy systems are represented by three basic models. Load model**,** It represents the thermal behavior of the building structure and its contents. Building envelope, internal loads and infiltration are considered in the load calculations to determine the amount of heat added to or extracted from the space to maintain comfortable indoor conditions. Other models included: system model and plant model.

This study used eQUEST as one of the building energy simulation programs. That is an hour-by-hour building energy consumption model, using hourly weather data for the location under consideration[8]. Input to the program consist of detailed description of the building being analyzed, including hourly scheduling of occupants, lighting, equipments, and thermostat settings.

very accurate simulations are provided by eQUEST of such building features as shading, fenestration, interior building mass, envelope building mass, and the dynamic response of differing heating and air conditioning system type controls.

Alternative analyses are made by making changes to the model that correspond to efficiency measures that could be implemented in the building. These alternative analyses result in annual utility consumption and cost savings for the efficiency measure that can then be used to determine simple payback, life cycle cost, etc. for the measure and, ultimately, to determine the best combination of alternatives.

The requierd information and data are:

- Building site information and weather data

Important building site characteristics include latitude, longitude and elevation, in addition to the information about adjacent structure and landscape that casts shadows on the building.

- Building operations and scheduling

For the accuracy of the simulation model a clear schedule of operation for the building is needed. This includes information about building occupancy when it begins and ends(times, days

[8] http://doe2.com/equest/

of the week, and seasonal variations), and HVAC and internal equipment operations schedules. That depends on building type.

- Building envelope, shell, structure, materials, and shades

Walls, roof, and floor of a building and their properities of transfering or storing heat. In addition to the geometry (dimensions) of the building, its construction materials, glass properities, windows, dimensions and window shades(overhangs or fins).

- Internal loads

Heat gain from internal loads (people, lights, and equipments). That can make large buildings relatively insensitive to weather. More importantly, the performance of almost all energy-efficient design alternatives will be impact either directly or indirectly by the amount of internal load within a building.

- HVAC equipments and performance

The good information regarding HVAC equipment effiecincy is important to the accuracy of any energy use simulation.

- Utility rate

Like hourly electricity demand

- Economic parameters

Like productivity data, lease rate, and occupancy rates.

According to heat transfer surfaces eQUEST deals with four types of surfaces, they are:

- light transmitting surfaces, such as, windows, glass block walls, sliding glass doors, and skylights.
- Exterior surfaces, such as, exterior walls, roofs, and floors.
- Interior surfaces, such as, interior walls, ceilings, and floors.
- Underground surfaces, such as, underground walls, basement floors and walls, and slab-on-garde.

4.2. BUILDING MONITORING AND DATA ACQUISITION

Monitoring is used to validate the study, By using semi-conductor data loggers, that contineously monitored the dry-bulb tempereture, ambiant tempbuilding to figure out how much energy differences between them, which indicates the efficincy of envelope design with the other variabels.

Data afforded by monitors have been compared with data that was afforded by calculations for resistance R of the totale envelope materials and their U value to reach the inside tempereture according to the outside one.

4.3. (SURVEY) FIELD OBSERVATION AND OCCUPANTS INTERVIEW

Field observation or survey was the first step to recognize the physical characteristics of the buildings that will help in determining the variables which will be included within the previous two methods, based on field survey to percept the site, buildings area, use of HVAC systems, patterns of activities, to calculate the balance point temperature and determining the comfort zone for each site by drawing the psychometric chart, evaluate roughly building heat efficiency and to investigate the used envelope materials with the use of architectural and construction drawings.

Occupant's interviews or questionnaires were adapted also as a self reported data, "*as a commonplace instatement for observing data beyond the physical reach of the observer*" (Leedy, 1989). To evaluate the perception of building heat efficiency according to the occupants, they were asked about definite times and their sensation towards thermal comfort. And an important interview was held with the designer to determine the main used strategies to reach building energy efficiency and the awareness of these strategies.

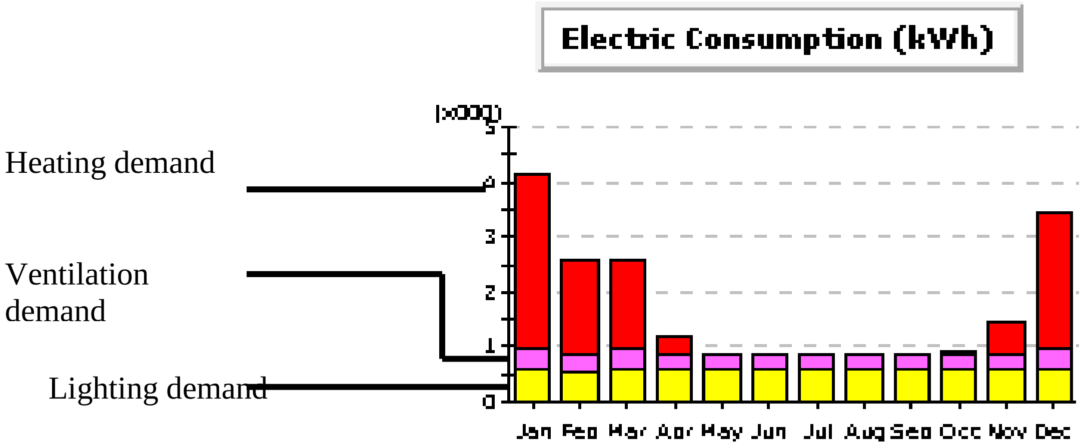
5. RESULTS AND ANALYSIS

5.1. PREDICTED BEHAVIOR

The simulations of the thermal behavior of the buildings showed similarities between Irbid and Amman location, while a difference in Aqaba. This is due to the variation in the weather between Irbid and Amman in one side and Aqaba on the other side.

Both Amman and Irbid have almost the same weather conditions, the same building materials, and the same architectural systems used. Taking into consideration that the three locations have same characteristics of occupants.

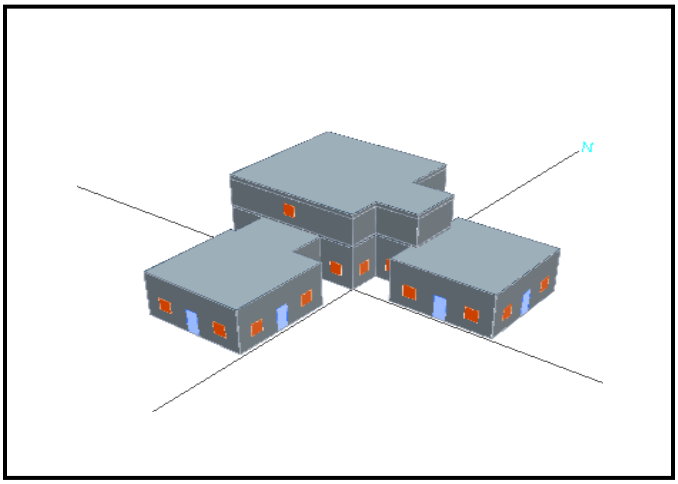
For buildings in Irbid and Amman, the largest part of electricity consumption used for heating, especially in December until March. While a constant amount all through the year is consumed for both lighting and ventilation. As shown in the figure:



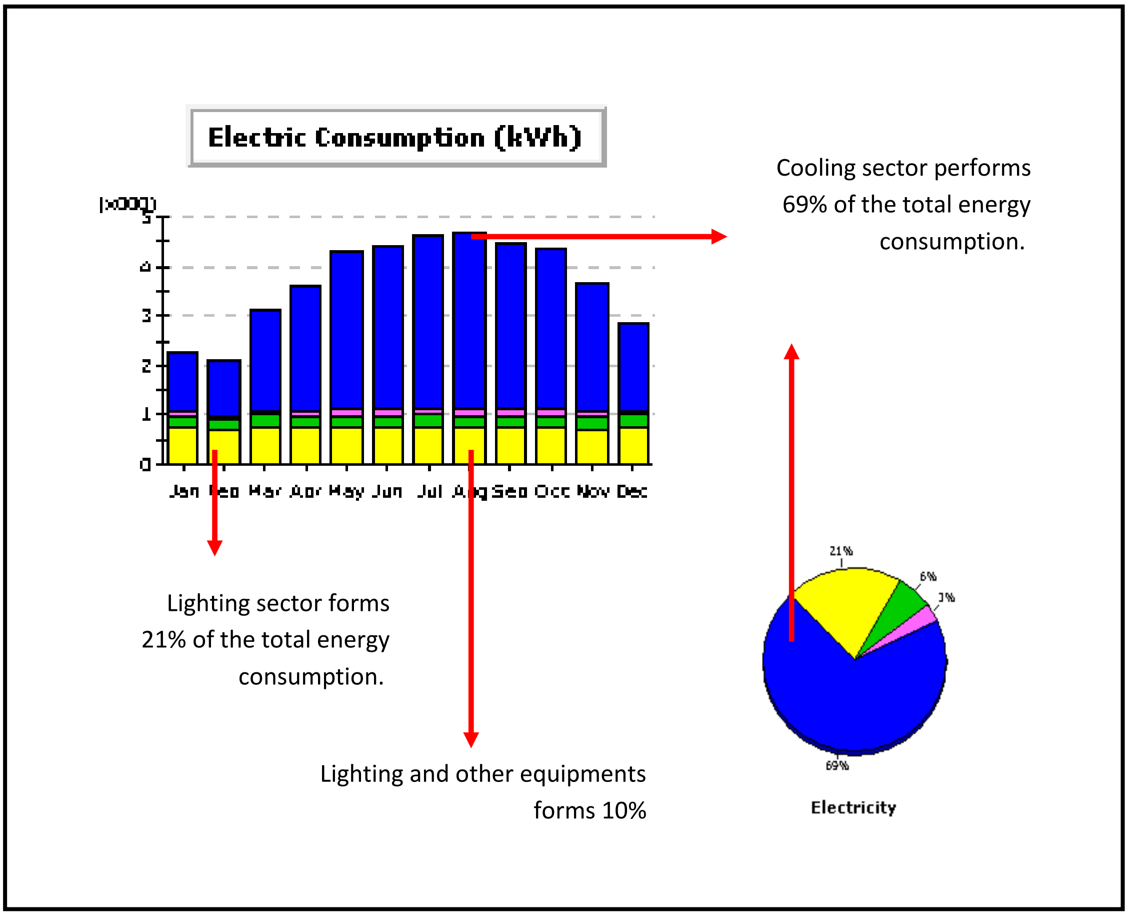
Graph.5.1.1.monthly energy consumption, irbid's SOS village building.
Source : eQUEST simulation program.

Lighting sector performs 30% of the total annual energy consumption, Ventilation performs 18%, and heating perform 42% of the total annual energy consumption.

Fig5.1.1 Aqaba’s village buildings unite



While It was clear from the simulation program eQUEST (quick energy simulation tool), for Aqaba’s buildings, that’s a largest portion of the electricity demand is consumed for cooling .in the contrary of Irbid and Amman, and that is because of the climatic differences) all through the year. While a constant amount for lighting and ventilation all through the year. As shown in Graph.5.1.2.



Graph.5.1.2.annual energy consumption in aqapa's unite.

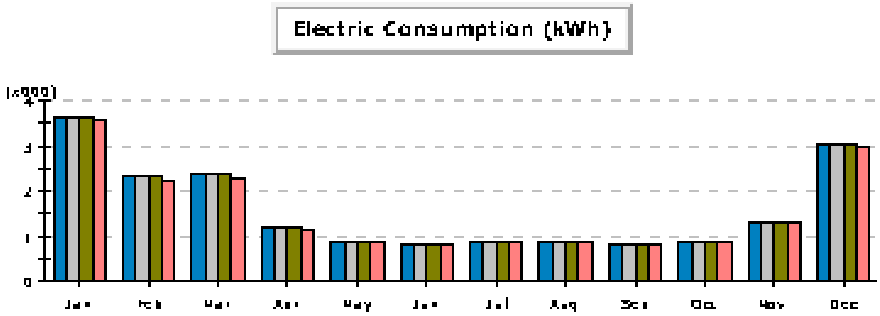
Source: eQUEST Simulation Program

Cooling energy consumption in Aqaba's buildings perform 69% of the total annual energy consumption, while in Irbid and Amman unite, heating energy consumption equals 42% of the total annual consumption.

Deferent strategies were applied as an experiment to minimize this large part of energy consumption for both cases. Such as:

1. Changing the azimuth angle
2. Using overhangs for all windows except the northern ones.
3. Adding roof insulation
4. adding wall insulation
5. Replacing single window glazing with double low-e ones for all windows accept the northern ones.

The first strategy was changing azimuth angle of the unites. For Irbid, Amman and Aqaba was simulated; 45, 90, and 180 with a comparison to the instant situation. It is clear as shown in the following graph that's there is no difference in energy consumption for the first two azimuth angle, and a small decrease appears in changing the azimuth angle to 180 , that is why it is more comfortable in the north facing units as

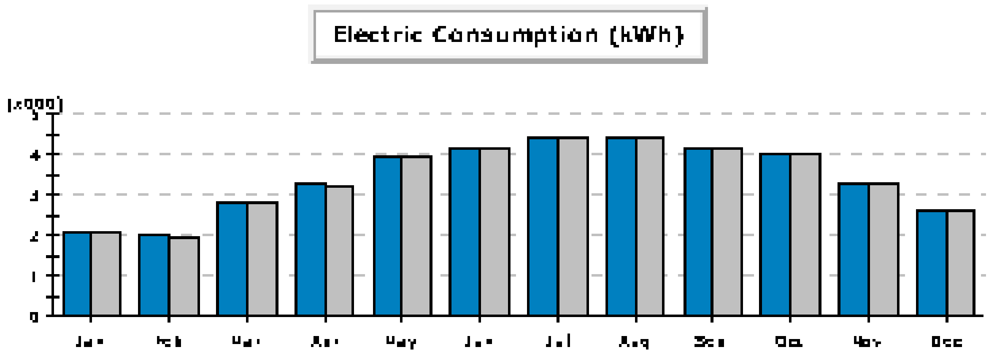


Graph.5.1.3.Monthly energy consumption in changing azimuth angle

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Run 1.	3.64	2.31	2.37	1.18	0.84	0.83	0.85	0.85	0.82	0.87	1.30	3.02	18.86
Run 2.	3.64	2.31	2.37	1.18	0.84	0.83	0.85	0.85	0.82	0.87	1.30	3.02	18.86
Run 3.	3.64	2.31	2.37	1.18	0.84	0.83	0.85	0.85	0.82	0.87	1.30	3.02	18.86
Run 4.	3.58	2.24	2.28	1.13	0.84	0.83	0.85	0.84	0.82	0.86	1.27	2.97	18.52

Table5.1.1. monthly energy consumption in changing azimuth angle

The second strategy was adding overhangs, of 3 feet for all building windows except the northern windows, because as known in Jordan's environment that there is no direct sun radiation for the north facing facades.



Graph.5.1.4.Monthly energy consumption

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Run 1.	2.10	1.97	2.82	3.24	3.95	4.14	4.42	4.41	4.14	4.00	3.28	2.61	41.08
Run 2.	2.13	2.00	2.85	3.27	3.97	4.15	4.42	4.43	4.16	4.02	3.31	2.64	41.33

Table5.1.2. monthly energy consumption for Aqaba's housing unites with the use of overhangs with the length of 4feet. (run 1. Current situation, run 2. Overhangs situation)

The third case was simulation for the roof insulation. Irbid, Amman. Aqaba roof insulation, was not an appropriate solution, approximately there is no significant difference between adding additional roof insulation, and the baseline case (instant situation).

Adding wall insulation was beneficial for both cases, it was clear that it is the most appropriate solution or strategy until this stage. A noticeable decrease in energy consumption is clear as shown in the following graphs.

1-The first run for the baseline situation

2-The 2nd one for roof insulation

3- The 3ed for wall insulation (by adding a second layer 5cm of rock wool)

4- And the fourth one for using a double brick wall insulated with 10 cm of rock wool.

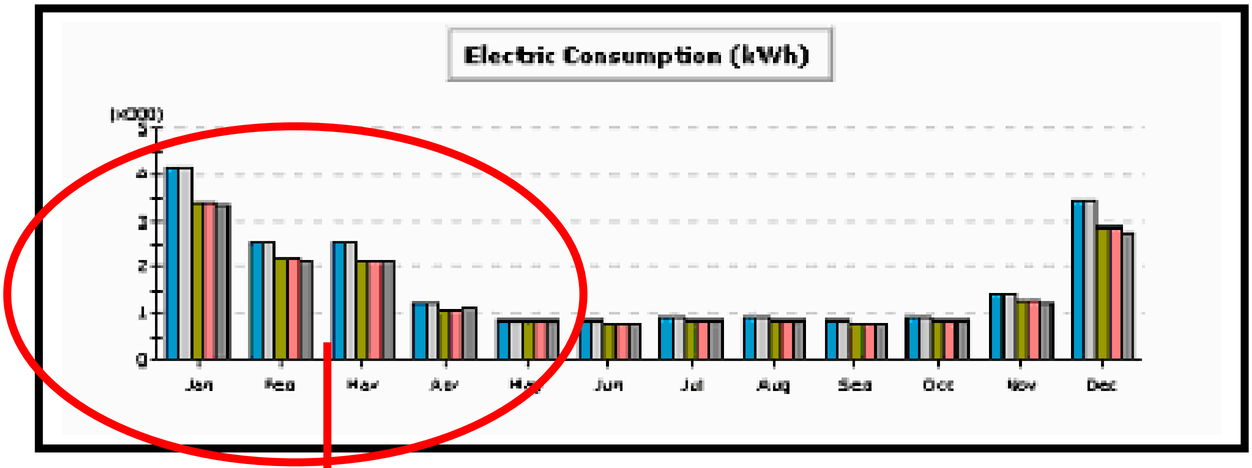


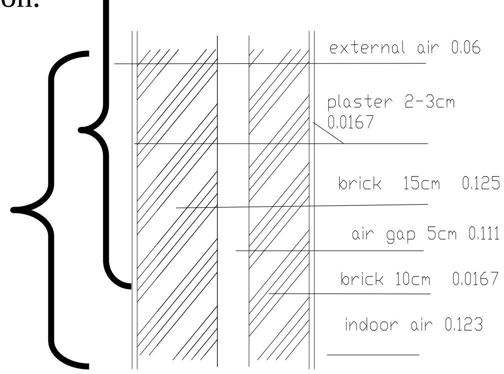
Fig5.1.5. Monthly Energy consumption with using wall insulation in Aqaba's unites

	Baseline case
	Roof insulation case
	Additional wall insulation case
	Insulated double brick wall

- The third case showing the additional wall insulation case; adding a 5cm of rock wool to the baseline case walls. That enhances and decreases the energy consumption.
- While the fourth one showing the case of using a double brick wall , with an insulation of rockwool. This is approximately near to the third case situation.

It is clear from the two cases that adding insulation or replacing the rock walls with an insulated double brick ones will be a good strategy for minimizing energy consumption and reaching human comfort situation.

This strategy is cheaper and gives similar results as stone insulated walls according to energy and thermal results.



In Calculating the Annual Energy and Demand for the three cases it's clear that in adding insulation for the walls it will be the best choice to minimize the energy consumption. The next table shows the amount of electricity consumption for the three cases:

Table5.2.3. Annual electricity consumption for Irbid housing unites.

	HVAC_Electricity KWh
Base Design	13,577
Roof insulation	13,577
Wall insulation	10,891

The last strategy is changing window glass properties, for Irbid's units exchanging the single glass with a double low-e one, for all the southern windows. It is concluded from the next graph that its affects are marked easily in minimizing monthly energy consumption.

	Baseline case
	Additional double low-e glass

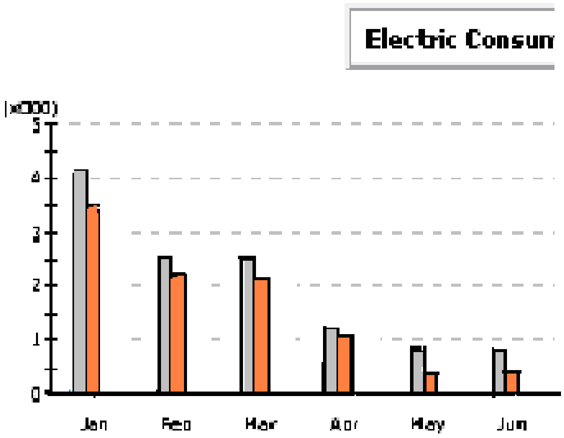
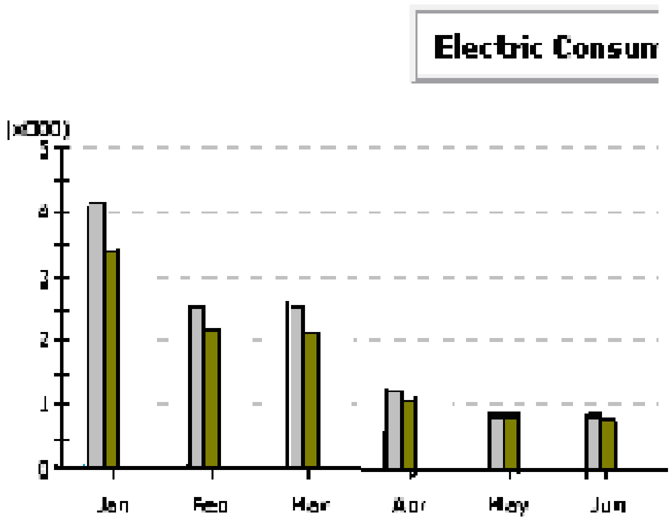


Fig5.1.6. Graph showing electricity consumption (in irbid SOS village) with an additional double low-e-glass



	Baseline case
	Double low-s glass addition

Fig5.1.7. Graph showing electricity consumption (in Aqapa SOS village) with an additional double low-e-glass

it can be concluded that Aqaba's SOS village buildings can be more comfortable in implementing the succeed strategies, which are: using a double low-e glass instead of single glazing, increasing wall insulation, and adding a small effect through rotating it 90°. And for a smaller cost it can be used a double insulated brick wall instead of stone ones with a similar results.

For Irbid's SOS village buildings it can be also be more comfortable in implementing the succeeded strategies, that includes :using a double low-e glass instead of single glazing, increasing wall insulation, and adding a small effect through rotating it 180°.

5.2. MONITORING AND BALANCE POINT CALCULATIONS

Based on the prior conclusions, it is visible to validate the results by plugging several data loggers in different locations in the buildings. Semi conducting HOBO where used to record dry bulb temperature and relative humidity. Data were recorded every 10 minutes. An average outdoor temperature and relative humidity for the last 5 years were used to calculate the balance point temperature behavior of skin of the building. In Irbid and Amman cities, the average outdoor temperature were calculated as 32.15°C and the range of data inside the unites were between 24-26°C. on the other hand, temperature in Aqaba are slightly higher; the average outside temperature was 33.5°C, and the inside were between 22.0-29.3°C.

Irbid's buildings Heat Flow Calculations:

SOS village buildings in **Irbid**:
Family house number …….1

Total Area = 292.39 m^2
Fist floor plan = 187.55 m^2
Second floor plan = 104.84 m^2

Total occupants = 10+10
= 20 person

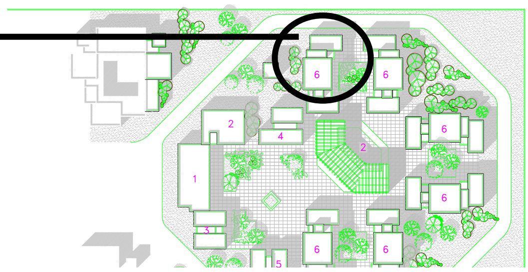
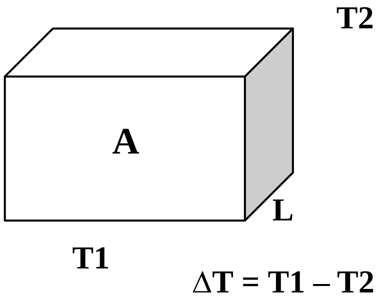


Fig5.2.1. irbid's SOS village site plan
Source: Tukan's office

- Heat transfer through **conduction**



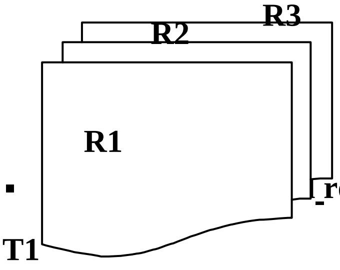
Q = (K/L)*A*ΔT…….. (20)

Q = U*A*ΔT…………. (21)

Q = (1/R)*A*ΔT………. (22)

ΔT = T1 – T2

WHILE: **Q:** Rate Of Heat Transfer
K: Thermal Conductivity (W/m C°)
A: Area (m^2)
ΔT: Temperature Difference (C°)
L: Thickness (m)
U: (K/L) Heat Transfer Coefficient (W/m^2 C°)
R: (1/U) Thermal Resistance (m^2 C°/W)



T2

$$R_{TOTAL} = R_1 + R_2 + R_3$$
$$= (L_1/K_1) + (L_2/K_2) + (L_3/K_3)$$

- **resistance** for building components

1. **<u>Single glass (6mm) with aluminum frame</u>**.

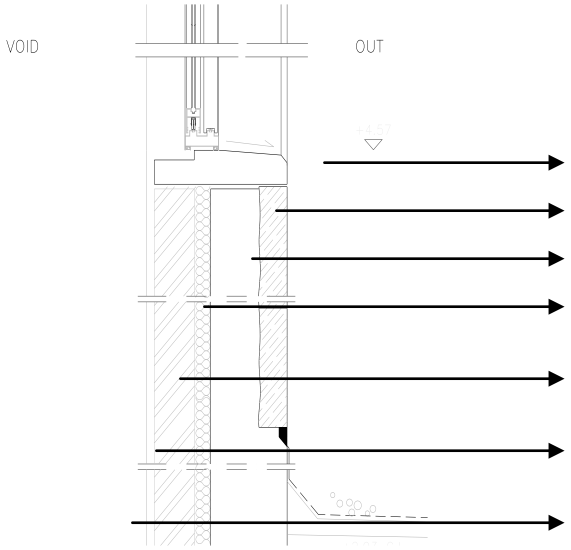
As a constant value, heat transfer coefficients for windows and doors were calculated depending on glass type and thickness, in the same way as it is calculated for building envelope, taking into consideration frame's material and its ratio to the overall window or door area. [9]

U (for glass) = 5.6 $W/m^2\ C^\circ$
R = 1/R = 0.1786 $m^2\ C^\circ/W$

2. **<u>Doors</u>**

U (for doors)= 3.5 $W/m^2\ C^\circ$
R = 1/U = 0.2857 $m^2\ C^\circ/W$

3. **<u>Walls</u>** (fig.5.2.2.)



1- Outside air

2- local stone 7 cm

3- concrete wall 12 cm

4- rockwool insulation 4 cm

5- block wall 10 cm

6- plaster and paint 2 cm

7- inside air

$$
\begin{aligned}
R_{TOTAL} &= R1+R2+R3+R4+R5+R6+R7 \\
&= 0.06 + (L2/K2)+(L3/K3)+(L4/K4)+(L5/K5)+(L6/K6)+0.123 \\
&=0.06+(0.07/1.4)+(0.12/1.75)+(0.04/0.04)+(0.10/0.9)+(0.02/1.2)+0.123 \\
&= 1.4294\ m^2\ C^\circ/W
\end{aligned}
$$

4. Roof (fig.5.2.3)

1- Outside air

2- wadi gravel 7cm

3- 2 layers waterproof

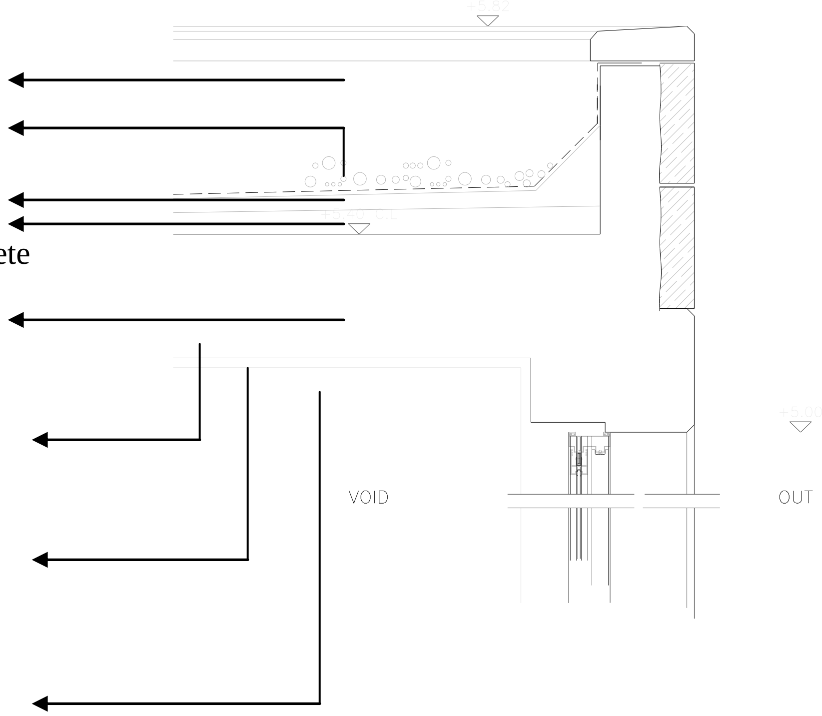
4- Light weight concrete

5- Ribs 18 cm

6-Reinforced concrete 20cm

7- cementPlaster and paint 2cm

8- inside air



$$R\ total = 0.04+0.028+0.0167+0.0285+0.143+0.189+0.0167+0.106$$
$$= 0.5679\ m^2\ C^\circ/W$$

Thermal resistance for air" beside any surface", is taken as a standard value, that is for accurate calculations, as the following values:

Heat transfer

Heat transfer through building components in the hottest day of the year, that was 32.9°C in July 2002 as noticed in the metrological departments files.

the indoor air temperature is 24° C (within the comfort zone)

Q= heat gain through windows + heat gain through doors + heat gainthrough walls + heat gain through roof

Building element	**Thermal resistance for outside air**	**Thermal resistance for inside air**
Roof	0.04	0.106
Wall	0.06	0.123

$$= (A_g*\Delta T)/R_{glass} + (A_d*\Delta T)/R_{doors} + (A_w*\Delta T)/R_{windows} + (A_r*\Delta T)/R_{roof}$$
$$=(26.66*(32.9-24))/0.1786 + (7.6*(32.9-24))/0.2857 +(329.34*(32.9-24))/1.4294+(187.55*(32.9-24))/0.5679$$
$$= 6570.81\ Watt$$
$$= 6.57KW$$ heat transfer in summer.

Heat loss through building components in the coldest day of the year, that was 3.9̊C in January 2002, as noticed in the metrological department files.

Assume the indoor temperature is 21° C within the comfort zone.

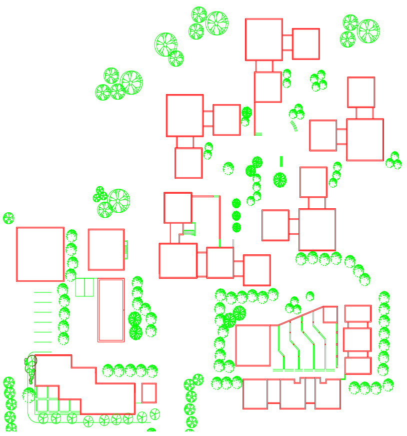
Q= heat loss through windows + heat loss through doors + heat loss through walls + heat loss through roof

$= (A_g*\Delta T)/R_{glass} + (A_d*\Delta T)/R_{\ doors} + (A_w*\Delta T)/R_{\ windows} + (A_r*\Delta T)/R_{\ roof}$

= (26.66*(3.9-21))/0.1786 + (7.6*(3.9-21))/0.2857 +(329.34*(3.9-21))/1.4294+(187.55*(3.9-21))/0.5679

= -12624.81475 Watt

= -12.624 KW heat loss in the coldest day of the year.



SOS village buildings in **AQABA**: (fig.5.2.4)

Family house number ….1

Total Area = 378.72 m^2

Fist floor plan = 253.56 m^2

Second floor plan = 125.16m^2

Total occupants = 10+10

= 20 person

Heat transfer

Heat transfer through building components in the hottest day of the year, which was 41.3̊C in July 2002. As noticed in the metrological department files.

Assume the indoor air temperature 24̊ C, “within the comfort zone”.

Q= heat gain through windows + heat gain through doors + heat gain through walls + heat gain through roof

$= (A_g*\Delta T)/R_{glass} + (A_d*\Delta T)/R_{\ doors} + (A_w*\Delta T)/R_{\ windows} + (A_r*\Delta T)/R_{\ roof}$

= (42.77*(41.3-24))/0.3186 + (8*(41.3-24))/0.2857 + (377.33*(41.3- 24))/1.4033+ (253.56*(41.3-24))/1.73

= 9994.1937 Watt

= 10KW heat transfer in summer.

Heat gain here is much greater than Irbid’s ones because of the high temperature differences.

Heat loss through building components in the coldest day of the year, which was 8.7°C in January 2002. As recorded in the metrological department files.

Assume the indoor air temperature 21° C, "within the comfort zone".

Q= heat loss through windows + heat loss through doors + heat loss through walls + heat loss through roof

$= (A_g*\Delta T)/R_{glass} + (A_d*\Delta T)/R_{doors} + (A_w*\Delta T)/R_{windows} + (A_r*\Delta T)/R_{roof}$

$= (42.77*(8.7-21))/0.3186 + (8*(8.7-21))/0.2857 + (377.33*(8.7-21))/1.4033 + (253.56*(8.7-21))/1.73$

= -7105.7 Watt

= -7.1KW heat loss in winter.

In comparing the thermal resistance for Irbid's SOS village buildings and Aqaba's ones, it is clear in the next table that:

Table5.2.1. Irbid's SOS village buildings resistance

Building components	**R_{value} $m^2C°/W$**	**Area m^2**	**% of total area**	**R_{total}**
Windows	0.1786	26.66	0.046	$1/R_{total} =$
Doors	0.2875	7.600	0.014	$1/R_G*\% + 1/R_D*\% + 1/R_R*\% + 1/R_W*\%$
Roof	0.5679	187.55	0.34	$1/R_{total}=$
Walls	1.4294	329.34	0.6	383.95
Total		551.15 m^2	1.00%	**R_{total} = 0.0026 $m^2C°/W$**

Table5.2.2. AQABA'S SOS village buildings resistance

Building components	**R_{value} $m^2C°/W$**	**Area m^2**	**% of total area**	**R_{total}**
Windows	0.3186	42.77	0.06226	$1/R_{total} =$
Doors	0.2857	8.00	0.01174	$1/R_G*\% + 1/R_D*\% + 1/R_R*\% + 1/R_W*\%$
Roof	1.73	253.56	0.372	$1/R_{total}=$
Walls	1.4033	377.33	0.554	351.395
Total		551.15 m^2	1.00%	**R_{total} = 0.00285 $m^2C°/W$**

It is clear that the total thermal resistance of Aqaba's buildings is greater than Irbid's ones. That is because of the thermal insulation in the roof layers of Aqaba's buildings that is not exist in Irbid's ones, in addition to the wooden layer "Mashrabiah", which is used in Aqaba's climate only. But the larger area of the outer surfaces with the harsh climate makes the Aqaba's building envelope not efficient as it is in Irbid's building envelope.

A Comprehensive study is important in designing any building; many elements must be studied just like: climatic factors, building envelope, use and architectural form. All play a complementary role to form one result.

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5.3.Occupants Questionnaire

In Aqaba's SOS village the questionnaires, that were answered in the period of 1-2/april/2004, it is concluded that the houses are completely comfortable in winter – from thermal comfort point view- because of the moderate climate that is mostly the average temperatures are within the comfort zone, with the thick insulated envelope that prevents or mainly minimize the heat loss through it, without any need for heating systems. While in summer, it is 90% uncomfortable, although the high mass envelope, the ceiling fans, wooden frames "Mashrabiah" for windows, and the wind towers "Malkaf", harsh hot climate have a large effect. And it is recommended (from the occupants) to use an air conditioners, and to enlarge the wind towers with dust filters, with the use of an alternative media (instead of the Mashrabias) that prevents the direct sun radiation and affords a good lighting level.

100% are using fans all through day and night in summer in all rooms, as a trial to minimize temperatures. All the occupants had closed the wind towers even some of them had failed in closing them easily so the covered it by a wooden pieces to prevent dust.Sitting room is the collecting space through the day, as the other two villages because it is the only choice for the daily activities. It is as mentioned comfortable in winter and too hot in summer, unless in some houses the northern breeze enhances the indoor weather a little bit.

Finally, it is reported from the questionnaires that 100% perceived the houses as a thermal comfort environment in winter, while it is far away from comfort in summer.

While in irbid's SOS village houses it was concluded that the houses are approximately comfortable in winter- from thermal point view- because of the use of the central heating system for two hours both in morning and evening, in addition to the good insulation and envelope design, unless they are obliged to use gas heating unit in the very cold days. While in summer, it is 50% comfortable, and 50% figured that it is not comfortable especially in the southern spaces, because of the direct sun gain that heats spaces. And 80% insured the importance of fans in summer. And they close the blinds in some hot summer days to minimize the direct solar radiation. And it was concluded from the questionnaire that 60% perceived the houses as a thermal comfort environment, with a small drawback cased by the direct solar heat gain in summer through the southern windows.

And in Amman's SOS village houses it was accomplished from the questionnaire that 80% perceived the houses as a thermal comfort environment, with a small negative aspect cased by the direct solar heat gain in summer through the southern windows. Especially in the sitting room that have a large glazed façade facing south direction.

CONCLUSIONS

As a result for occupant's questioners and designer interview it's clear that a big contrast exist between theoretical ideas and real life. The designer considers Aqaba's SOS village buildings as a thermal comfort environment and efficient buildings. There is no need for air conditioners, the high thermal mass, insulation, windows and mashrabias are all playing a good role in reaching the comfort situation. Wind towers are good affording good ventilation. While through occupants interviews it was clear that Aqaba's village housing buildings are completely uncomfortable buildings in summer. Wind towers were closed because of the dust, a very inside high temperatures are a real problem can't be minimized in using any affordable solution.

Similar results were clear in monitoring, that the inside temperatures were higher than the comfort ones. High energy consumption for cooling was also announced through simulation results and a high heat flow through envelope because of the harsh climate was calculated.

Definite strategies were postulated with the help of the simulation program, that indicates that in maximizing the wall insulation, and in a double low-e glass instead of the single ones a large decrease in energy consumptions will be an easy goal.

Having a comfortable environment is a summation of many factors play all together forming the final conclusion; Envelope materials, insulation, glazing type, orientation, shading systems and many other factors can minimizes energy consumption and facilitates reaching thermal comfort zone. An insulated double brick wall can equals the insulated stone wall, having a little bit smaller resistance value. For that it can be used for cheaper cost. That means Thermal mass as a major factor helps in preventing heat gain and loss to maintain a comfortable built environment, plays with all other factors to earn that aim and minimizes residential or built-up energy consumption. High material's resistances and the good position of the insulation forms major factors that shape a good and effective thermal mass. And that was very clear in SOS buildings in adding more wall insulation, good heat prevention occurs which led to minimize annual energy consumption.

The main strategies can be as guidelines for similar residential projects having a similar thermal properties, that can be summarizes in the following table, but generally, each building must be studied as a separate case, because: geometrical design, proportions of elevations, area of openings in each side, height of the space, and many other geometrical properties, which differ from one building to another, plays a significance effect besides the effect of thermal properties.

main strategies(guidelines)	
1-	Having a high wall thermal resistance value, by adding wall insulation.
2-	The use of a low-e glass.
3-	Long elevation which is parallel to north-south axis to became facing east - west direction, (to minimize sun's facing area).
4-	The use of the appropriate material, from thermal performance viewpoint, like the use of insulated double brick walls instead of insulated stone walls that performs the same performance.
5-	The use of *Mashrabiyas* helped in minimizing the effect of solar radiation, can be replaced with a good designed overhangs that can prevent solar radiation's effect also with a good interior lighting level.
6-	In Aqaba's village, the used wind towers are not effective; on the contrary they perform negatively, so a wide research for wind towers is needed to be designed correctly.
7-	Climatic strategies are very helpful in minimizing the artificial system by using the good recommended strategy.
8-	A good roof insulation will minimize heat penetration through it, because it is facing the sun all through the day.

It is recommended that designer, who plays the main role in determining building performance, must take these issues seriously into consideration besides building form and function, it is became very easy through using simulation programs to check building performance and to check the efficiency of any suggested solutions after a good understanding for the main ideas of energy efficiency, sustainable design and green building designs and to follow green building principals and to take environment into consideration.

Similar studies can be applied to similar projects; because low cost housing projects need to be a low cost in operation in addition to construction total cost, and also for the reduplicated housing projects.

REFERANCES

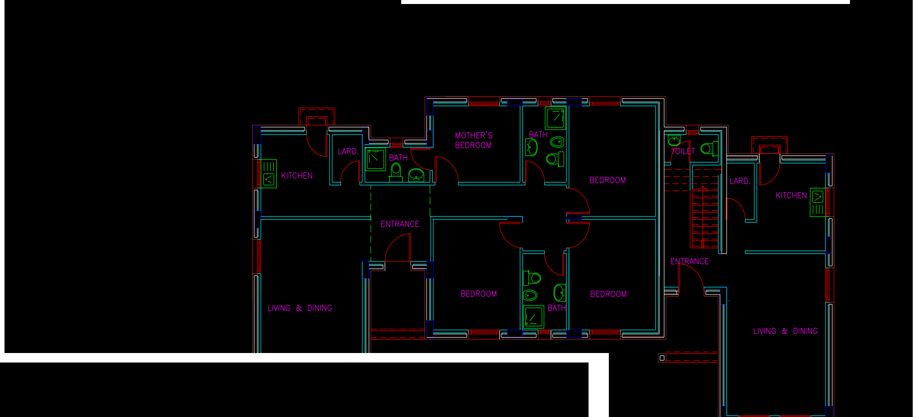
1. (ASHRAE handbook of fundamentals , 1997)
2. Givoni, *Man, Climate And Architecture*, second edition
3. M.A.Tahat, "Performance Of A Low-Energy-Consumption House Experiencing A Mediterranean Climate". *Applied energy* vol. 71 (2003) page 1-13
4. Leedy, Paul D. *practical research planning and design*, 5th edition 1998
5. Al-asad, M, 2001, *The Aqaba SOS Children's Village by Jafar Tukan*. At http://arcnet.org/library/documents/one-document.tcf?document_id=758
6. "An interview with The Aga Khan". *Architectural record*. Vol. 190. n0.2. 2002
7. Ali, Hikmat. *Bio-climatic design principles and its role in thermal comfort in residential buildings in Jordan*.2002
8. Utzinger M., wasly J., *building balance point* 2002
9. C. Gallo, M. Sala, A.A.Sayigh, *Architecture : Comfort And Energy*, 1988
10. Duffy, *methodological triangulation*. 1984
11. E.S.Mitchell, "*multiple triangulation: a methodology of nursing science," advances in nursing*8 (1986):18-26

APPENDIX NO.1

VILLAGES DRAWINGS

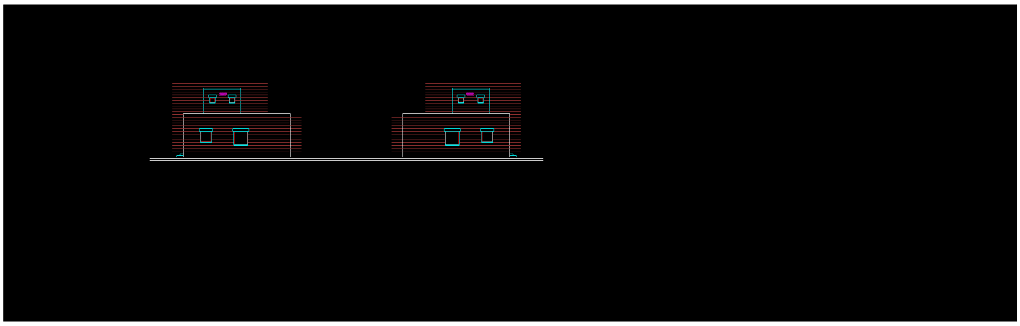
IRBID'S VILLAGE

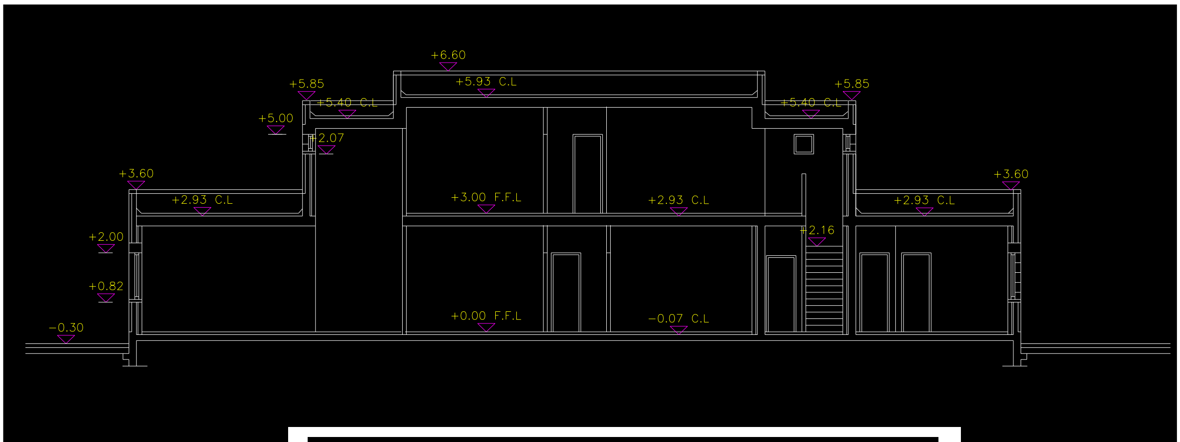
FIRST FLOOR PLAN



2ed FLOOR PLAN

ELEVATIONS



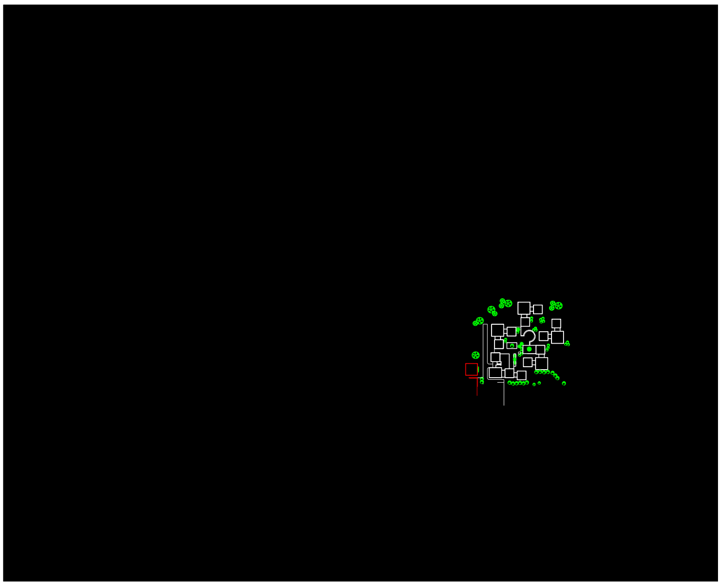


SECTIONS

APPENDIX NO.2

AQABA’S VILLAGE

SITE PLAN



FIRST FLOOR PLAN

APPENDIX NO.3

Jordan's climatic zones

Source: http://www.fao.org/ag/AGP/AGPC/doc/Counprof/Jordan.htm