The Possibility of Applying the Earth-Sheltered Building System in Egypt

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The Possibility of Applying the Earth-Sheltered Building System in Egypt

A dissertation

submitted to
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in fulfillment of the requirements
for the degree of

Doctor of Engineering

in
Department of Architecture
Graduate School of Human-Environment Studies

by

Heba Hassan

January 2018

またアッラーは，あなたがたのために創造なされた物で日影を創り，山々に避難の場所を蝕け，
またあなたがたのために，暑熱を防ぐ衣服と，暴力からあなたがたを守る衣を，定められた。
かれがこのようにあなたがたに対し恩恵を成し遂げられるのも，きっとあなたがたがアッラー
（の意志）に服従，帰依するからである。

神聖なコーラン，〔アン・ナフル〕81

To
The Next Generation of
Future Architects and Engineers,
This “message from the past” is just to unveil the topic,
Please complete in the way.

ACKNOWLEDGEMENTS

In the name of Allah, the most compassionate, the most merciful. All praise is due to Allah, the Lord of the worlds.

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Heba Hassan
January 2018
Fukuoka, Japan

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ABSTRACT

The main function of the building is to provide thermal comfort for users. However, fulfilling this need became more difficult, especially in the harsh climate. This harsh climate raises the problem of the unsuitability of the ordinary building systems for those areas since it consumes a large amount of energy for the active air-conditioning systems, which are growing up to tremendous expenses.

One of the most effective techniques to achieve the trade-off between thermal comfort and low energy consumption in hot-arid climates is Earth-sheltering.

This research introduces a complete vision of this system, which aims to measure the suitability of applying the Earth sheltering technique at hot-arid climates, in Egypt as a case study. Through several topics; thermal comfort and energy savings perspective, architectural design guidelines, site selection and urban planning guidelines perspectives.

Moreover, measuring the balance between the thermal comfort, and energy savings through a parametric optimization analysis.

The research proves the hypothesis that the best thermal performance of the Earth sheltered buildings for energy savings is highly achievable in arid climates, rather than the moderate ones.

From the architectural perspective, the research proved that the main obstacle for application is only psychological due to lack of knowledge. From the photo-questionnaire experience, we gained satisfactory results about the system and positive attitudes.

Finally, this research presents site-specific guidelines, for architects and urban planners regarding the application of this technique for residential buildings.

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   共著者　Ahmed Mohamed El_Kotory

NOMENCLATURE

Nomenclature for Chapter 4

Nomenclature		Tav.	Average monthly temperature, °C.
Cp.	Specific heat capacity of each layer, J/(Kg-ºk).	Tn.	Neutrality temperature (T neutrality), °C.
K	Thermal conductivity of each layer per unit area, w/(m-ºk).	V	Volume of each layer per unit area, m3.
L	Thickness of each layer, m.		
m	Mass of each layer, Kg.	Greek letters	
R	Resistivity of each layer, ºk/w.	ρ	Density of each layer per unit area, Kg. /m3.

CHAPTER 1

1. INTRODUCTION

The energy problem at Egypt is growing higher every year, especially the electricity consumption of the residential sector compared with other sectors.

Egypt in numbers; • Area:1002450km^2 • Population: 86502500 • Population density:84/ km^2 • GDP: total $275.748 • Per Capita: $3213. (Osman 2013).

It could be noticed clearly by studying the energy distribution that the residential sector is the highest of energy consumption in comparison with other sectors. Moreover, the electricity consumption pattern in the residential sector is divided into nine parts, where the space cooling is consuming around 13%. It is expected to grow up to an extreme level, because of the recent trend to use the air-conditioning systems, if we did not control such consumption. (Fig. 1.1) (Aldali and Moustafa 2016).

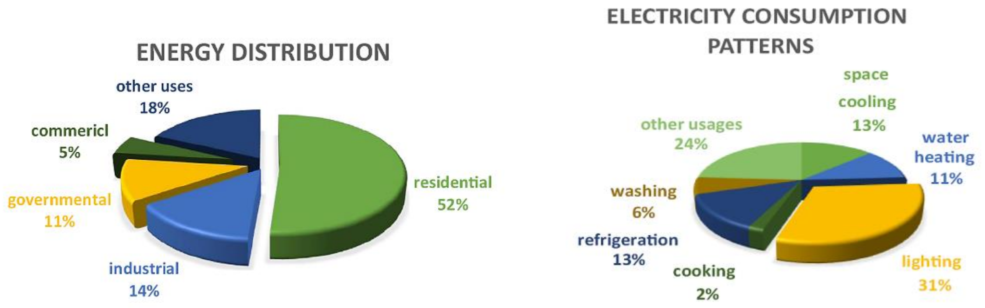


Fig. 1.1. Energy distribution percentage according to the building sector, and the consumption pattern of the residential usage.

The research suggests using passive systems rather than the active ones, in an attempt to lower the energy consumption of the residential sector.

Recently, some passive design attempts had appeared on the architectural scene trying to solve the thermal comfort issue but had gained unsatisfactory psychological results. Such as: using arches, vaults, and domes.

This research is raising a call for sustainable building design of the Egyptian desert with a new architectural perspective using the Earth in construction to gain more integration with the environment and to add another new aesthetic dimension to the surroundings.

1.1. Research Purpose and Objectives

The main purpose of this research is to reduce the energy consumption in the residential sector. Therefore, we try to promote more thermal comfort building type in Egypt. To reach this purpose, we should grasp:

- The effectiveness of the thermal comfort of Earth-sheltered buildings at Egypt.
- The features of the Earth-sheltered buildings.
- The acceptability of living inside the Earth-sheltered buildings.
- Introducing general guidelines to architects and urban planners for the application of the earth-sheltered buildings at the early-design stage in the hot-arid climates.

Therefore, this ***research scope*** is focused on creating guidelines for architects, and urban planners who wish to work with the Earth-sheltered building system, especially in new communities of the hot-arid climates.

The main objectives of this research could be summarized in:

- Measuring the thermal comfort extent.
- Measuring the energy savings extent.
- Measuring people’s perception extent.
- Introducing architectural design guidelines.
- Introducing urban planning and site selection guidelines.

1.2. Research Significance

To simulate the Earth sheltered construction, one must calculate the prospective ground temperature, in order to gain exact simulation outputs.

Although many previous types of research touched the topic, they did not describe in detail how to calculate or simulate the ground temperature at Egypt, with integration to the whole building simulation.

There is no previous optimization analysis study for Earth sheltered buildings using the genetic algorithm approach for site-specific guidelines in hot arid climates or in Egypt.

Our research created a benchmark for simulating and optimizing basements and earth-sheltered constructions at hot arid-climates, especially Egypt.

To apply such kind of buildings to a wide sector, it is of utmost importance to measure people's attitudes towards living or dealing with it, the subject that is not sufficiently covered in the literature. Although some researchers spotted the light on it, they recommended not to generalize their outcome to the public.

Our research significance at this point is that the results could be generalized to the public. Therefore, we could grasp some architectural and urban design guidelines for architects and urban planners for the implementation stage at new communities.

1.3. Research Methodology

1.3.1. Simulation Model

As it was noted in previous researche that Earth-sheltered buildings could be above or under zero level (Sahar N. Kharrufa 2008).

Therefore, to measure the effect of Earth contact with the building on the thermal comfort and energy savings, it was recommended to measure a basement model.

Hence, we calibrated a basement model in Al-Minya city at Egypt, as a case study of the harsh hot-dry climate.

Using the Basement preprocessor of the EnergyPlus we calculated the heat flux and the soil surface boundary temperature for the 3D heat transfer between the building and the soil. We adopted an iterative approach to reach a convergence of the ground temperature, which was the main sensitive input of the DesignBuilder/EnergyPlus for calibrating the basement model.

Moreover, we calibrated two zones from the last floor residential apartment; conditioned bedroom and unconditioned living. In order to show the difference between the basement and last floor, we used the same last floor plan and operating schedules as a hypothetical displacement in the underground level.

We did not gain direct results from this step, rather than preparing the accurate model inputs for the next step of the parametric optimization.

1.3.2. Parametric Optimization

We performed a parametric optimization study using the genetic algorithm provided by DesignBuilder/EnergyPlus software V4.7 to reach the optimal performance of the building with the best combination of design variables.

- ***Objectives:*** Was to reach the trade-off between minimizing the discomfort summer ASHRAE 55 Adaptive 90% acceptability, and minimizing the net site energy consumption, which typically conflicts.
- ***Constraints:*** We excluded the high discomfort hours from the results, choosing only the cases with no more than (1000 hrs./year) per year, discomfort summer ASHRAE 55 adaptive 80% acceptability.
  More than this hour's number, we considered them as failed constraint cases.
- ***Design Variables:*** Were the combination of five aspects:
  - *Window/Wall ratio percentage*, ranging from 10-50% with 5 steps increment, for the building as a target object, resulting in 9 cases.
  - *Orientation,* ranging from 0°-315° with 45° steps increment, for the building as a target object, resulting in 8 cases.
  - *Location template*, with 5 options of the cities' weather files inputs (Ismailia, Sharm-El-Sheikh, Al Minya, Marsa-Matrouh, Al Kharga), for the building as a target object, resulting in 5 cases.
  - *Cooling set-point temperature*, ranging from 20-28°C with 1°C step increment, for the conditioned bedroom zone as a target object, resulting in 9 cases.
  - *Heating set-point temperature*, ranging from 18-24°C with 1°C step increment, for the conditioned bedroom zone as a target object, resulting in 7 cases.

After the parametric optimization process, we chose the optimal design variables combination for the design guidelines recommendations, in accordance with the questionnaire results experts' recommendations.

1.3.3. Questionnaire and Interviews

The questionnaire sample was (n=164) of Egyptians and Japanese, it passed three sequential steps:

- A pilot study photo questionnaire, with a sample of Egyptians' architecture fourth-year grade undergraduates, postgraduate architects and architecture university teachers. Questions were in Arabic language and were moving around their attitudes and reactions. This stage was followed by interviews with the respondents (Ismail et al. 2013).
- The interviews stage was done at Egypt with Egyptian architects and at Japan with Japanese architects, to measure their attitudes about the Earth-sheltering technique and recommendations about the final questionnaire design (Heba Hassan et al. 2016).
- The internet form photo-questionnaire was the last stage which was designed to measure architecture specialists' attitudes. Besides, contribution to their experience in choosing the most appropriate architecture, site selection, and urban design guidelines. The sample was limited to postgraduate students, architecture specialists, and architecture university teachers. Questions were designed in a photo comparison way in an internet form. There were two forms; English language for Egyptians, and Japanese language for Japanese. Afterwards, a comparison was made between both of their attitudes and different choices directions, as a representative of different climates and attitudes (Heba Hassan et al. 2016).

Results obtained from the questionnaire responses passed a chi-square test to be able to generalize the results to the public. We had chosen the significant results only for the design guidelines' contribution.

1.4. Organization and Research flow

As Figure (Fig. 1.2) shows, the thesis organization and the research flow. It could be divided into three main parts:

- ***Introduction and Inspiration***, which contains chapters 1, 2.
  - The introduction.
  - The theoretical approach to the Earth sheltered buildings.
- ***The research core***, which contains chapters 3, 4, 5.
  - Measuring people's perception using photo-questionnaire survey.
  - Measuring the thermal comfort and model comparisons using simulation analysis.
  - Parametric Optimization study for Earth-sheltered buildings.
- ***The complete research vision and conclusion***, which contains chapters 6,7.
  - The design guidelines for earth-sheltered buildings.
  - The research conclusion.

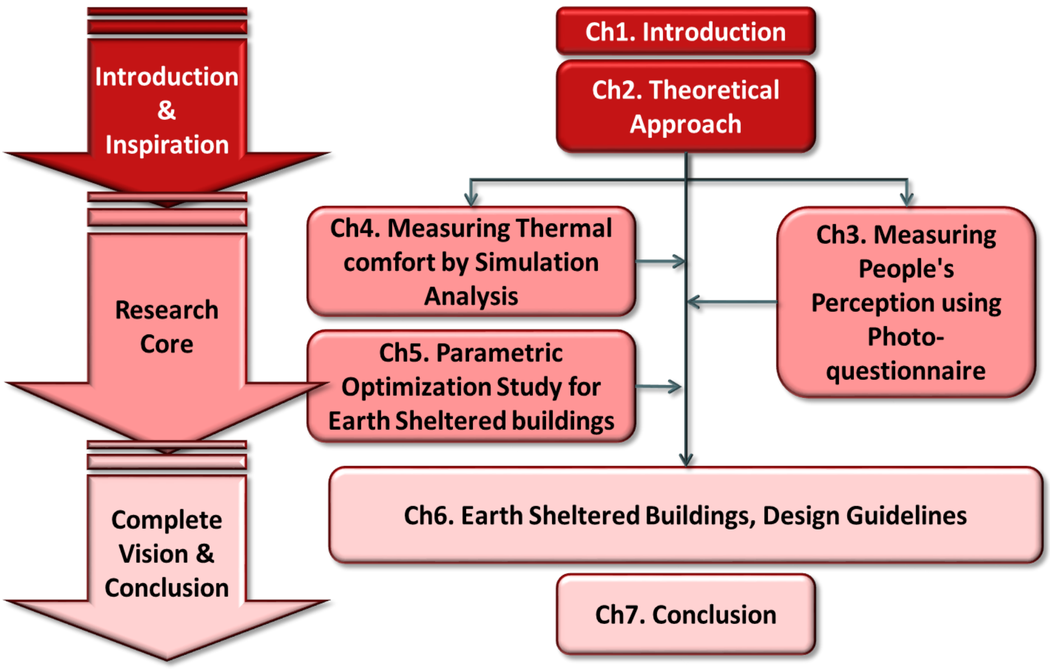


Fig. 1.2. Thesis organization and research flow.

CHAPTER 2

2. THEORETICAL APPROACH

This chapter is discussing the Earth-Sheltered building type with analytical point of view.

In this context, it started by a brief definition and classifications about this type, and studies the opportunities and constraints related with the urban and architectural design. Besides, it displays a quick overview of the contemporary use which is concentrated on the residential use all over the world.

Afterwards, the research makes a brief explanation for some case studies of this building type at both of the residential and small clusters levels.

The chapter mainly focuses on discussing the possibility of using the Earth-sheltered building type in the housing projects at the Egyptian deserts with its harsh climate, through arguing that Earth-sheltered housing would be more appropriate or not.

Besides, it examines the adaptation of the existing application constraints of this type in Egypt. The research suggests some urban and architectural applicable recommendations to overcome some of these constraints at different climate situations.

Finally, the research recommends using this type of buildings for housing projects in the new communities in the Egyptian deserts, for better environment.

2.1. Background

The energy crisis has been alarmingly increased during last decade. This in turn induces Architects to look for a suitable building system, which can effectively lower the energy consumption. There have been many attempts to reach this goal.

However, one of the most effective systems that are found to be capable of saving the energy inside buildings is the use of the earth cover as an effective insulator (Jhon Carmody and Sterling 1993). In addition, it can be considered environment friendly as it protects the Earth cover against desertification (Woods 2000).

The Earth-Sheltered Construction system is not a new style nor extinct. Traditionally, it had been used effectively all over the world as an energy conservative building system, there are many Earth-Sheltered buildings built for various purposes (Golany 1983). It started with living in the existing and excavated caves in the ancient eras. Also, it had been used as Temples and Tombs at the ancient civilizations such as Pharoses Tombs.

The Earth-Sheltered usage for housing purposes has been considered the most common especially in harsh climates and relatively among the poor class of people in order to save the land surface for other purposes, or more protection from the harsh climate and the security reasons. There are many vernacular cases in China, Turkey, Iran, and North Africa (Tunisia), and many others (Al-Temeemi and Harris 2004).

The Modern Earth-Sheltered architecture developed later to include other uses, especially Housing. The main objective to use this style is saving energy by the isolation of earth cover and other environmental passive solar-cooling or heating, passive ventilation systems (Wines 2000).

The modern samples use the same concepts in the traditional vernacular architecture but with more development and technology.

The Earth-sheltered architecture has some special basic characters (its classification types, opportunities and constraints) (Golany and Ojima 1996; Jhon Carmody and Sterling 1993).

2.2. Definitions

At the first glimpse when we mention the Earth-Sheltered buildings; it may be thought that it is completely under the zero level, whereas, it is just one kind of its classifications according to relation to the surface. On contrary, the modern examples of the Earth-Sheltered buildings are usually existed above zero level but are covered with a soil layer.

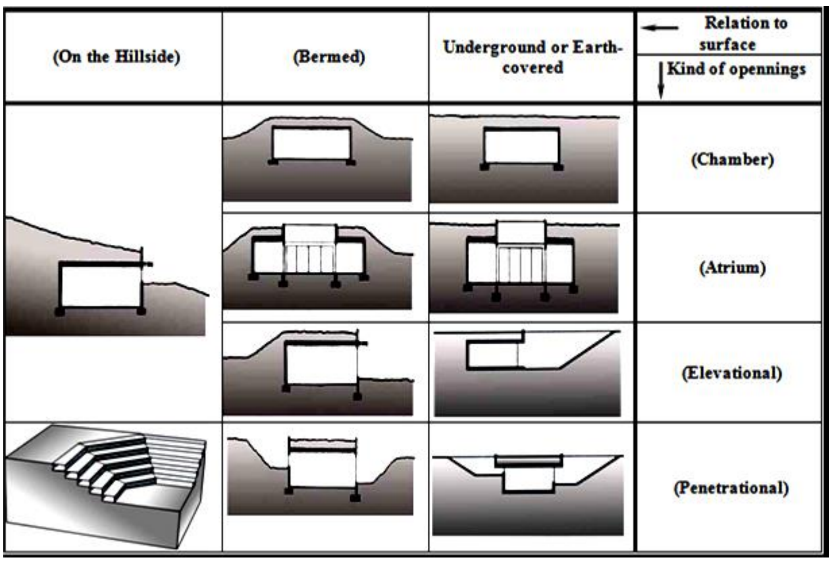
Earth shelters could be defined as: *"structures built with the use of earth mass against building walls as external thermal mass, which reduces heat loss and maintains a steady indoor air temperature throughout the seasons"*(Anselm 2012).

2.3. Classifications

There are many classifications of Underground Architecture depending on many characters (use or purpose, construction system, relation to the surface, opening relation to the surface). The major construction concepts are the bermed or banked with earth, the envelope, or the true underground type (Anselm 2012).

Therefore, studying the types and classification procedures is very important before going deep through the research in order to find the possibility of taking advantage of the geo-space for the design purpose either functionally or aesthetically. This research tried to combine different classification major types, as shown in (table 2.1).

Table 2.1. Classification of the Earth-Sheltered building type.
(H Hassan et al. 2014).



Through studying the classification, basements could be considered as the underground type of the Earth-Sheltered buildings. Accordingly, the research started by measuring its thermal performance, to predict the other types' thermal performances with simulation programs in future research.

2.4. Opportunities and Constraints

There are many opportunities for the Earth-Sheltered building system we can make use of it. On the other hand, the drawbacks of this building type which we can avoid with good design, are focused on the main reason for refusing to be underground especially (psychologically and physiologically), and how to overcome these bias, as in (table 2.2).

2.5. Case studies

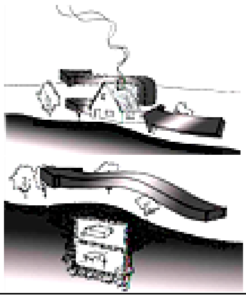
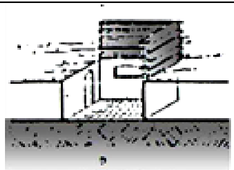
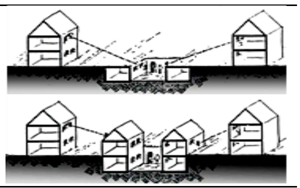
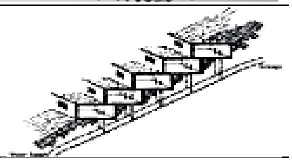
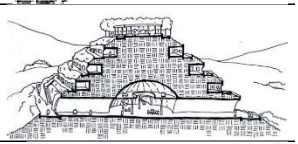
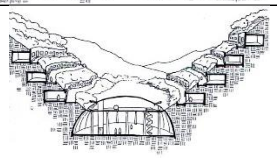
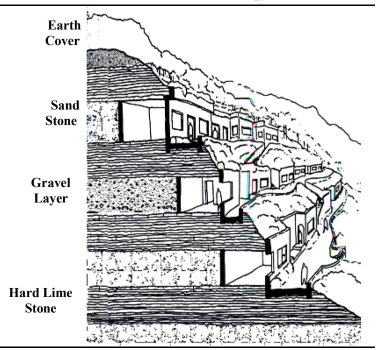
The Earth-Sheltered Architecture has been commonly used worldwide within the Housing sector rather than the public one (Carmody and Sterling 1985). Sterling supports this note when he made several studies on workers at factories, libraries, and governmental buildings. He found that the productivity had been lowered as much as workers are isolated from the natural environment outside. Besides, the air quality is relatively poor(Jhon Carmody and Sterling 1993).However, Ojima conducted many types of research on workers at Japanese libraries, he gained very good results of satisfaction about the working environment they are working at (Golany and Ojima 1996).

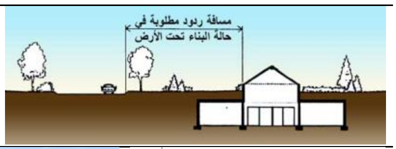
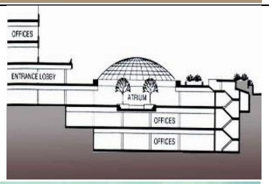
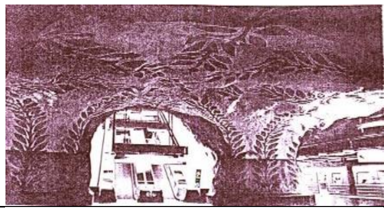
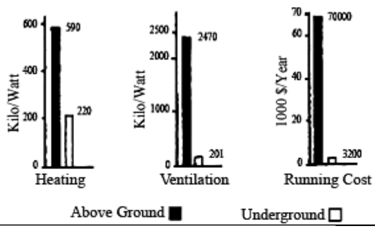
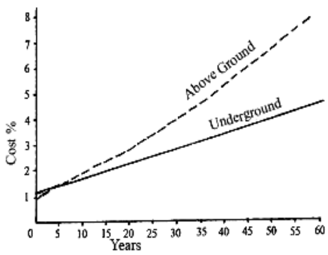
This chapter is concentrating on the domestic use of Earth-sheltered building style, as it is the most common nowadays. The researcher believes that the negative attitude towards Earth-Sheltered homes will disappear with evidence of successful designs found in several parts of the world (Heba Hassan et al. 2016; Ismail et al. 2013).

2.5.1. Residential buildings

One of the most significant earth-sheltered buildings in modern times is the Aloni House. It was built in Anti-Paros Island in Greece and won the Greek Piranesi Award in 2009 (Anselm 2012). The overall shape of this long rectangular structure responds to green needs (controlled natural light, heat and cooling crosswinds) as well as the slopes of two adjacent hillsides.

Table 2.2. Evaluating opportunities and constraints related to Earth-sheltering.
(Jhon Carmody and Sterling 1993)

<table>
<tr><th>Category</th><th>Sub-category</th><th colspan="3"></th></tr>
<tr><td rowspan="3">The Effect of Being Underground</td><td>Climate</td><td colspan="2">Isolation from Harsh Climate. Poor Ventilation if not Properly Designed.</td><td></td></tr>
<tr><td>Natural Hazard Protection</td><td colspan="2">High Protection from Natural Hazards like (Earthquakes, Floods, Sandy Storm, Fire). But if Entrances were not well Designed, it will be Flooded, Buried or Smoke Confined.</td><td></td></tr>
<tr><td>Security</td><td colspan="3">High Security at all levels, but Poor signals.</td></tr>
<tr><td rowspan="5">Site Selection, Planning & Geology</td><td rowspan="4">Topography</td><td>Flat</td><td>Easy Access, No Privacy.</td><td></td></tr>
<tr><td>Sloped</td><td>Good Sewage, difficult water pumping.</td><td></td></tr>
<tr><td>Opened</td><td>Good Ventilation and opened Natural View.</td><td></td></tr>
<tr><td>Closed</td><td>Poor Ventilation and poor view.</td><td></td></tr>
<tr><td>Geology</td><td colspan="2">Some Geological Structures are more Suitable, but others are impossible to build on it.</td><td></td></tr>
</table>

	Site Planning	It needs a more in-between area to be built above zero level, but it will be more helpful if it is built totally underground within Large Cities.	
Building Design and Aesthetics.	**Outdoors**	Keeping Historical places site theme without a big change, but if Entrances not designed well, it will give a very bad impression.	   
	Indoors	It enables the creative environment for Designers, but if poorly designed, it will give a very bad impression.	 
Economic Issues.	**Initial Cost**	Is very high, but if we can use the Mountain Rocks as a building material, it will lower the initial cost.	
	Long Run Cost	Is very low compared with Conventional buildings, but if poorly designed it will raise maintenance cost.	
Physiology and Psychology.		Physiologically, poor ventilation affects air quality, therefore, affects the Health.	
		Psychologically, most people do not like to be under a ground cover, even if it is above zero level; it has a bad image in the back mind.	
Building Codes and Low.		To get a permission to build totally Underground Building, will be more difficult, according to the Ventilation and Natural Light codes; which are different according to the place and Country.	

The house emerges only in the center, and it looks like a half-buried contemporary underground home, as shown in (Fig. 2.1).

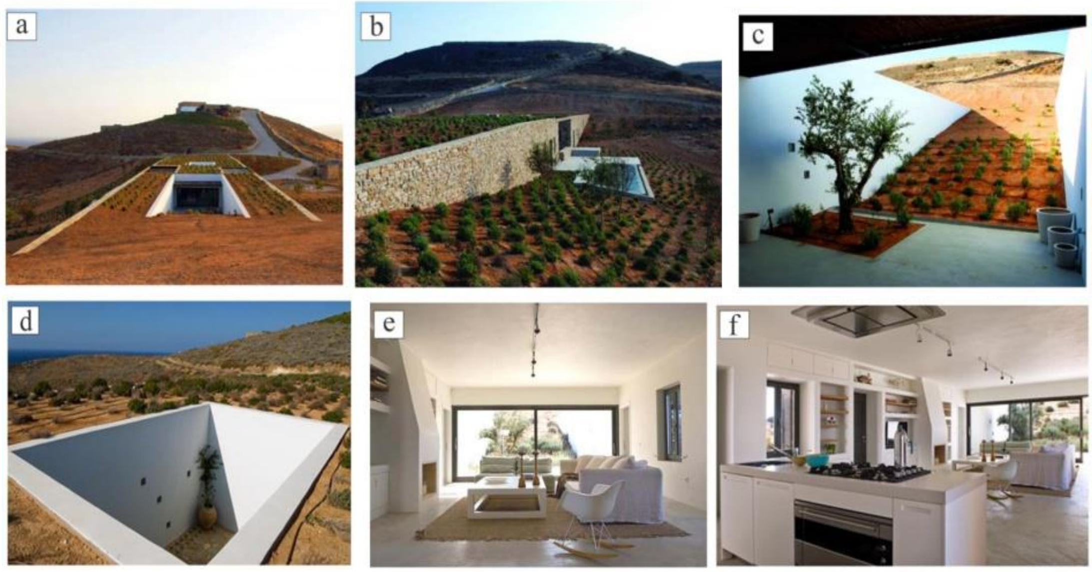


Fig. 2.1. Aloni House.
(a) View from the hilltop (b) from the top of the house (c) Opening leading to the courtyard (d) The central courtyard (e) Interior view of the living room (f) Interior view from the kitchen. (Images by Julia Klimi), (Anselm 2012).

Joe Eric and his wife have been lived in this home since 1985 until now, at Cincinnati, Ohio. They believe to reach the goal of a world free of fossil fuel by the year 2020. They tried to collect and research for solar information, as much as possible before building the home, from different sources. They built their home themselves with little help other expertise.

The home is very bright and has cross ventilation with low relative humidity inside. It consists of three bedrooms and a sunroom as a living room. At winter, the air is heated at the sunroom then forced through ducts of gravel bed under the house, worming the floor area by radiation.

At summer, the deciduous tree shade is preventing the Sun angle to penetrate the home, and cold air is collected through the gravel bed at night to reduce the home temperature next day long. The home is very light and bright, as shown in (fig. 2.2), (http://www.joe-davis.com).

Fig. 2.2. Joe Eric Earth sheltered home.

Many other examples of the Earth-sheltered buildings at its modern form in the residential sector have been analyzed through previous pieces of research, however, most of them at cold climates (Alkaff, Sim, and Ervina Efzan 2016; Kaliampakos et al. 2014), (Fig. 2.3). Is an example of the rest area at Ohio (Hoyle 2011).

Fig. 2.3. Earth sheltered rest area along Interstate 77 in Ohio.

2.5.2. Small Clusters

Since the research focuses on the study of the applicability of this method of development projects at the Egyptian deserts; the examples will be limited to viewing and analyzing of communities that used this method in the world and the extent of sustainability and compatibility with the surroundings of each site.

1) Residential community of monks

The Holy Island, Scotland, Architects; Andrew Wright & Consultants. The community cluster was divided into two separate buildings; for "Monks" and for "Nuns". It had been directed towards the south in an attempt to get the highest possible acquisition warming.

The design team tried to reach the maximum level of integration between man and surrounding nature in perfect harmony, and a high degree of self-sufficiency in most aspects of water, food, energy, and sanitation.

There are parts of the bottom of the residential terraces used in the cultivation of wheat, and the top of the island is used as places for "Lama" pens. Water is collected naturally from rain and groundwater and is distributed across the island using the gravity. The sewage is discharged in long wells deep in the soil, due to gravity.

The community was designed and excavated into the soil in order to consume the least amount of energy. Until now, statistics and figures show that the community had consumed only 32% of the consumption compared with conventional buildings at the adjacent sites. And the rest of required energy is obtained from the wind blowing on the island. (Fig. 2.4).

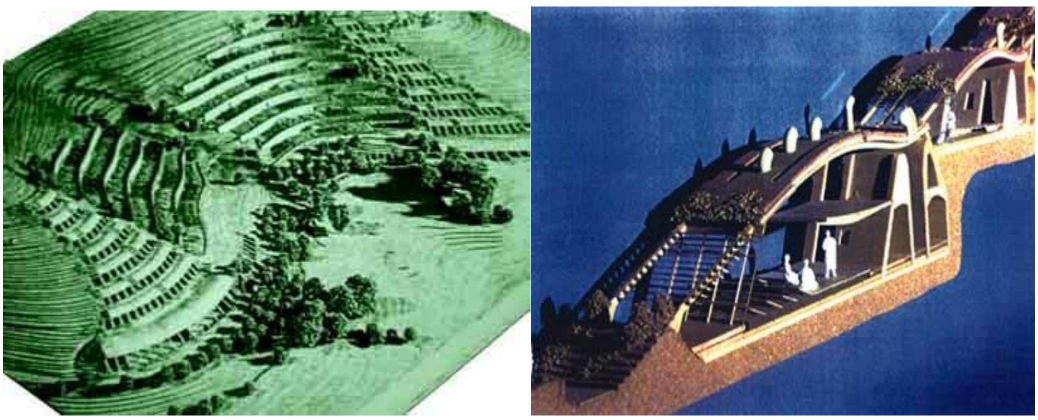


Fig. 2.4. The Project Model of First Prize, Royal Academy, Bovis (Grand Prize), 1994.

2) Urban cluster, Daitkon, Switzerland.

It was the duty of the architect "Jencks" and his wife "Keswick" to plan a residential community for the government office staff in Switzerland.

Both had been surprised that the site is scheduled to be built is lying on a series of small hills integrated with a number of old lakes that had been formed due to rainwater over years, randomly with a total length of about 120 meters.

The couple decided to keep the situation as it is and respect the Nature. They made a teamwork from experienced builders to accomplish that task. The very unique and attractive thing about the teamwork was that the design and implementation were very close to the original site nature.

In addition, the housing community achieved a high level of energy saving, which was the main objective on the top of a list of priorities that must have been achieved by the project. This project hits the finest example of what can be achieved at minimum cost and maximum utilization of natural resources available at the site, with the highest level of innovative design. (Fig. 2.5).

Fig. 2.5. The community after Earth sheltering, with maximum energy savings.

2.5.3. Egyptian Experience

The Earth-Sheltered construction at Egypt is not found as a domestic use until now, it is all used as tombs at different eras. Pharos made some temples earth-sheltered by digging it into the mountains like Abu Simple and Hatshepsut temples, (Fig. 2.6).

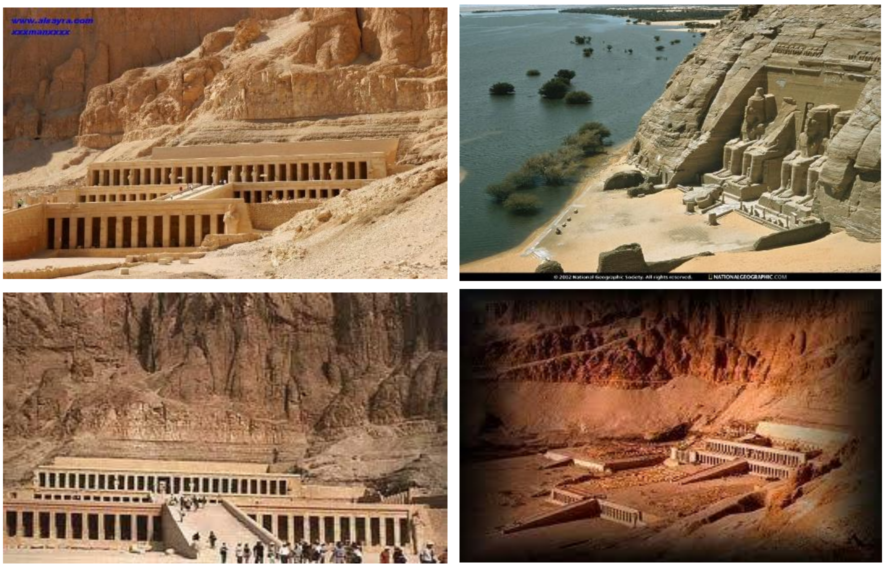


Fig. 2.6. Egyptian temples were carved into rocks for a better environment.

Pharos understood that it will be cooler than the outside atmosphere at this very hot city (Luxor). Later, Egyptians found other tombs at Siwa city. But, they did not find dead people at it. So, they used it later as homes. It is called the Mountain of the Dead (Gebel El Mawta) (Fig. 2.7).

Fig. 2.7. Mountain of the Dead, Siwa, Egypt.

At 1980th. Hassan Fathy, the great Egyptian architect built the new (El Gorna) village for farmers, Qena City. The old village was carved into rocks.

However, people refused to live in the new village, as it was similar in style to the tombs. Unfortunately, now there is no one at both villages, (Fig. 2.8).

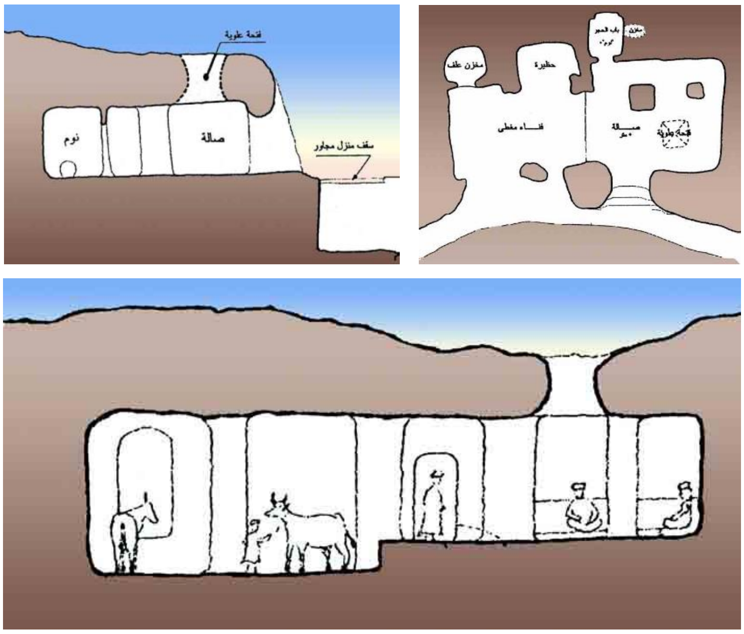


Fig. 2.8. Cross-section and plan of the old village.

From the previous examples it is obvious that:

- The Earth-Sheltered architecture suites many environmental conditions, extreme weather, and sometimes contradictory, where there were many examples in the very cold or hot regions.
- The use of the Earth-Sheltered building type is increasing day after day, with new uses and activities.
- The ancient and modern examples use the same concept of passive treatment for thermal comfort, lighting, and ventilation, but with more innovations in the design techniques and materials.

2.6. Literature review

In this section, we demonstrate the energy savings of the Earth-sheltered buildings, the ground temperature calculation methods, and the psychological issues as well.

2.6.1. Energy savings potential

Egypt is classified as arid-desert-hot climate(BWh) according to the world climatic zones classified by Köppen-Geiger classification method, (Fig. 2.9) (Rubel and Kottek 2010).

That derives the way towards searching for a sustainable solution to reach thermal comfort and energy savings.

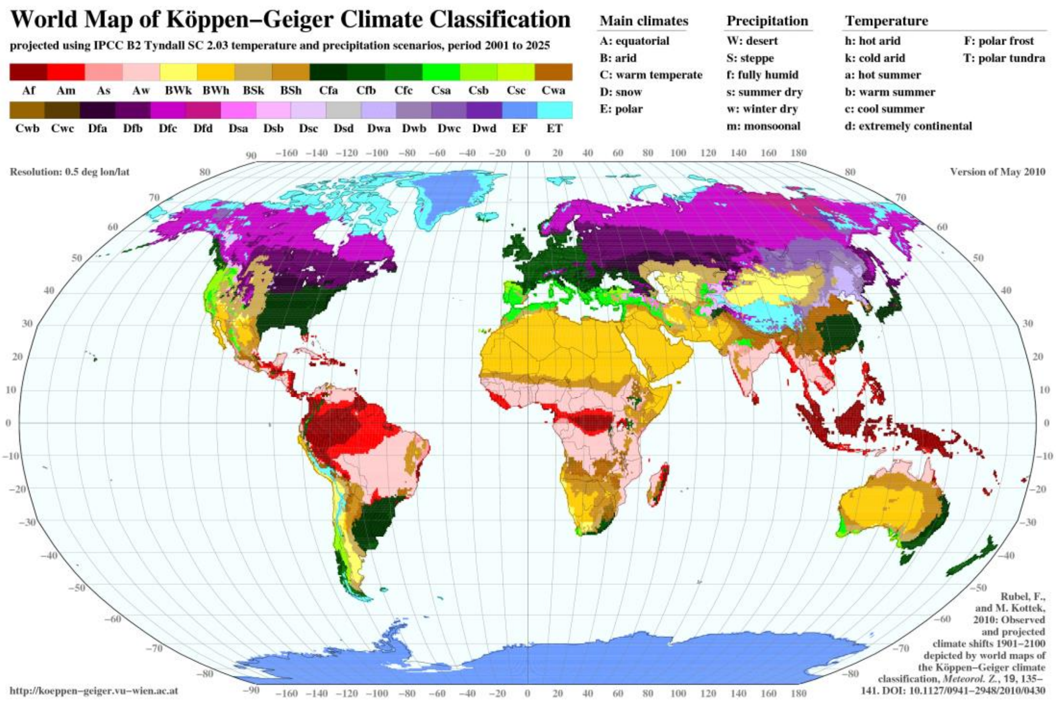


Fig. 2.9. Egypt is located in the arid-desert-hot zone according to Köppen classification.

The building envelope structure design as a passive way to reach thermal comfort is a non-ending issue, many types of research were done in this field.

The Earth-sheltered houses are often constructed with energy conservation and savings in mind. Owing to its very high thermal capacity, the temperature of the ground is lower than that of the outdoor air in summer and higher in winter. Consequently, the heating and cooling energy of a building considerably sunk into the ground are lower than that of a corresponding aboveground building (M. Staniec and Nowak 2011).

Not only the temperature difference between the exterior and interior is reduced, but mostly because the building is also protected from the direct solar radiation (Sahar N. Kharrufa 2008; Sheta 2010).

The Earth's mass absorbs and retains heat. Over time, this heat is released to surrounding areas, such as an earth shelter. Because of the high density of the earth, changing the earth's temperature occurs slowly. This is known as *"Thermal lag".* Because of this principle, the Earth provides a constant temperature for the underground shelters, even when the outdoor temperature has great fluctuation(Hoyle 2011).

Moreover, basements required much lower cooling loads to reach thermal comfort, because it is not exposed to the outside environment, even at (-1m.) level. (Sahar N. Kharrufa 2008).

Other characteristics include the reduction of air infiltration within the dwelling because three walls of the structure are mainly surrounded by earth, the very little surface area is exposed to the outside air (Anselm 2012).

This alleviates the problem of warm air escaping the house through gaps around windows and door.

Furthermore, the earth walls protect against cold winter winds, which might otherwise penetrate these gaps. However, this can also become a potential indoor air quality problem. Healthy air circulation is key (Hoyle 2011).

Since most of the modern earth-shelters are built with concrete, which can absorb the excess energy from the soil. This absorbed heat is naturally released back into the building whenever the indoor air temperature is below the thermal mass, as shown in (Fig. 2.10).

A typical relationship between the annual air temperatures and corresponding temperature fluctuation below ground surface(El-Din 1999).

Sherief A. Sheta, concluded the energy saving benefits reasons of earth sheltering in four main points (Sheta 2010):

1) Reduction of conduction, due to earth mass.

2) Flattening peak conditioning loads.

3) Controlling air infiltration.

4) Cooling through evaporation, due to greening the roof.

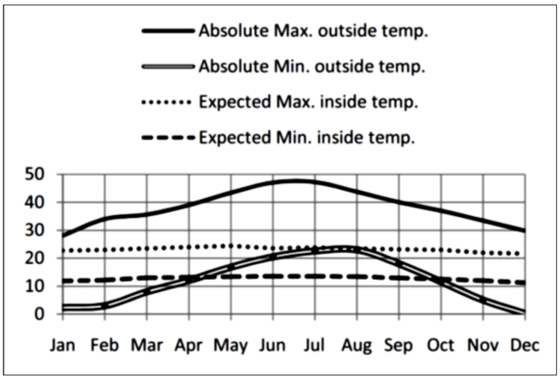


Fig. 2.10. Annual temperature fluctuations in Riyadh from below zero, to 48°C and expected temperature fluctuations at (3.0m.) below ground level between 14°C and 24°C.

Okba developed a checklist for envelope design techniques, based on the main elements of the envelope design (Okba 2005).

Sadineni et. al., introduced very rich study review about the passive techniques for the building envelope, one of them was the thermal mass to maximize the thermal latent heat storage (Sadineni, Madala, and Boehm 2011).Later, Kharrufa tested many passive techniques against the cooling loads using monitoring equipment to test the effectiveness extent of each technique at the hot-arid climates (S.N. Kharrufa and Adil 2012).

At Saudi Arabia, Alaidroos and Krarti performed multiple monitoring tests on different passive cooling systems, to select the best combination of which could give the best performance for lowering the cooling loads (Alaidroos and Krarti 2016).

Regarding the design guidelines in general issues, Takkanon tested many design variables against thermal comfort limits in Bangkok and provided design guidelines for both naturally ventilated and air-conditioned row houses in Bangkok (Takkanon 2006).

Therefore, we may consider the Earth-sheltering technique as one of the ways to reach thermal comfort passively, through enlarging the thermal capacity of the building envelope and maximizing the thermal lag of heat transfer of the walls (Carmody and Sterling 1985).

2.6.2. Basement's Thermal Performance Evaluation

As earth-sheltered buildings could be defined as the structures built with the use of Earth mass against building walls as external thermal mass, (Anselm 2012). We might consider the basements as one kind of earth sheltering technique (Heba et al. 2012).

Carmody and Sterling analyzed the effect of earth integration on heating and cooling in a conceptual way, for winter and summer performance. Moreover, providing a regional design approaches based on different climate conditions (Carmody and Sterling 1985).

Regarding the ground temperature profile variation with depth, many researchers developed their own numerical expression models to predict the heat flow inside the ground (Al-Temeemi and Harris 2003; Derradji and Aiche 2014; El-Din 1999; Janssen, Carmeliet, and Hens 2004; Lazzarin, Castellotti, and Busato 2005; Serageldin et al. 2015; Maja Staniec and Nowak 2016).

In terms of thermal comfort in underground spaces, some researchers developed a mathematical model for calculating the heat transfer, then calculated the thermal comfort improvements using Predicted Mean Vote (PMV). However, it was a hypothetical model only without actual measurements. (Szabó and Kajtár 2016).

Anselm used fluid dynamics simulation program (Phonics-VR) to predict the energy savings in the earth-sheltered model as a whole building simulation (Anselm 2008). Later, 2009 Ip. and Miller monitored the thermal performance of an Earth-ship, as a kind of earth-sheltered buildings (Ip and Miller 2009).

However, simulations only or monitoring only is not enough for a complete vision of the issue, one should integrate both for a valuable research.

The most innovative and powerful pieces of research performed a comparison between the measured and simulated data, using simulation programs with and/or without mathematical models to predict the boundary condition temperature, and simulate the whole building performance (Andolsun et al. 2011; Freney, Soebarto, and Williamson 2012; Sahar N. Kharrufa 2008; Kumar, Sachdeva, and Kaushik 2007; M. Staniec and Nowak 2011).

2.6.3. Psychological Issues and Questionnaire Analysis

Most of the previous pieces of research were concentrated on measuring people's attitudes with buildings, about windows proximity with classrooms and office buildings. All of which had proved the hypothesis that productivity, psychology, and physical comfort had increased with direct windows contact (Aries, Veitch, and Newsham 2010; Barrett et al. 2015; Jhon Carmody and Sterling 1993; Nagy, Yasunaga, and Kose 1995; Niroumand, Zain, and Jamil 2013a, 2013b; Yildirim, Akalin-Baskaya, and Celebi 2007).

As this research is mainly predicting and measuring about something still not applied, we used the photo-questionnaire technique.

Researchers used it with buildings and urban planning, in different topics, for predicting preferences and attitudes, (Hammitt, Patterson, and Noe 1994; Santosa, Ikaruga, and Kobayashi 2013; Sullivan, Anderson, and Lovell 2004).

Valuable researches about assessing the suitability and attributes of Earth-Sheltered buildings at hot-arid climates were introduced (Al-Temeemi and Harris 2004; Sheta 2010). They are depending on the theoretical analysis and created an organized guidelines and Earth-Sheltered attributes. Although the Earth-Sheltered buildings had proved very high level of thermal comfort experimentally (Benardos, Athanasiadis, and Katsoulakos 2014; Derradji and Aiche 2014; Van Dronkelaar et al. 2014; H Hassan et al. 2014; Kaliampakos et al. 2014; Tundrea et al. 2014), but still the application is not widespread in the world.

Even many architects think that it is only limited to basements or underground structures (Bobylev 2010; Kaliampakos et al. 2014).

Two recent books where Basil and Akubue talked about the Earth-Sheltered construction on its modern form, regarding the energy savings potentials, benefits and drawbacks, construction typologies, and the structural integrity (Anselm 2012; Hoyle 2011), in details for deep seekers about the system.

The relative researches to this work were since the eightieth; no further researches on the acceptability of Earth-Sheltered buildings using a questionnaire survey analysis had been published, until the pilot study of this research at 2013 (Ismail et al. 2013).

At Japan, there are two recent types of research about the acceptability of living at the basements (Kazumori and Yuske 2004; Mariko, H, and Taguchi 1999), but it is not recommended to do so.

The research team at Oklahoma university 1980, gained results from 34 questionnaires from people who already participated in designing their earth-sheltered houses. The majority felt satisfied by the energy savings, whether 40% felt dissatisfaction about their energy consumption, Boyer thought it might be because of over expectations from users (L. L. Boyer and Grondzik 1980). Because, they already measured the energy savings inside these buildings around the year, and gained a noticeable energy saving (L. Boyer et al. 1980; L. L. Boyer, Grondzik, and Fitzgerald 1981).

At South Carolina, another research done by Stewart and his group (McKown and Stewart 1980). The sample farm (n=250), were interested volunteers had been hosted in an earth-sheltered house, and had been asked the questionnaire about their attitudes, to gain their reactions towards selected design features Ex.: (size, special arrangement, lightening, privacy, access, expected maintenance costs, and energy efficiency…) (Stewart, McKown, and

Newman 1981). They proved the visitor's desire to live in a similar house was related to three main attributes, every architect should consider them when designing such a house; community acceptance, accessibility, and lightning. That study should not be generalized beyond its limitations.

In 1981, Baggs conducted a valuable research at Australia (Sydney 1981). He performed a postal survey at the beginning with 88 respondents, and then he conducted interviews with 53, both of which aboveground and underground dwellers, in an attempt to explore user attitudes before and after occupying an underground dwelling. He used the random number tables' statistical method to equalize both samples. He advised conducting a photo-questionnaire at future pieces of research like this, because during his interviews, most of the respondents had changed their passive reactions into positives, after seeing photos of modern earth-sheltered houses. Again, this research outcome could not be generalized; it is only limited to that community.

Combs conducted a questionnaire at Nebraska, Lincoln, mailed to 182 sample of homebuilders, to gain their expertise about their acceptability of the constructed earth-sheltered houses (Combs 1985). He obtained the result that, those homes that were built within existing neighborhoods, were less accepted by the public than those were built in rural areas. The research was only concentrated on the psychological acceptance point.

At Minneapolis, St.-Paul, Minnesota. Bartz conducted a post-occupancy questionnaire (n=39), regarding the level of satisfaction after a real experience of this kind of buildings (Bartz 1986). He found that residents were very satisfied psychologically and with their internal thermal comfort.

In addition, about two-thirds of them had negative attitudes before that experience, which turned into positive ones. Moreover, three-fourths of them recommended this type for others to live in.

Finally, this research scope is directed to architects and urban planners who work with Earth-sheltered building system, especially in hot-arid climates.

2.7. Discussion

When earth sheltering is mentioned most people think that it is under zero level.

However, by studying the classification types, we may notice that it could be only one type of earth-sheltered construction; like basements; which had been discussed in this research.

By measuring basements thermal performance, it proved high thermal comfort than conventional ones.

That could be considered as an indicator to other earth sheltered building types to give a similar thermal performance.

On the other hand, basements are usually poor in daylight and cross ventilation.

Accordingly, this is not a call through this research to live in basements; it is only a proof of good thermal comfort for the earth sheltering system.

Furthermore, when studying other recent stand-alone earth-sheltered buildings like Aloni house; one can find that it has a full height conventional façade, which imitates residential buildings, and had good natural daylight and ventilation.

The researcher believes that most people avoid living or building an earth-sheltered construction, only because of its name, and because of the negative background image in minds about poor ventilation and lightning in basements.

Psychological bias is discussed in chapter 3 (Heba Hassan et al. 2016; Ismail et al. 2013).

2.7.1. Application's Possibility Guidelines

In order to measure the application possibility, there are many aspects that architects should measure separately, then integrated together for a complete image, as a very important issue, in order to gain a realistic view. Al-Temeemi had listed some important steps (Al-Temeemi and Harris 2004). However, we think that there are more aspects to be measured:

- **Accessibility** could be measured by studying urban maps and choosing the appropriate site which is near to natural resources and infrastructure.

- Geology should have been measured by studying the soil structure maps. Since wrong decision to choose a site with inappropriate soil structure could lead to a catastrophe.

  Likewise, the case happened at Muqattam mountain at Egypt, when people built their homes by themselves on a porous rock of limestone structure, then a complete part of the mountain had a landslide and fall-down with hundreds of victims.

- Acceptability should be measured by making a survey questionnaire; in order to measure people's attitudes towards these buildings.
- Thermal Comfort could be measured by simulation programs. Moreover, the thermal comfort sensation is different between countries, according to people's perception of heat and cold.
- Energy saving could be measured by energy monitoring and calculating the actual energy saving, in comparison with conventional buildings. The energy saving extent could be measured also by simulation programs.

2.8. Conclusion

This chapter conducted an analytical study of the earth-sheltering building type through historical and recent cases.

The Earth-sheltered architecture is not a new style of buildings; it has been used a long time ago. Nowadays, architects are reusing the same concept with modern innovative designs. The application at Egypt has many obstacles, mainly the psychological one.

We demonstrated the state-of-the-art energy saving potential benefits of earth sheltering system. The expected ground temperatures at more depths were more stable.

In an attempt for application; there should be extensive studies to measure the suitability extent, using different tools like survey questionnaire and simulation programs to measure the thermal load.

This chapter demonstrated application guidelines for the best application in hot climates, for architects to measure the application's suitability anywhere.

Chapter 3

3. MEASURING PEOPLE'S PERCEPTION USING, PHOTO-QUESTIONNAIRE SURVEY

This chapter is measuring people's acceptance, to live in or deal with these buildings, who had no previous experience, using the photo-questionnaire survey and interviews with a purposive expert sample (n=164) at Egypt and Japan.

Using the chi-square test, to generalize the results, the inferential statistics showed that 48.8% from the whole sample had a little knowledge, which means that it started to be recognizable among experts. In addition, 55.5% from the sample chose the application at a touristic city with mild climate. Moreover, 43.3% chose the residential usage, and 40.0% chose the touristic one. Which infers that the only bias of applying those buildings was psychological, according to its name related with "Earth". However, when people had experienced the questionnaire through videos and pictures, they showed good reaction about those buildings.

The significant results recommended for architects and urban planners to use this kind of buildings first at a touristic city with mild climate as a beginning, to give the public a chance to try it for short time as a resort or hotel. Afterwards, they can apply it at the residential sector.

3.1. Methodology

This part of the research is exploratory type, discussing a hypothetical topic, regarding the application of the Earth-Sheltered buildings and people's attitudes, whom do not have previous experience, towards living in or dealing with these buildings.

The chapter used the (EMIC) approach, by using the photo-questionnaire survey beside interviews, to assure the reliability of the results and avoid the subjectivity bias.

3.1.1. Questionnaire Design

The chapter is divided into four main core parts:

- The methodology, where we discussed the research different measures, and the statistical analysis methods.
- The results section contains the descriptive and inferential statists, without deep analysis.
- Besides, the discussion section, where we covered the "so what" factor in this research.
- The previous parts are preceded by the introduction and followed by the conclusion.

3.1.2. Questionnaire Sample

The questionnaire study used a (non-probability) sampling technique, through a purposive sampling, namely (expert sample). The sampling farm were post-graduate students, architects, university teachers at the architectural departments at both Egypt and Japan, and some others (architects who are not very specialized or working on the field from both nationalities).

The sample was also divided, as a control variable, into specialists (architects and university teachers), and non-specialists (post-graduate students and others) for both Egyptians and Japanese.

3.1.3. Measures

The research used triangulation techniques, to avoid bias and subjectivity (Olsen 2004), such as pilot study, interviews, and web-based-questionnaire respectively

1. Stage one (Pilot Study)

The sample was a collection of fourth year grade architectural university students, postgraduate students and university teachers, all were at Egypt. The researcher gathered them in a class and described in a short demonstration about the Earth-Sheltered system.

Around 99% of them did not have an idea about the building system before. The questions were in Arabic language. It was concentrating on the idea of the psychological bias regarding the name of "Earth-Sheltered". It was also photo-questionnaire, trying to gain reactions from indirect questions.

Most of the respondents were impressed by the idea and liked it, especially when they discovered by the end of the questionnaire that most of the beautiful buildings, they thought it is conventional, were Earth-Sheltered.

The meeting was turned into interactive after finishing the questionnaire, which encouraged the researcher to make individual interviews after finishing that stage. The pilot study questionnaire was published in 2013 (Ismail et al. 2013)

2. Stage two (Interviews with Respondents)

The interviews were done at three stages:

The first stage was with Egyptians (undergraduates, postgraduates, university teachers) after the pilot study. The interview with undergraduates was similar to demonstrating about the system, they did not know too much to reply about the open questions. Postgraduates and university teachers gave contradictory replies. Some of them liked the idea, were eager to apply it, and agreed to make new projects with this system.

Others did not like it and kept stuck on the bad background image about this type, in which it will be dark, damp, contains insects, etc., even when they saw nice modern buildings as a good example, but still kept on the refusal side about this type.

Some of the experts' side gave advices about the questionnaire words and design, when they knew it was a pilot study. Total respondents from all interviewees were (n=100).

The second and third stages, were during the main web-based-photo-questionnaire regarding this research. Whereupon, when the researcher was at Egypt, she interviewed Egyptians, and when she was at Japan she interviewed Japanese. The information gathered through face-to-face interviews, during informing them about the questionnaire, and through the open-ended questions at the end of the questionnaire itself.

Regarding Egyptians reactions, it varied again between the right and left sides, even when it was very different questionnaire's questions, pictures, language (it was English), and respondents (this time we excluded the undergraduates and enlarged the experts' part). Still people were divided, but that time the reactions' percentage was for the benefit of supporting the idea, recommending good places for the application, and providing new ideas for implementation. Very little percent around 5.0% still do not support the system's application at Egypt.

Regarding Japanese reactions, the percentage was almost the opposite. Japanese supported the idea of applying it only at Egypt. Around 95% of them gave the reaction that it will not be applicable or suitable for living in Japan. Most of them thought it would be very humid, damp and cold from inside. Although after those interviews, the researcher found an applied real project at Japan. We asked some of them again, but still on their opinion, that it would not be good example at Japan, because of the high humidity level.

3. *Stage Three (Web-based photo-questionnaire)*

The research used the web-based photo-questionnaire as a tool for measuring people's attitudes using google forms.

For Egyptians it was in English, English questionnaire form, 2015, (Appendix E).

For Japanese it was translated into Japanese, Japanese questionnaire form, 2015 (Appendix F), to assure clear understanding of the questions, and to assure the research reliability.

Afterwards, the Japanese answers were translated into English and were gathered together with the Egyptians answers to form the complete sample.

The questionnaire is divided into six parts, as shown in (Fig. 3.1):

- The first part regarding socio-demographic characteristics, we concerned only about the gender. Because most of the sample were from the same age layer, around 30^{th} to 40^{th}.

  This age layer influenced the assessment of the Earth-sheltered buildings style positively.

  That sample age layer had the experts' experiences, joined with the youth spirit. Therefore, we could count on their opinions to get the right decision with a modern futuristic perspective.

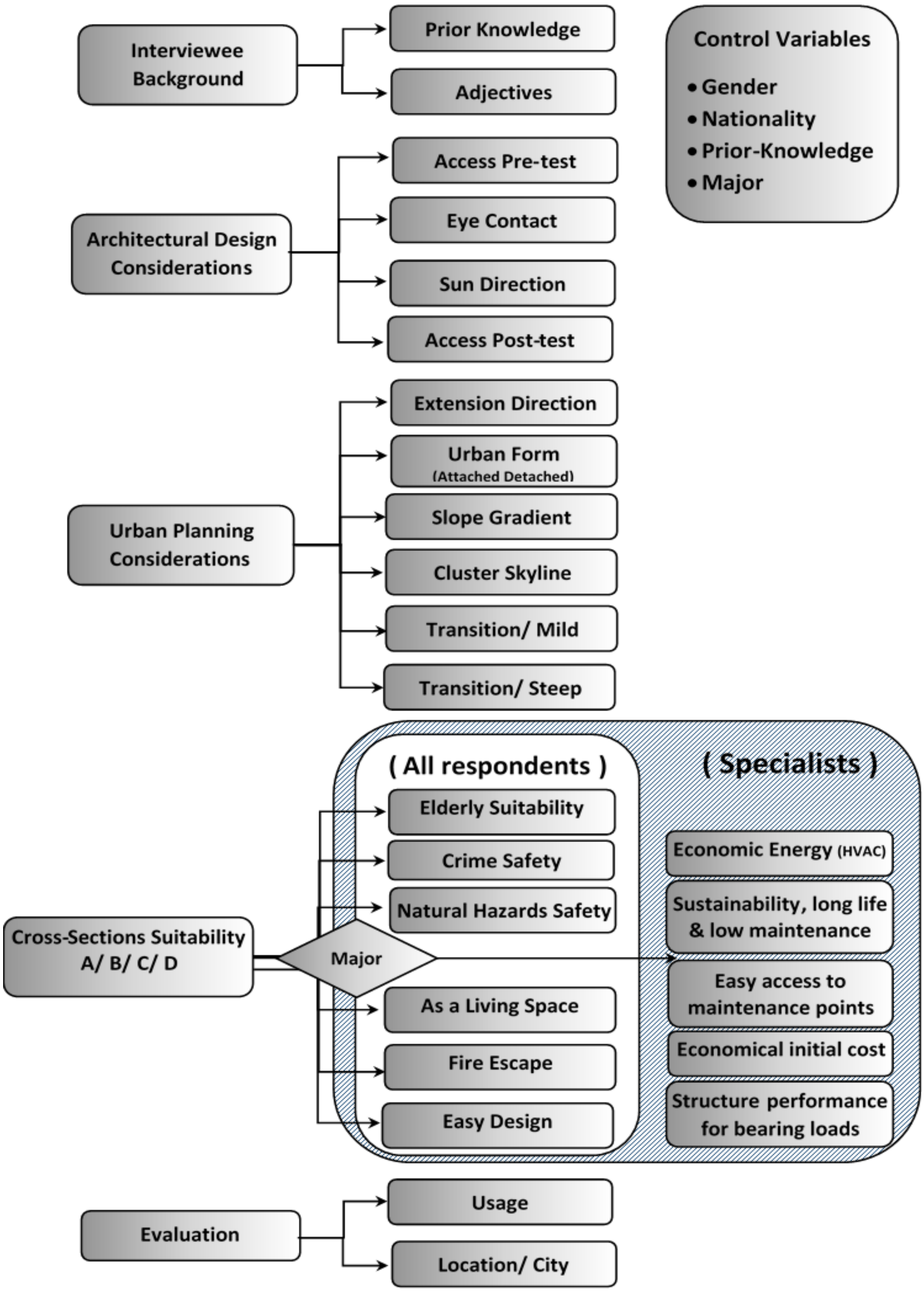


Fig. 3.1. A diagram concluding the questionnaire parts and the control variables.

- Followed by, the interviewee background idea, and the prior knowledge extent in a four Likert scale question. Moreover, the adjectives related in the mind about the Earth-Sheltering.
- Those two previous introductory sections were followed by two core sections helping in the design guidelines on the architectural design, and on the urban design themes.
- The question about the respondents major we moved it to the middle. According to the interviewee major, whether specialist or not specialist, the rest of the questionnaire would be different. In order to unify the questions at the first half and divide the respondents according to their major at the second half.
- At the cross sections' suitability question, (Fig. 3.2), we asked the sample about their reactions about four cross-sections and its suitability from different aspects, regarding elderly, against crime, natural hazards, as a living space, fire escape, and easy architectural design.
- We added more questions for experts about economical use of air-conditioning energy, sustainability, long life span, and low required maintenance, easy access to maintenance points, economical initial cost, and the best structure performance for bearing loads, as shown in (Fig. 3.1).
- Finally, the last part about usage and location questions represents the research outcome contribution for application.
- The Japanese questionnaire had different cities and locations from the Egyptian one, and then the answers had been gathered together as a general classification according to the city nature and climate. For example, touristic (mild climate), beautiful (hot climate), extreme climate (hot/ cold), or other.

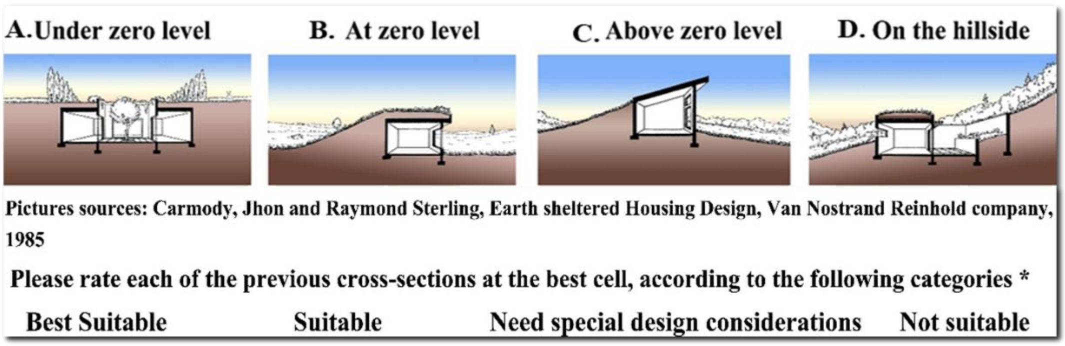


Fig. 3.2. A screenshot, cross sections' four Likert scale suitability, questionnaire's questions.

3.1.4. Statistical Analysis Method

1. Descriptive Statistics

Responses were analyzed by descriptive statistics, to predict the intellectual trends for both Egyptians and Japanese.

We used the contingency tables to tabulate the categorical data, to get the occurrence frequency of possible levels combination. For continuous data of the four Likert scale question, we used the measures of central tendency, the Mean Average. The most important outputs were presented in the form of Excel graphs for visual analysis, and better understanding

2. Inferential Statistics

The informant responses were analyzed using a statistical method of Chi-square test (χ^2), to be able to generalize the results, as it is the best suitable for categorical data of the interviewee responses (Lehner 1979). This test assists in rejecting random change variations between two categorical variables. We used a level of significance ($P \leq 0.05$), to gain 95% confidence of the results.

Followed by, some crosstabs for different combinations between control and other questions' variables.

Finally, we concluded people attitudes from the (χ^2) analysis of the last two questions about city and usage, combined with both open-ended question's comments, and the respondents' interviews, to achieve the triangulation.

3.2. Results

3.2.1. Descriptive statistics

1. People's Socio-demographics, and Background

The Egyptian sample was (n=101), and the Japanese sample was (n=63). The specialists from both nationalities were (n=84), and the non-specialists from both nationalities were (n=80). Total males were (n=96), and females were (n=68).

In a multi-checkbox question about adjectives related in mind towards earth-sheltered buildings. This question drives the way to construct design strategies to overcome the most negative adjective related with the "Earth-Sheltered" buildings. Around 20% from each Egyptians and Japanese think that it is Eco-Friendly. Although, most Japanese chose bad adjectives; on the contrary, most Egyptians chose good adjectives, (Fig. 3.3).

We thought that maybe most people did not know too much about these buildings before. Therefore, we asked the interviewee about their prior knowledge of this type of buildings, in a four Likert-scale question. By measuring the mean for both, it was (Mean≅2). Which means, most of the sample have a (little knowledge) about this type before the questionnaire, (Fig. 3.4).

Regarding the major question, the postgraduate students were high in both samples, 55% in Egyptians, and 37.6 % in Japanese. (Fig. 3.5).

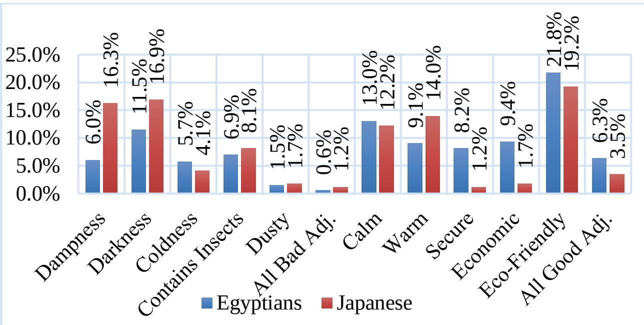


Fig. 3.3. Egyptians and Japanese adjectives of earth-sheltered buildings' selections.

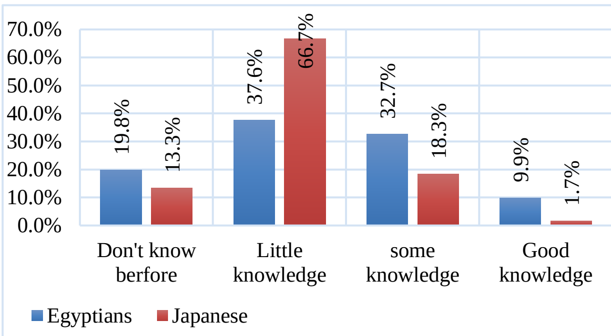


Fig. 3.4. Most of the people had a little knowledge.

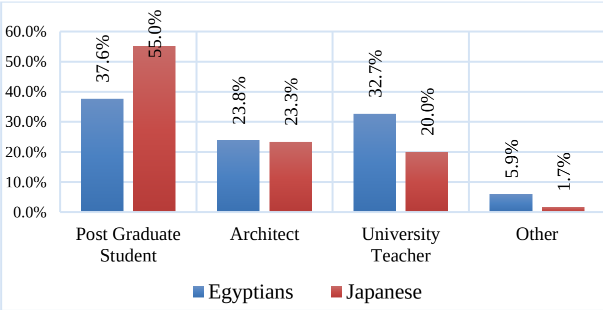


Fig. 3.5. The Sample Majors, the postgraduate students were the highest in both samples.

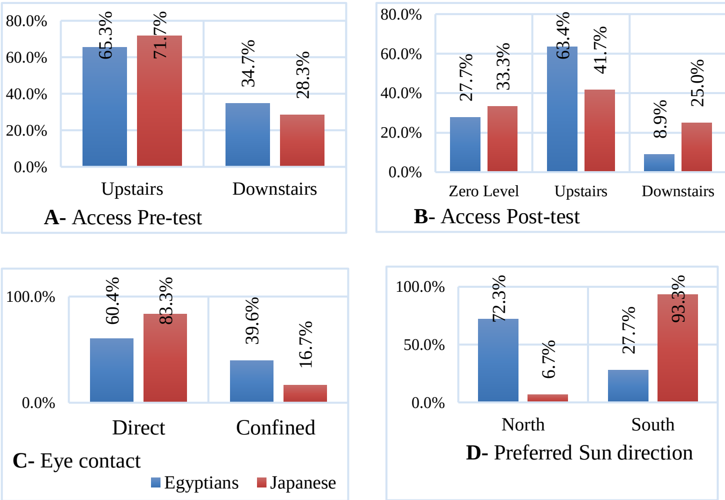


Fig. 3.6. Architectural Design Considerations for Egyptians and Japanese

2. *Architectural design considerations' questions*

Architectural design considerations questions Were about, accessing the unit, eye contact, and the preferred Sun direction. About the access preferences, we asked the question twice, as a crosscheck process. Once with the architectural design section, while showing a hand-drawing figure, asking about the up and down access only, and the other one at the urban design section, while showing three modified pictures, asking about the up and zero and down accesses. To measure the effect of showing pictures, and to find whether some of them would change their preference or not. Still the higher percentages were for accessing the unit upstairs, from both pre-test and post-test, by 65.3%, and 71.7% for Egyptians and Japanese respectively, at the pre-test, and by 63.4% and 41.7% for Egyptians and Japanese respectively, at the post-test, (fig. 3.6. A & B).

For the eye contact, 60.4% Egyptians and 83.3% Japanese chose the direct eye contact as a preferred choice.

For the Sun direction, we gained very different preferences; Egyptians chose the North by 72.3%, however Japanese chose the South by 93.3%, (fig. 3.6. C & D)

3. Urban design considerations' questions

Urban design considerations' questions were about, the extension direction, urban form (attached/detached), slope gradient, cluster skyline, and the preferred transition way between levels at the mild and the steep slopes.

We modified a picture of a proposed hotel in Chinghai, from vertical level to a horizontal and to three levels. However, both samples did not prefer the original one. While Japanese chose the horizontal extension direction by 51.7%, Egyptians chose the two or three level extension direction by 51.1%. (Fig. 3.7. A).

Both nationalities preferred the detached urban form, 79.2% Egyptians, and 66.7% Japanese. (Fig. 3.7. B). In addition, both preferred the (30% slope gradient), Egyptians by 61.4%, and Japanese by 66.7%. (Fig. 3.7.C).

Moreover, both preferred river type skyline (closed), Egyptians by 66.3%, and Japanese by 70.0%. (Fig. 3.7. D).

About the transition way between slopes (mild/ steep), 51.7% of Japanese preferred the short steps, while 35.6% of Egyptians preferred the stairway, for the mild slopes. In addition, 56.7% of Japanese preferred using climbing wagon, while 39.6% of Egyptians preferred using the car or shuttle bus for the transition between steep slopes. (Fig 3.7. E & F).

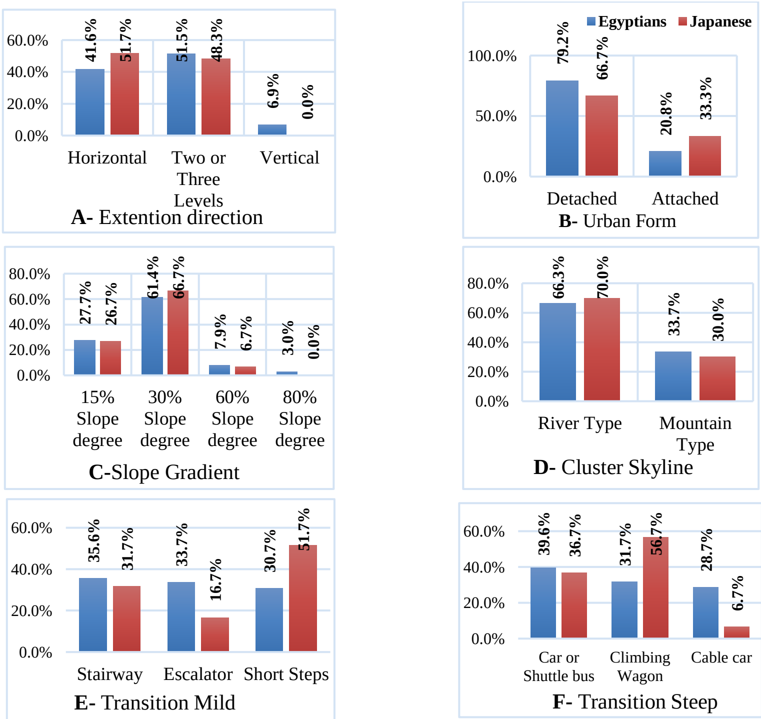


Fig. 3.7. Urban Design Considerations for Egyptians and Japanese.

4. Regarding the cross-sections' preferences question

We ranked the suitability aspects from the least importance to the most importance according to the whole sample, by the measures of central tendency of the arithmetic mean, as shown in (table 3.1). By calculating the mean to the whole sample of the different suitability aspects, then we sorted them from the least to the highest. By the first glimpse to it, we can conclude that according to the mean, the most suitable cross-sections from the whole sample's point of view are (B & C) cross-sections shown in (Fig 3.2), and the most unsuitable cross-sections according to the whole sample are (A & D) cross-sections shown in (Fig 3.2).

By concluding the chart from this table, we can grasp the trend of the preferences, as shown in (Fig. 3.8); the most suitable cross-sections from different aspects are (B & C) cross-sections shown in (Fig 3.2), and most unsuitable cross-sections from different aspects are (A & D) cross-sections shown in (Fig 3.2).

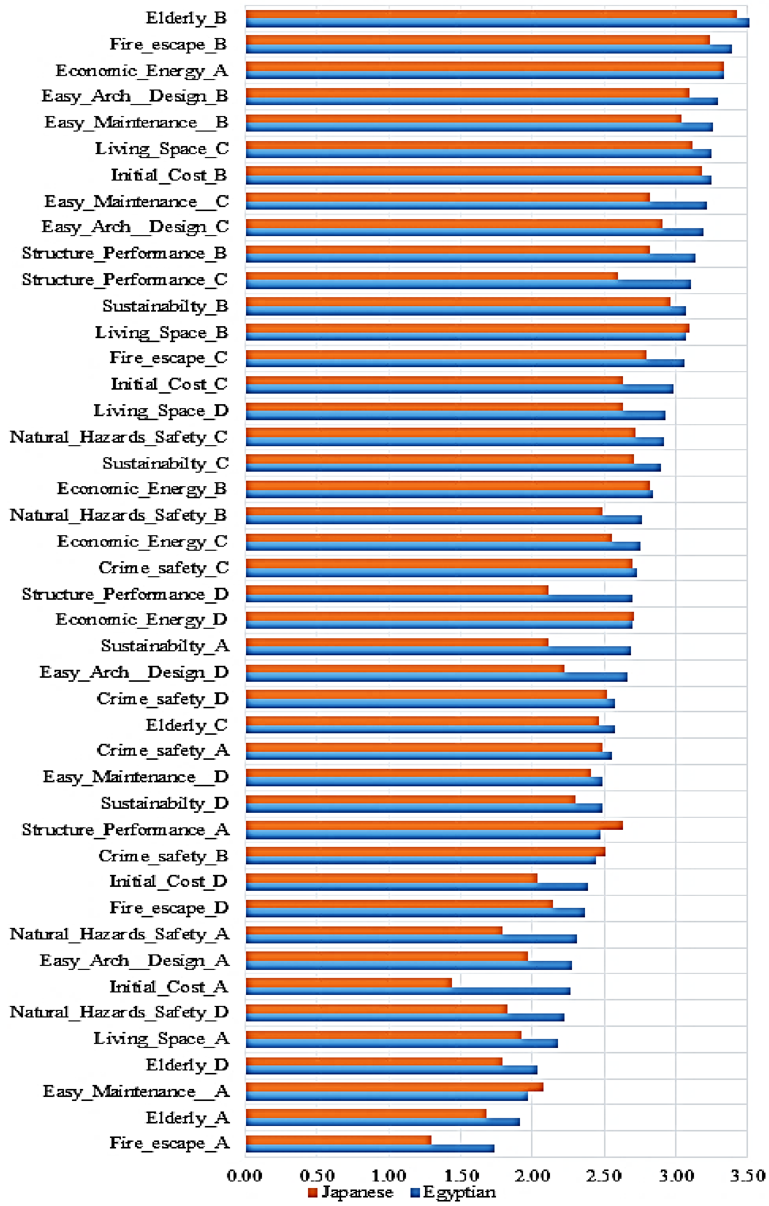


Fig. 3.8. Cross-section's preferences for both Egyptians and Japanese.

We consider the city location and the usage preferences, the most important output from this chapter. For the preferred city location, both Egyptians and Japanese liked to start the application at a touristic city with mild climate, Egyptians by 64.4%, and Japanese by 41.7%. However, they deferred in choices about the usage. Egyptians preferred to try it with the residential usage by 51.5%, but Japanese preferred to try it with the touristic usage by 38.3%. (Fig. 3.9. A & B).

Table 3.1. Cross sections' suitability's (Mean) for whole sample.

Descriptive Statistics		
	N	Mean
Fire_escape_A	164	1.57
Elderly_A	164	1.82
Elderly_D	164	1.95
Easy_Maintenance__A	84	2.00
Initial_Cost_A	84	2.00
Natural_Hazards_Safety_D	164	2.07
Living_Space_A	164	2.08
Natural_Hazards_Safety_A	164	2.11
Easy_Arch__Design_A	164	2.16
Initial_Cost_D	84	2.27
Fire_escape_D	164	2.28
Sustainabilty_D	84	2.43
Easy_Maintenance__D	84	2.46
Crime_safety_B	164	2.47
Easy_Arch__Design_D	164	2.49
Sustainabilty_A	84	2.50
Structure_Performance_D	84	2.51
Structure_Performance_A	84	2.52
Crime_safety_A	164	2.53
Elderly_C	164	2.53
Crime_safety_D	164	2.55
Natural_Hazards_Safety_B	164	2.66
Economic_Energy_C	84	2.69
Economic_Energy_D	84	2.70
Crime_safety_C	164	2.72
Living_Space_D	164	2.82
Sustainabilty_C	84	2.83
Economic_Energy_B	84	2.83
Natural_Hazards_Safety_C	164	2.84
Initial_Cost_C	84	2.87
Structure_Performance_C	84	2.94
Fire_escape_C	164	2.96
Structure_Performance_B	84	3.04
Sustainabilty_B	84	3.04
Living_Space_B	164	3.08
Easy_Maintenance__C	84	3.08
Easy_Arch__Design_C	164	3.09
Easy_Maintenance__B	84	3.19
Living_Space_C	164	3.20
Easy_Arch__Design_B	164	3.22
Initial_Cost_B	84	3.23
Fire_escape_B	164	3.33
Economic_Energy_A	84	3.33
Elderly_B	164	3.50
Valid N (listwise)	84	

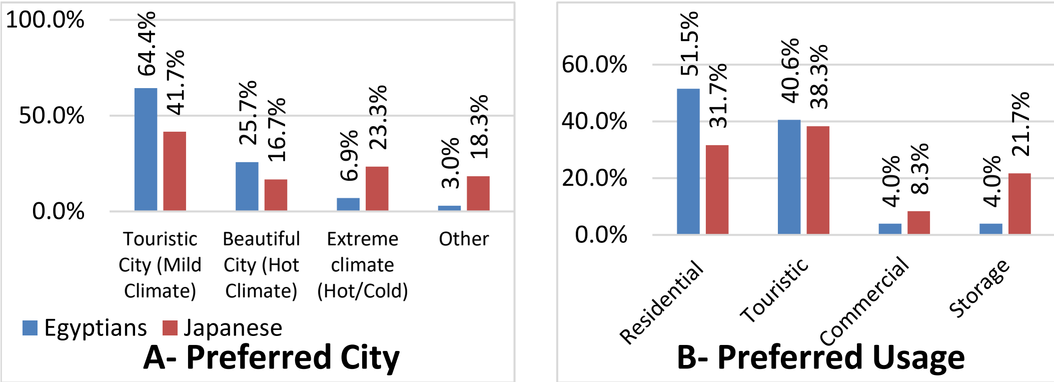


Fig. 3.9. Sample's choices for their preferred city and usage

3.2.2. *Inferential Statistics*

1. *Chi-Square test.*

The Egyptians responses frequency differed significantly from the Japanese ones, χ^2 (Degree of Freedom, N=164), P⩽0.05 = 95% confidence. We performed the test according to the Nationality and Gender, as shown in (table 3.2), where the (*) shows that the relationship is significant, and the (---) shows that the relationship is not significant. The complete test tables could be found at Appendix A.

Table 3.2. Nationality and Gender Chi- Square test, Appendix A.

	Nationality	Gender
Prior Knowledge	*	*
Adjectives	*	----
Access (Pre-test)	----	----
Eye-Contact	*	*
Sun Direction	*	----
Entrance Approach (Post-test)	*	----
Extension Direction	*	----
Urban form (Attached-Detached)	*	*
Slope Gradient	*	*
(River/Mountain) Type	----	----
Transition Mild	*	----
Transition Steep	*	*
Major	*	*

Therefore, we can generalize the previous descriptive results for both Egyptians and Japanese societies, except (access pre-test and cluster skyline). Moreover, we conducted the chi-square test for the (City) and (Usage) preferences with the whole sample, both nationalities, gender, and specialization. It was significant for all, (table 3.3).

Table 3.3. City and Usage Preferences Chi-square test, Appendix B.

Chi-Square According to:		City	Usage
All Sample		*	*
Nationality	EGP.	*	*
	JP.	*	*
Gender	M.	*	*
	F.	*	*
Specialization	Specialist	*	*
	Not Specialist	*	*

2. Cross Tabulation

At the beginning, we tabulated the control variables, and the access pretest and posttest, in the form of a diagonal correlation matrix. We provided the descriptive numbers within each correlation, and highlighted only the significant relationship cells, according to the chi-square tests we conducted, as shown in (table 3.4). The empty cells above the diagonal would be repeated, so we omitted them. The empty cells under the diagonal, we did not conduct the chi-square test, because no significant information would be added.

For Nationality and Major relationship, we already mentioned it before, with the graph at the descriptive section, (fig. 3.5).

According to the significant correlations between the prior knowledge and specialization, both specialists and non-specialists had the higher percent for (little knowledge). However, with a deep look we can conclude that only 2.5% from the non-specialists (postgraduate students, and others) had a good knowledge, while 10.7% from the specialists (architects and university teachers) had a good knowledge.

On the other hand, only 8.33% from the specialists, seven persons did not know before about this kind of buildings, and 26.25% from the non-specialists did not know about it before.

Regarding the specialization with accessing the unit pretest, and posttest, the higher percentages were for the upstairs.

Table 3.4. Cross tabulation for control variables, access pretest, and posttest.

(* significant relationship, χ^2 tables at Appendix C).

			Gender		Nationality		Prior Knowledge				Major				Specialization		Access Pretest	
		Total	M.	F.	EGP.	JP.	Do not Know	Little Know	Some know	Good Know	Post G. St.	Arch.	Univ. Tea.	Other	Spec.	Not Spec.	Up	Down
Gender	M.	96																
	F.	68																
Nationality	Egyptians	101	55	46														
	Japanese	63	41	22														
Prior Knowledge	Don't know	28	17	11	20	8												
	Little Know	80	43	37	38	42												
	Some Know	45	27	18	33	12												
	Good Know	11	9	2	10	1												
Major	Post G. St.	73	44	29	38	35	19	40	12	2								
	Arch.	38	17	21	24	14	5	19	12	2								
	Uni. Tea.	46	32	14	33	13	2	18	19	7								
	Other	7	3	4	6	1	2	3	2	0								
Specialization	Special.	84	49	35	57	27	7	37	31	9		38	46					
	Not Special.	80	47	33	44	36	21	43	14	2	73			7				
Access Pre-test	Up	111	68	43	66	45					45	26	37	3	63	48		
	Down	53	28	25	35	18					28	12	9	4	21	32		
Access Post-test	Zero	48	26	22	28	20					18	13	16	1	29	19	29	19
	Up	91	53	38	64	27					37	21	29	4	50	41	78	13
	Down	25	17	8	9	16					18	4	1	2	5	20	4	21

However, with deep analysis, we could conclude that:

The percentage of the up and down had decreased, from 75% specialists and 60% non-specialists, to 59.5% specialists and 51.25% non-specialists, for the benefit of the zero-level entrance. Also, the percentage of Down had decreased from 25% specialists and 40% non-specialists, to 6.0% specialists and 25% non-specialists, for the benefit of the Zero level entrance. It reached at the posttest to 34.5% specialists and 23.75% non-specialists.

Finally, the access (pretest/posttest) crosstabs, we can conclude that high percentage 35.8% changed the (Down) entrance choice for the benefit of the (Zero-level) entrance, while not very high percentage 26.1% changed the (Up) choices for (Zero-level) entrance.

The final two important questions at the questionnaire were for the City and Usage preferences, as shown in (table 3.5). According to both nationalities distribution, we already mentioned before with the graph at the descriptive section, (fig. 3.9. A & B).

According to the whole sample, 55.5% preferred the application at a touristic mild climate city. In addition, 43.3% preferred the residential use, followed by 40.0% preferred the touristic use.

According to the specialization variable, both the specialists and non-specialists preferred the application at a touristic mild climate city by 58.3% and 52.5% respectively. Moreover, both preferred the residential use by 42.9% and 43.8% respectively. Followed by the touristic use by 40.5% and 40.0% respectively.

Table 3.5. City and Usage choices (χ^2) test with Nationality, Gender and Specialization.
(* significant relationship, χ^2 tables at Appendix D).

		City		Usage					
		Touristic, mild climate	Beautiful, hot climate	Extreme climate	Other	Storage	commercial	Touristic	Residential
All Sample		91	37	25	11	18	9	66	71
Nationality	EGP.	65	26	7	3	4	4	42	51
	JP.	26	11	15	11	14	5	24	20
Gender	M.	58	15	14	9	12	5	39	40
	F.	33	22	11	2	6	4	27	31
Specialization	Special.	49	22	10	3	10	4	34	36
	Not Special.	42	15	15	8	8	5	32	35

3.3. Discussion

In this section, we elicited general architectural and urban design guidelines, and we recommend putting into consideration its observance before new implementation.

3.3.1. General Architectural Design Guidelines

From the adjectives questions we can conclude that:

The plan should be opened to the outer environment, from both natural daylight and ventilation aspects, to overcome the possibility of feeling darkness or dampness. Japanese felt that it might be warm more than cold. Egyptians felt that it might be cold more than warm; it is good reaction about both climates. Most Egyptians chose good adjectives, before they saw the video, which means that these buildings have good image in minds.

Although most of the respondents had little prior knowledge, they gave the right answers according to the hypothesis. Which confirms Baggs hypothesis to use photo questionnaire with little knowledge people, for accurate information delivery and right imagination about buildings (Sydney 1981).

The preferred access direction was to be upstairs, to prevent water flooding, or sand dunes cover. Moreover, regarding the crosstabs results, we should concern about the Zero level entrance, to give natural feeling, like conventional buildings.

Although both nationalities preferred the direct eye contact, Japanese liked it more than Egyptians do, which liked more privacy. Moreover, the hot environment at Egypt makes people tend to close windows, regardless from the outer view. In addition, concerning about the environment, the North direction is preferred from Egyptians, and the south direction is preferred from Japanese.

3.3.2. General Urban Design Guidelines

The horizontal extension direction for the urban community is preferred at the Japanese society, while two or three levels are preferred at the Egyptian one. The vertical is not preferred.

Both Egyptians and Japanese prefer detached form, contrary to the supposed research hypothesis. We recommend the attached form to save heat exchange between the building and environment, while most of the sample preferred the opposite.

As a special case, for building on mountain steps, the 80% gradient slope is not preferred for the water supply and drainage, and the 30% is the most preferred. In addition, the river type (closed) is preferred to avoid wind turbulence and rain erosion. For transition between slopes, it is recommended to use the short steps at the mild slopes, and a climbing wagon at the steeps slopes.

For different cross-sections relationship with zero level and its suitability with different aspects, we recommend the most suitable cross-sections (B & C), and most unsuitable (A & D).

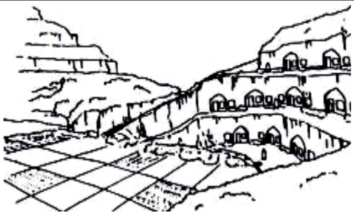
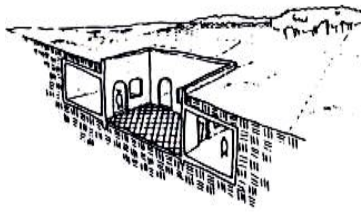
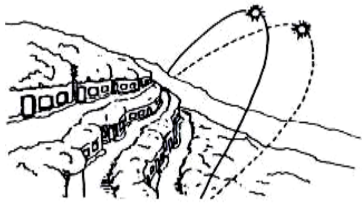
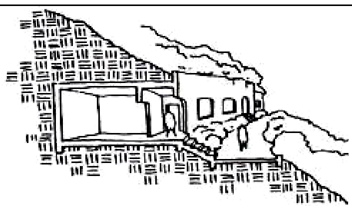
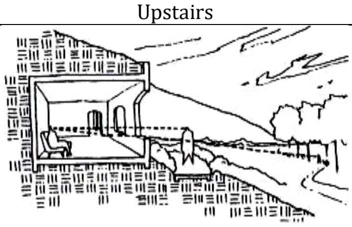
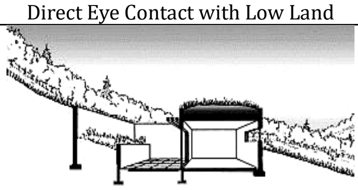
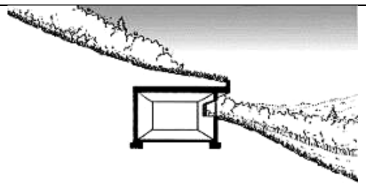
People prefer to try this kind of buildings first at a touristic city with mild climate, and then other climates came with different preferences ranking.

The preferred usage was swinging between the residential and touristic uses. This proves the research hypothesis; that the only barrier was psychological. When people saw video and pictures, they had good reactions about those buildings.

3.3.3. Recommended Adaptation

The research will measure the hypothesis of the suitability of different positions and some placements for creating some appropriate design guidelines for architects for innovative designs of earth shelters to allow the maximum energy savings when building an Earth-Sheltered construction, as shown in (table 3.6).

Table 3.6. Adaptation Design Guidelines for Architects, according to the questionnaire results.

	Preferred Position	Non-Preferred position
Site Selection	 On the Hill Side	 Flat Site
Orientation	 Towards North, Preferred at Hot-arid climates	 Towards South, Preferred at cold climates
Accessibility	 Upstairs	 Downstairs
Eye Contact	 Direct Eye Contact with Low Land	 Closed View
Natural Ventilation	 Good Cross Ventilation	 Poor Cross Ventilation

- About the **site selection**, it is preferable to build on slopes rather than flat sites. Slopes have many advantages related to geo-space buildings.
- About **orientation**, it is preferable at Egypt to face the building towards North direction, at Japan the direction preferred is reversed. At Egypt, they need to cool down the building as much as possible. In Japan, they need to gain heat and sunlight more than cooling aspect.
- About **accessibility**, it is preferred to access the building upstairs not downstairs; this will make people feel like conventional buildings.
- About the **natural view and eye contact**, it is preferred direct eye contact with the outer environment; the closed view raise the confinement feeling.
- **Natural ventilation** is a very important issue, especially at hot-humid climate. Otherwise, if it is not available, they can use negative ventilation by a suction effect. Counting on one façade is not preferable for ventilation.

3.4. Conclusion

3.4.1. Summary and Main contributions.

- The research measured people's attitudes towards Earth-sheltered buildings. The sample were experts from Egypt and Japan. By performing the chi-square test, this research outcome could be generalized on both communities.

  Moreover, they helped in the implementation's recommendations for architectural and urban design guidelines, and choosing the city, and usage, as presented in the discussion section.

- The most different attitude was about whether to apply it or not. While Egyptians supported the idea, Japanese did not support it at Japan. However, about specific questions they had no big difference, except what was related with different climates, like Sun direction.

- Most of the negative attitudes (cold, damp, dark, etc.…), had been changed by the end of the questionnaire to good ones, when they chose touristic and residential sectors.
- For architectural design guidelines, the research recommended accessing the unit upstairs, and the building's cross-section would be above zero level, to give the conventional appearance. Moreover, maintaining eye contact with the outer environment, to lessen the confinement effect, and the possibility of claustrophobia.
- For application at Egypt and the hot climates, it is recommended the North façade direction, while at Japan and the cold climates the South direction is recommended.
- For urban design guidelines, the research recommended two or three levels elevation's extension direction by maximum. In addition, to plan the community in a detached form. For sloped sites, as a special case, the 30% slope degree, closed skyline, and using the short steps and the climbing wagon for transition between the mild and steep slopes respectively, are recommended.
- For new communities' implementation, it is better to start with touristic city at mild climate, then the residential one.

3.4.2. Limitations.

- Maybe some of the respondents had been affected by (Hawthorne Effect) (McCambridge, Witton, and Elbourne 2014) because of the questionnaire title, which contains words like "The touristic use". Therefore, they chose the touristic use at the end of the questionnaire. Moreover, none of the sampling farm had lived or dealt with this kind of buildings in the real life.
- Threats to external validity. Interviewees in the questionnaire; already saw pictures and videos to know more about this kind of buildings. However, people in the real life will not have this opportunity. Therefore, maybe they still have doubt to apply this kind of buildings at hot-arid climates, especially, Egypt.

CHAPTER 4

4. THE THERMAL COMFORT POTENTIAL BY SIMULATION ANALYSIS

Reaching thermal comfort at hot-arid climates is getting more difficult nowadays without the use of high energy consuming mechanical systems. Therefore, the need to use passive energy design techniques is getting higher. One of the most effective techniques is the earth-sheltered buildings.

This chapter describes a part of the research which evaluates the basements' thermal performance to claim reaching the thermal comfort without active air-conditioning systems, despite of the harsh climate conditions, through monitoring and simulations. The case study was in Al-Minya city, Egypt, which is known by its high diurnal range. The study calibrated a non-conditioned basement model versus the monitored data to estimate its thermal performance. The most important parameter was to calculate the ground temperature around the building. We used an iterative approach between packages of the Basement preprocessor and EnergyPlus/DesignBuilder until reaching convergence.

The iterative way results showed high agreement, between the measured and modeled data, with correlation of 99%, and errors with mean bias error MBE and normalized root mean square error NRMSE of -0.78 and 7.0%, respectively. The calibrated model analysis evaluation using Fanger thermal comfort model showed satisfactory results within the range of +2: -2 of the thermal comfort sensation range.

The research significance is for the precise and customized detailed iterative way to create the inputs which subsequently lead to "near-to-actual" outputs in comparison with other ways. It could be used as a benchmark for simulators for easy and precise ground temperatures' calculations and earth-sheltered buildings' simulations.

We can conclude that reaching the thermal comfort at basements, as a kind of earth sheltering technique, is easy achievable due to the building contact with soil.

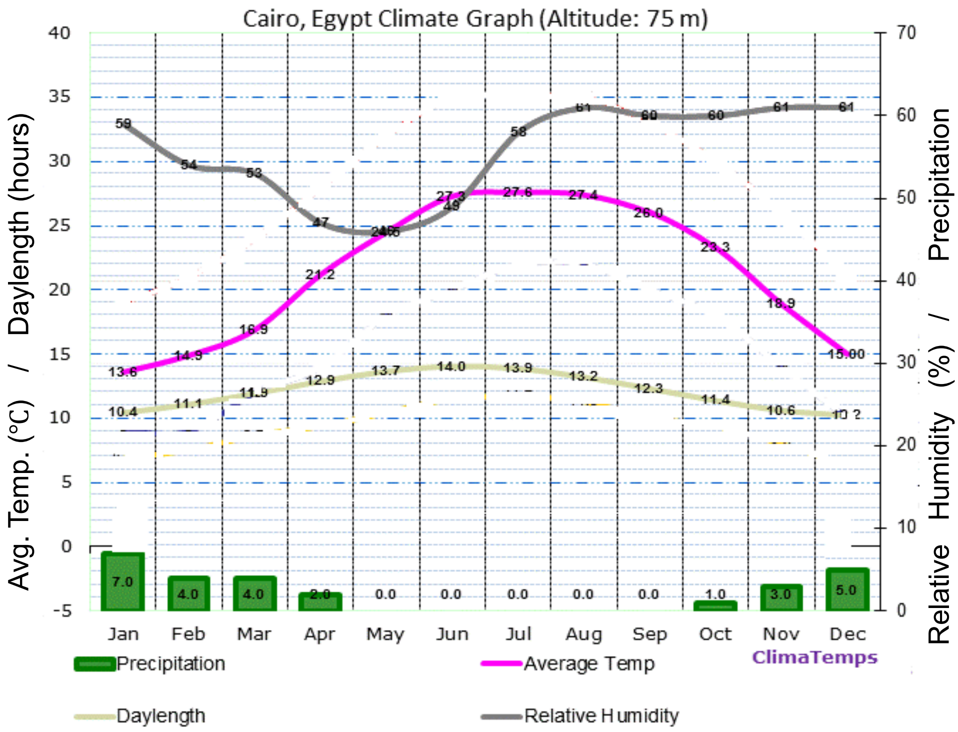
4.1. Climate analysis of the selected city at Egypt

Our research focuses the scope on Egypt's climate zone as one of the hot-arid climates. The dilemma was to choose the suitable city for the best earth-sheltered buildings' application. (Fig. 4.1) comparing between the climates of Al-Minya and Cairo cities, showing that Al-Minya city has the highest differences between Summer and Winter.

After the weather data analysis using the (Climate Consultant 5.4) software, as shown in (Fig. 4.2), we can grasp that Minya city has the highest temperature differences between day and night, and is one of the cities that has the highest temperature differences between winter and summer.

Analyzing the thermal comfort using (Al-Minya) city weather file, with the psychrometric chart using the (Ecotect Weather Tool 2011). It is clear that, it is recommended for the design to has an exposed mass plus night purge ventilation, as shown in (Fig. 4.3) This will expand the comfort area to cover most of the measured temperatures.

Therefore, it is expected that using the earth sheltering technique as a kind of a large thermal mass, will cover more comfort range at the chart.



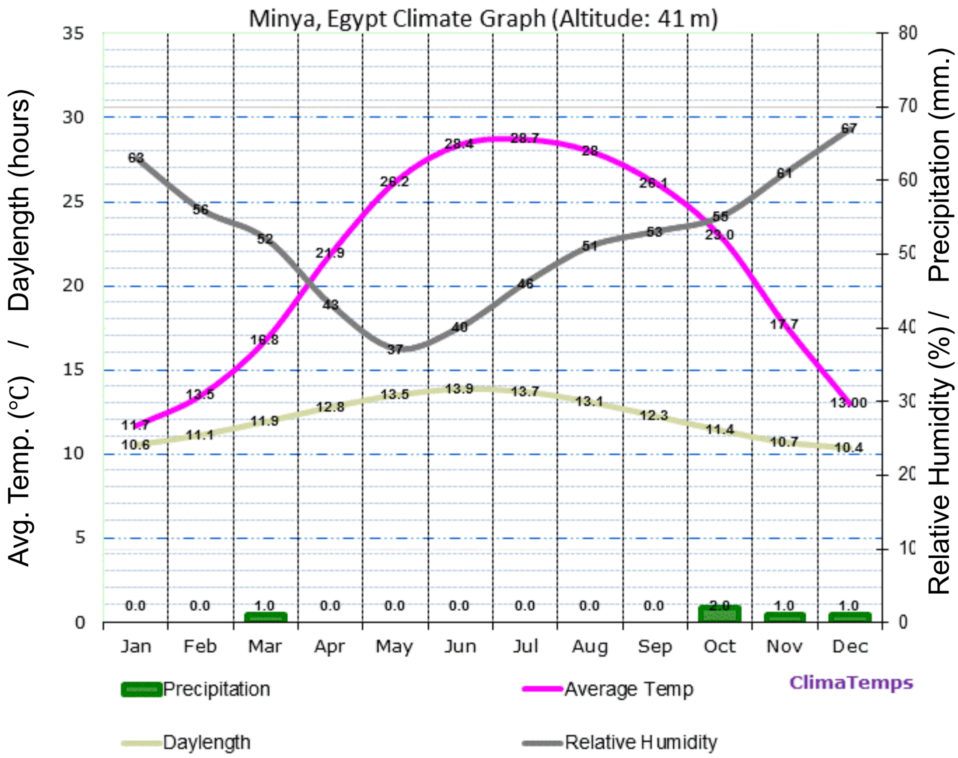


Fig. 4.1. Comparison between Minya and Cairo cities of the avg. monthly dry bulb temp.
Minya has the highest differences between Summer and Winter.
(Source: http://www.egypt.climatemps.com/)

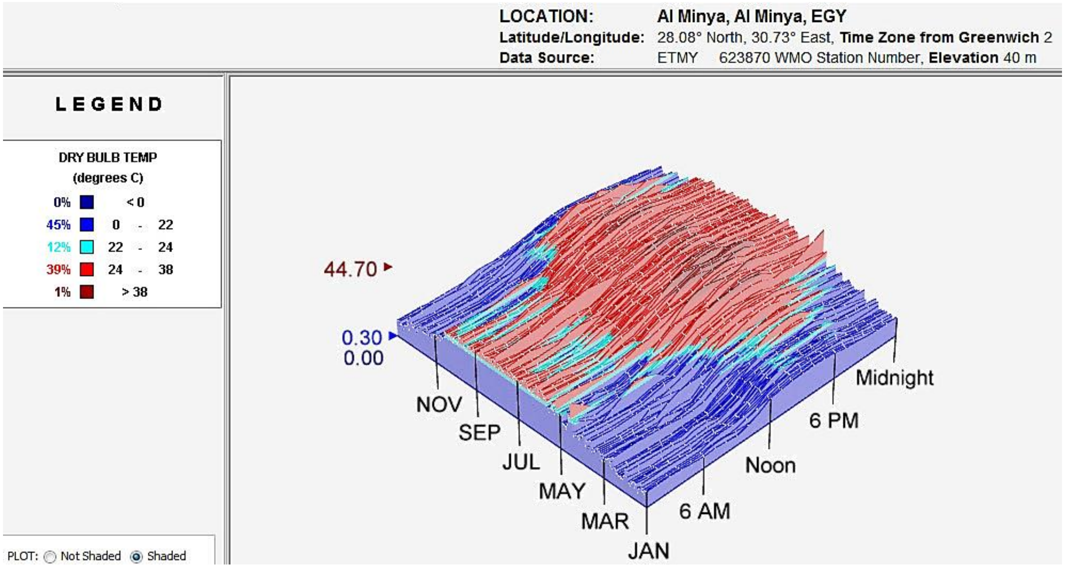


Fig. 4.2. Daily Dry Bulb Temp., showing the hottest and coldest day.
(Source: Climate Consultant 5.4)

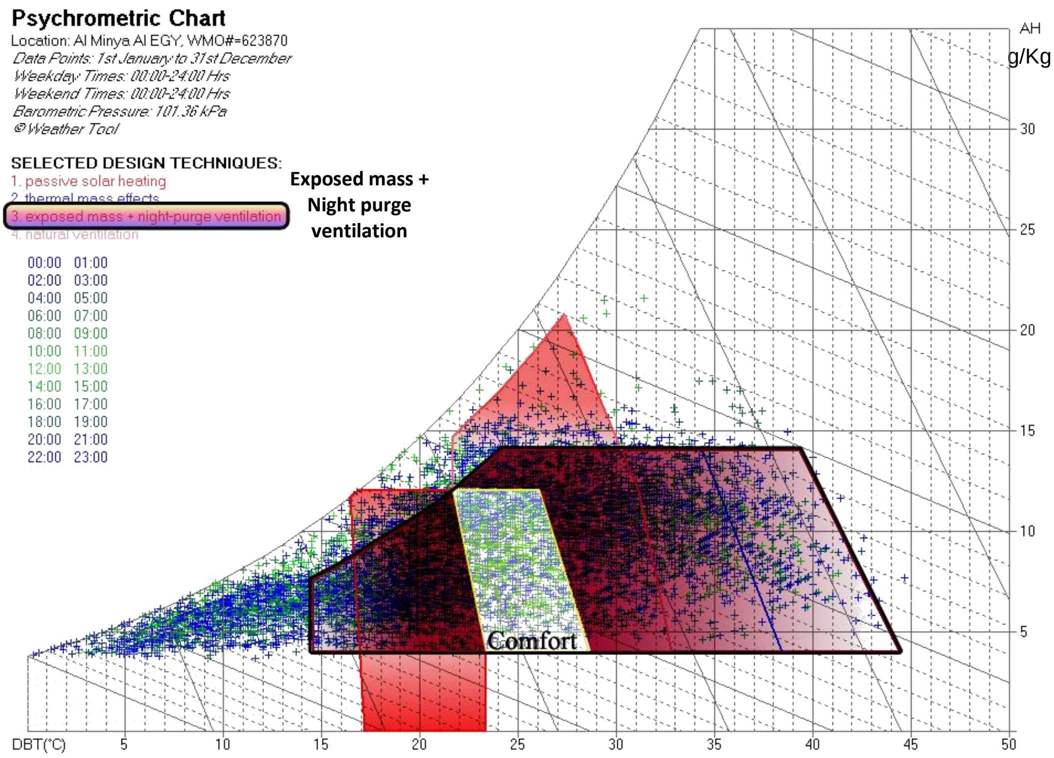


Fig. 4.3. Psychrometric Analysis for Minya City.
Showing hourly weather data and the small comfort area, and extreme high and low temperatures.
The exposed mass + night purge ventilation will expand the comfort area to a wider range.
Other strategies have lower effects on covering the discomfort range.
(Source: Ecotect Weather Tool 2011)

Going a step further after testing the ground temperatures at different depths (0.5, 2.0, 4.0 m.) using the Minya city weather file, if earth-sheltered concept is used, we may gain much higher thermal comfort and stable conditions, as shown in (Fig. 4.4). Especially, if the surface ground is covered with freshly mown grass, making use of the evaporative cooling, due to greening the roof.

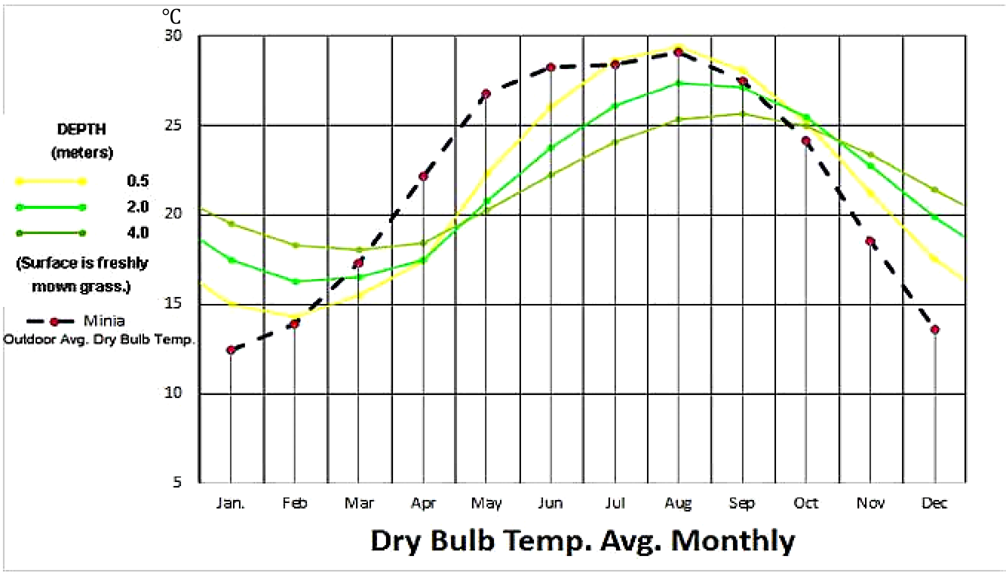


Fig. 4.4. Predicting Temperatures under the ground surface.
At depths of 0.5, 2.0, 4.0 m. The bigger the depth, the more stable thermal comfort conditions underground.
(Source: Climate Consultant 5.4)

4.2. Methodology

In this section we described about the measurements' details with sensors, and the weather file compared with the outdoor measurements, then how we calculated the ground temperature and the basement's comparison process, followed by the inputs at both Basement preprocessor and the DesignBuilder/EnergyPlus.

4.2.1. Measurments

The research conducted measurements of temperatures and humidity outside and inside the building for three winters' and three summers' months from 1st. January to 27th. March, and from 1st. August to 25th. October, using (RH) sensors by the increment of (30 mins.) resolution (KN. Labs 2010), (Fig. 4. 5). Measurements were adapted to the resolution of (1 hr.) for the comparison purpose with the simulated models' zone temperatures outputs.

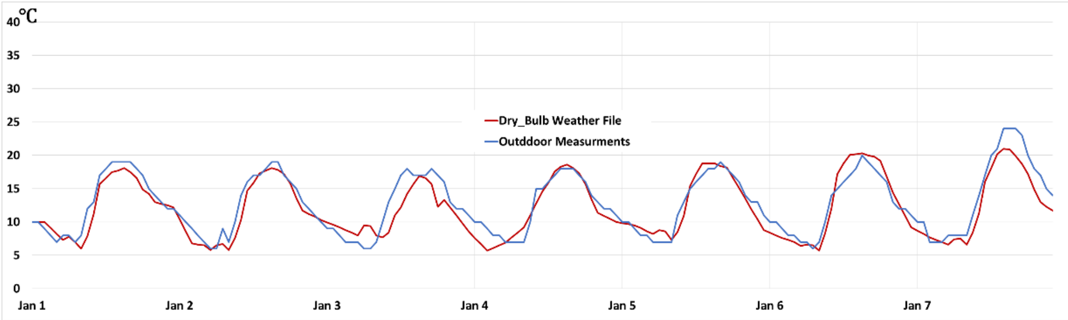
Fig. 4.5. The Hygrometer sensor for the measurement of dry bulb temp. and RH%.
Source: (KN. Labs 2010)

Measurements were taken at unconditioned basement gym, and at the last floor of the same building at a residential apartment, at an unconditioned living zone, and at a conditioned bedroom zone. Sensors were located at the height of (1.1 m.) from the slab level of both the basement and the last floor. The basement's slab was located at (-2.7 m.) under zero level of the street.

4.2.2. Weather file

In the simulation process we used the typical year weather file Egyptian Typical Meteorological Year (ETMY) which was developed for standards development and energy simulation by Joe Huang from data provided by U.S. National Climatic Data Center for periods of record from 12 to 21 years, all ending in 2003. Joe Huang and Associates, Moraga, California, USA. The location of the study is (Al Minya 623870).

However, we used the measured temperatures of the six winter and summer months at the year of 2014 for the comparison purpose only. (Fig. 4. 6) shows a comparison at the measured periods.



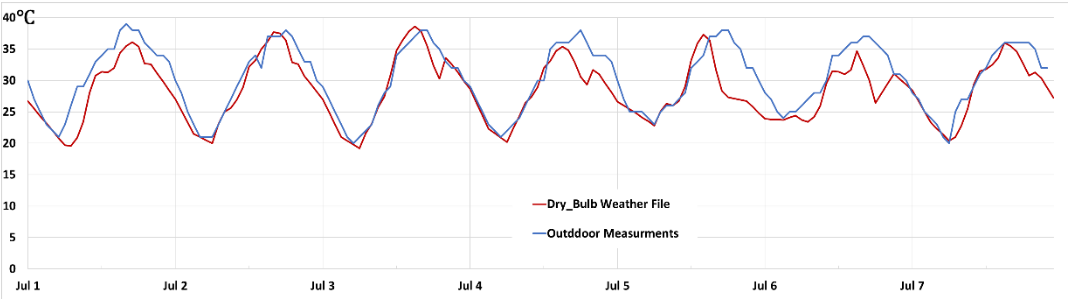


Fig. 4.6. A comparison between typical year weather file, and actual measurements' temperatures, for the year of 2014.

The previous approach supports what Wasilowski and Reinhart had concluded from their research as they discovered that differences were very slight between the typical weather file and the measured data, they proved that statistically. And it didn't worth the big effort that was conducted to create a custom year weather file (Wasilowski and Reinhart 2009).

4.2.3. Ground temperature calculation process

Starting to calibrate the basement, the most important problem was to find a "near-to-actual" ground temperature, which is located at the boundary between the building and the Soil. And it became more complicated because the basement was not a conditioned space. We could describe the main problem as follows:

The building affects the ground temperatures beneath it, and the ground temperatures affect the zone temperature inside the building. The less insulated the basement is, the greater reciprocal affectation we get.

In terms of simulations (if we are using DesignBuilder/EnergyPlus and Basement preprocessor), it means a paradox; in order to calculate ground temperatures using the (Basement preprocessor) we need to know building internal temperatures. On the other hand, in order to calculate building internal temperatures (DesignBuilder/EnergyPlus) we have to know the surrounding ground temperatures.

If we have a permanently conditioned building the problem is solved, as we already know reasonably building internal temperatures. However, the problem begins when we have a building that is conditioned just for a certain period, and become significant when the building is not conditioned.

We used an iterative approach that implies a series of iterations between packages: (Andolsun et al. 2011), (M. Staniec and Nowak 2011).

1. Run a first basement simulation using comfort conditioning temperatures as internal building temperatures.

We used theoretical comfort temperatures for each month calculated with the neutrality temperature Tn. (Eq. 1), which provides the center point for comfort zone. (Takkanon 2006).

$$T_{n.} = 17.6 + 0.31 * T_{av.} \quad (1)$$

Where ($T_{av.}$) is the mean outdoor temperature of the month.

2. Run a first DesignBuilder simulation using obtained ground temperatures.
3. Run a second Basement preprocessor simulation using monthly internal temperatures obtained within DesignBuilder.
4. Run a second DesignBuilder simulation using previously obtained ground temperatures.
5. Run a third Basement preprocessor simulation using previously internal temperatures obtained within DesignBuilder.

After point 5 differences were very slight, but we continued until 5 iterations for each of the DesignBuilder and the Basement preprocessor, as shown in the flow chart, (Fig. 4.7).

The most sensitive parameter for the basement's simulation was the ground temperature. After reaching a reliable ground temperature as an input, we continued to simulate the basement model changing some other uncertain different parameters until reaching the zone temperature.

Accordingly, we chose the best inputs after analyzing the Normalized Mean Bias Error (NMBE), and the correlation coefficient compared with the real actual measurements by the sensors.

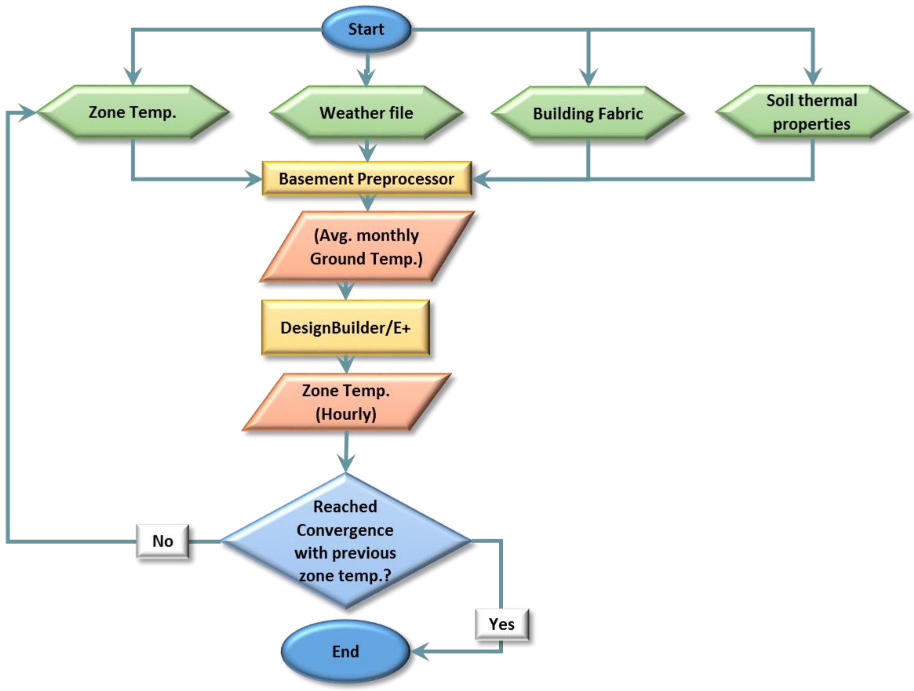


Fig. 4.7. A flow chart describing the ground temperature and basement's simulation process.

4.2.4. *Inputs for the Basement preprocessor*

Using ground temperatures with basements, the basement routine is used to calculate the face (surface) temperatures on the outside of the basement wall or the floor slab.

The output of Basement preprocessor was the ground temperature, which was applied to the outer surface of every surface has a ground adjacency. (Fig. 4.8) shows the zone of the basement and its adjacencies conditions.

The construction of the basement's wall: cement/plaster 3cm., limestone 20cm., moisture insulation (bitumen) 2cm., and the soil, from inside to outside respectively, with a total thickness of 25cm. The construction of the basement's slab: ceramic tiles 2cm., cement/mortar 2cm., sand 4 cm., moisture insulation (bitumen) 2cm., aerated concrete 15cm., and the soil, from inside to outside respectively, with a total thickness of 25cm. as shown in (Fig. 4.9).

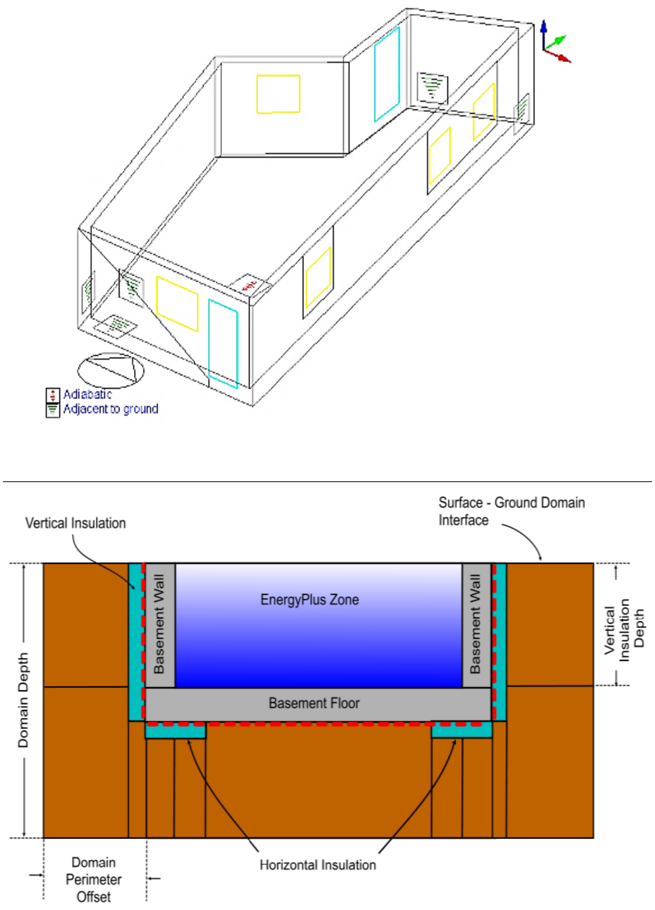


Fig. 4.8. The basement zone's adjacencies conditions.

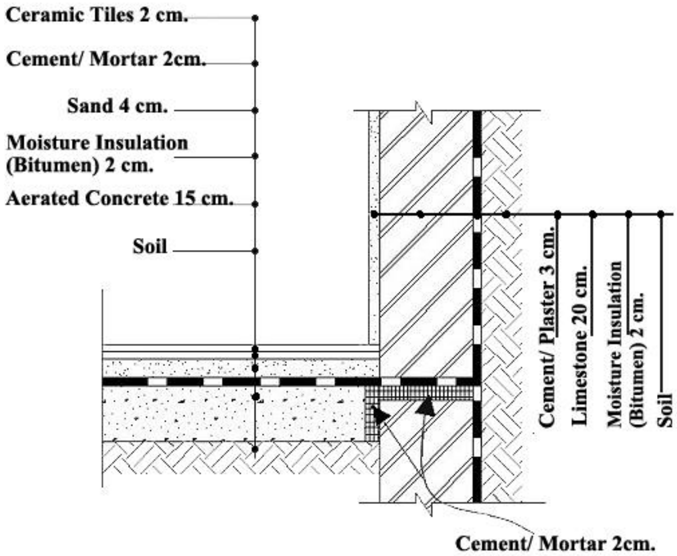


Fig. 4.9. Cross-section of the calibrated basement floor and slab layers

We customized the inputs of the Basement preprocessor as much local as possible in order to reach the ground temperature as an output, as shown in (table 4.1) (EnergyPlus 2015).

To calculate the wall's and slab's thermal properties, we used the cross-section at (Fig. 4.9) and equations (Eq. 2 - 4).

$$\rho_{Total} = \frac{\sum(m)}{\sum(V)} \qquad (2)$$

$$\sum C_p = \frac{m_1}{\sum m} \times c_{p1} + \frac{m_2}{\sum m} \times c_{p2} + \frac{m_3}{\sum m} \times c_{p3} + \cdots \ldots \ldots \ldots \ldots etc \qquad (3)$$

Table 4.1. Inputs for the Basement preprocessor, the Egyptian local building material properties.

Basement GHT.idd				
Object	Category		Input	Source
MatlProps	Density (kg/m3)	Density for Foundation Wall	1575	Calculated*
		Density for Floor Slab	2108	Calculated*
		Density for Soil	1960	Designbuilder, Alluvial clay 40% sand
		Density for Gravel	1840	Designbuilder, Gravel
	Specific Heat Capacity (J/Kg-K)	Specific Heat for Foundation Wall	979	Calculated**
		Specific Heat for Floor Slab	951	Calculated**
		Specific Heat for Soil	840	Designbuilder, Alluvial clay 40% sand
		Specific Heat for Gravel	840	Designbuilder, Gravel
	Thermal Conductivity (W/m-K)	Thermal Conductivity for Foundation Wall	0.63	Calculated***
		Thermal Conductivity for Floor Slab	0.7	Calculated***
		Thermal Conductivity for Soil	1.21	Designbuilder, Alluvial clay 40% sand
		Thermal Conductivity for Gravel	0.36	Designbuilder, Gravel
Insulation	R-Value (m2-K/W)	R value of any exterior insulation	0.01	
		Flag: Is the wall fully insulated?	(FALSE)	
SurfaceProps	ALBEDO	Surface albedo for No snow conditions	0.3	For “Asphalt” (T.R. 2015)
	EPSLN	Surface emissivity No Snow	0.95	For “Asphalt” (T.R. 2015)
	VEGHT (cm.)	Surface roughness No snow conditions	0.032	For “Asphalt”
BldgData	DWALL (m.)	basement wall thickness	0.25	The model
	DSLAB (m.)	the thickness of the floor slab	0.25	The model
ComBldg	Every month’s average air temperature	specifies the 12 monthly average basement temperatures (air temperature) (°C)	- First, calculated by the formula (Eq.1) using Tav. For each month. - Then, the zone temp. output from EnergyPlus.	
EquivSlab	APRatio (m.)	the Area to Perimeter (A/P) ratio for the slab	(63.9533/36.1396) =1.023 m. The model.	
	EquivSizing	Flag	(FALSE) the dimensions will be input directly	
AutoGrid	SLABX (m.)	X dimension of the building slab	7	The model
	SLABY (m.)	Y dimension of the building slab	13.5	The model
	ConcAGHeight	Height of the fndn wall above grade	0.0	The model
	SlabDepth (m)	Thickness of the floor slab	0.25	The model
	BaseDepth (m)	Depth of the basement wall below grade	2.4	The model

* Density: Calculate the Mass of each layer. Then, Sum. of Masses and Sum. of Volumes, to calculate the Density of the assembly (Eq. 2).

** Specific Heat capacity: A mass-weighted addition of the parts (Eq. 3).

*** Thermal Conductivity: To obtain the R-value of each layer, according to its thickness, per unit area. Then, Sum. of R. Finally, calculate the total Thermal conductivity according to the total Thickness and Sum. of R-values, (Eq. 4).

4.2.5. Inputs of the simulated model

The selected model is a basement in which was used as a gymnasium, located under an unoccupied warehouse in a five-story residential building, (Fig. 4.10).

Moreover, we simulated a residential unit’s two zones conditioned bedroom, and non-conditioned living room, in the same building at the top floor, and compared its output with the actual measurements, (Fig. 4.11).

Afterwards, we located the same simulated residential unit with same schedule and same zones in the basement level, (Fig. 4.12), and compared between both levels to measure the earth-contact effect on the thermal comfort and the energy consumption.

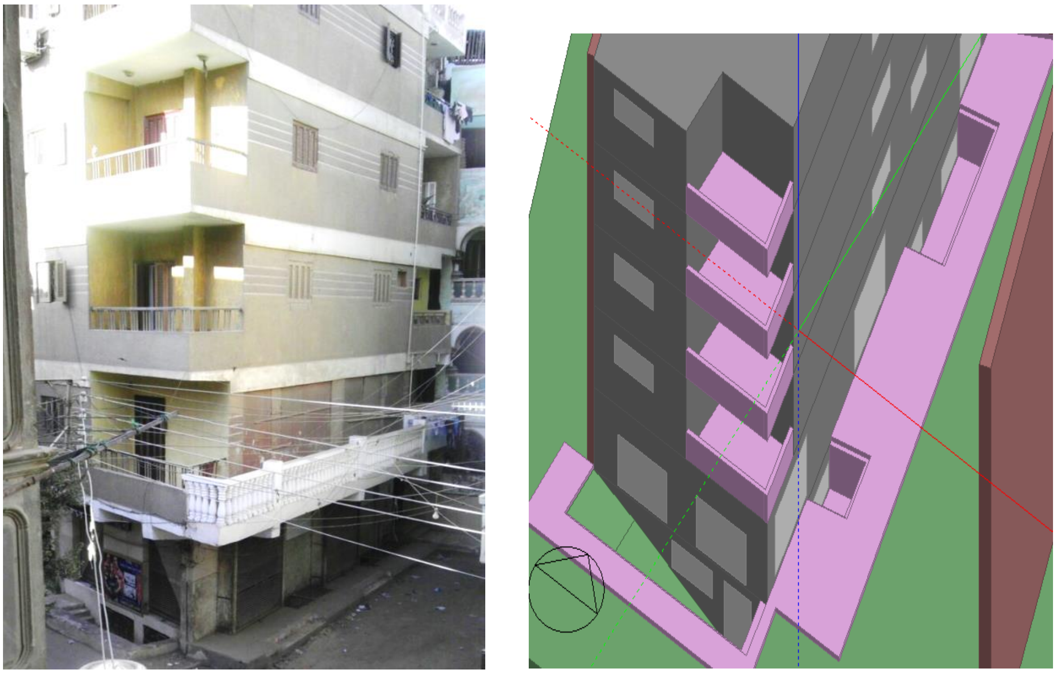


Fig. 4.10. The actual selected building Vs. the simulated model.

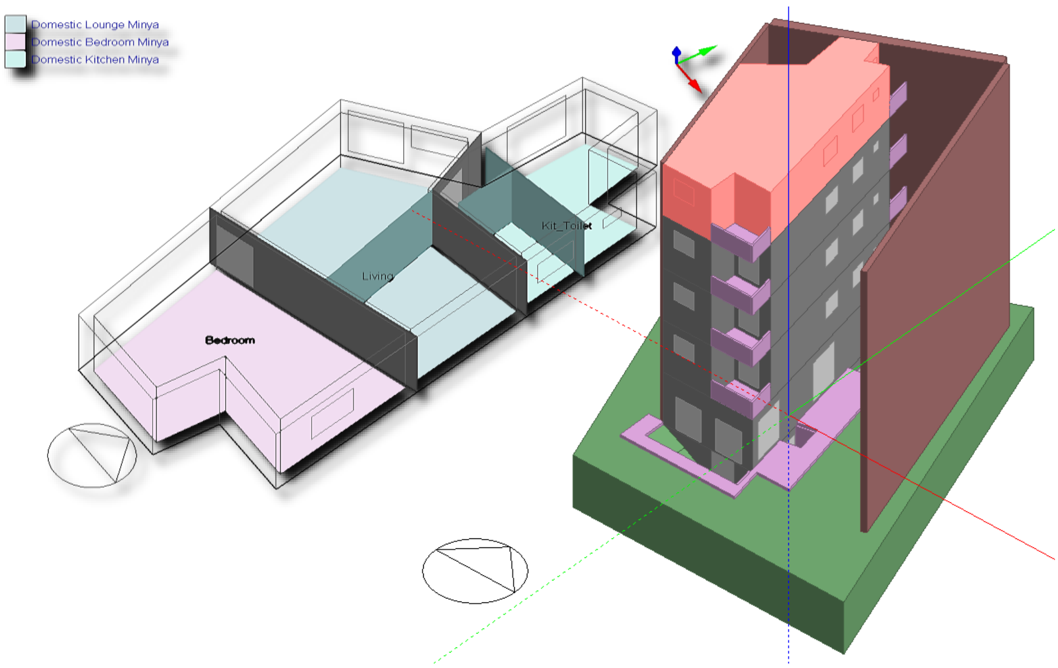


Fig. 4.11. The top floor residential simulated model.

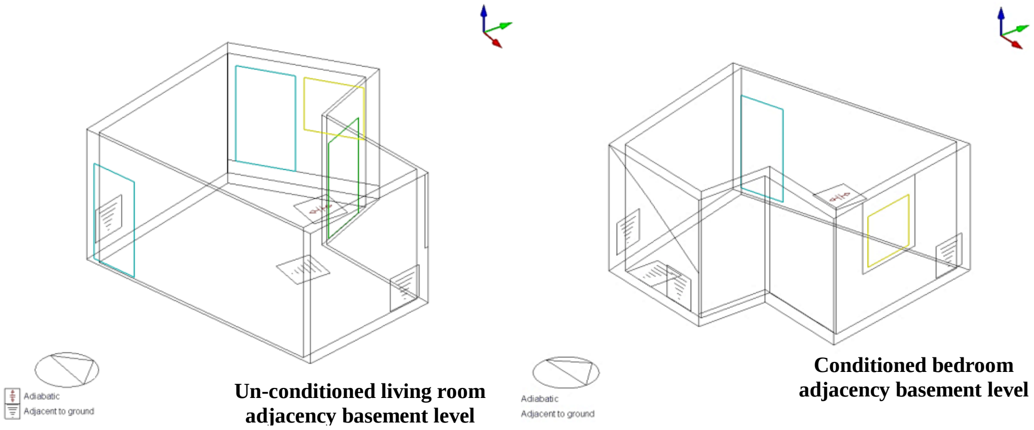


Fig. 4.12.The residential unit placement in the basement level's adjacencies.

According to the actual measurements, the site survey, and the ground temperature calculations, we created our customized inputs for the DesignBuilder model.

In (table 4.2) we demonstrate the customized inputs for the local buildings' construction details of the calibrated model in Egypt. The conditioned bedroom usage schedule is demonstrated in (Fig. 4.13). It is designed according to the start and end time of the period and the fraction of the usage percentage of the space.

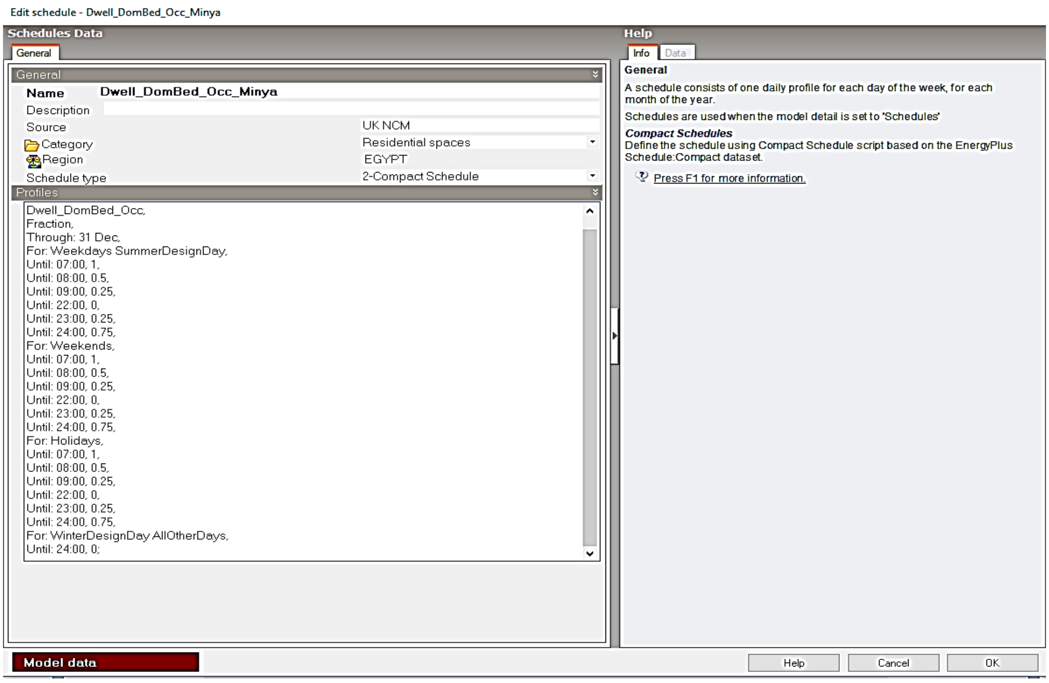


Fig. 4.13. The conditioned bedroom usage schedule.

Table 4.2. Customized inputs for the building model simulation in DesignBuilder.

Category	Sub-category	Item			Input
Activity	**Occupancy**	Density (People/m^2)			0.15
		Latent Fraction			0.5
		Metabolic rate			Exercise
		Metabolic Factor			1.0
		Occupancy Schedule			From 15:00 to 22:00
	Other gains	Computers, Load (w/m^2)			300
		Workday profile			From 15:00 to 22:00
		Miscellaneous (two Ceiling fans), load (w/m^2)			2*88= 176
		General lighting, workday profile			From 15:00 to 22:00
	Environmental control	Natural ventilation			
		Natural ventilation set point (°C)			24º
		Lighting, Target Illuminance (Lux)			300
		Default display lighting density (w/m^2)			20
Construction	**Walls**	Name	Thickness (m.)	No. of layers	U-value
		External/Air.	0.25	4	2.08
		External/ground.	0.25	3, Fig. 3.8	1.771
		Internal/Partitions.	0.15	3	3.369
	Roof/Floor/Slab/Ceiling	Flat roof.	0.2	5	2.695
		Floor slab (Basement).	0.25	5, Fig. 3.8	1.767
	Thermal mass	Same as (Internal part.).	0.15	3	3.369
	Doors	External door.			Metal door
	Airtightness	Infiltration rate (ac/h).			0.01
Openings	**Glazing**	Single clear (6 mm.), 1 layer, painted wooden window frame, U-value (w/m^2k)			5.778
		Total Solar Transmission (SHGC).			0.819
	Shading	Window blinds type: Blind with medium reflectivity slats. Position: Inside. Control type: Night outside low air temp. + day cooling.			
Lighting		Fluorescent, compact (CFL), Normalized power density (w/m^2-100Lux).			5.00
		Luminaire type.			Suspended
HVAC		(Living room) zone: Natural ventilation – No Heating/Cooling. (Bedroom) zone: - Mechanical Ventilation-Fresh-air rate 10 ac/h. - Infiltration rate 0.01 ac/h. - Heating set-point: 15°C/ Cooling set-point: 30°C. - Relative Humidity Dehumidification set point 73.0%. - Cooling system seasonal (COP) 1.8.			

4.3. Results

4.3.1. Measurements' comparisons above and underground

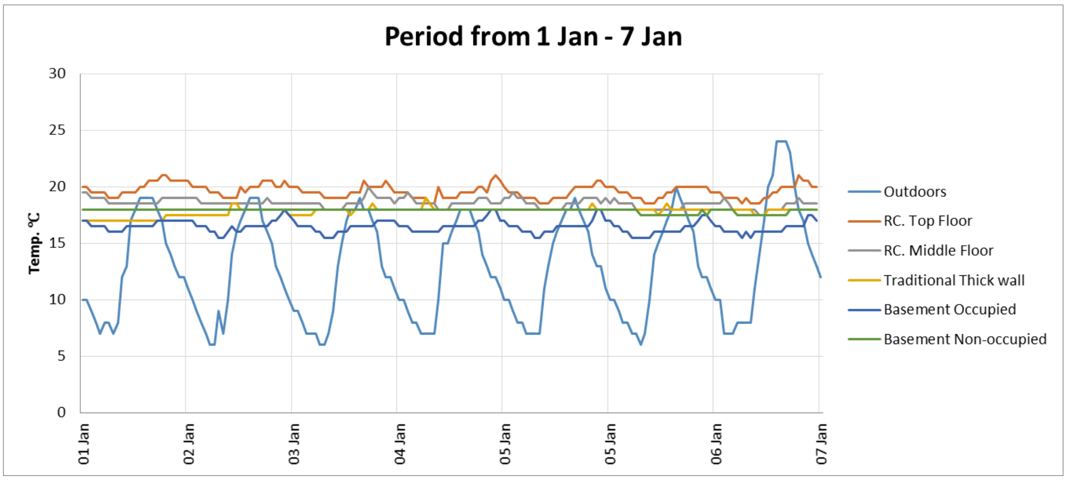
The research conducted measurements processes during winter days with three different building structures:

1- Reinforced Concrete (Top floor and middle floor).

2- Traditional bearing walls 50cm. thick (intermediate floor).

3- Basements (occupied; gymnasium and non-occupied; warehouse).

As shown in (Fig. 4.14), it is clear that highest stable thermal conditions gained with basements, and the lowest was with the conventional buildings, especially the top floor due to high solar radiation absorption.



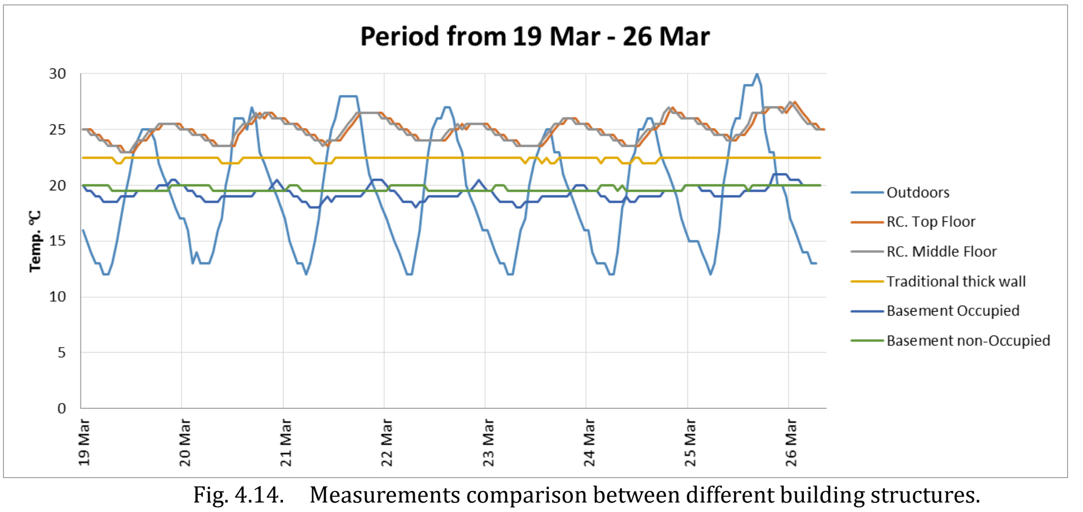


Fig. 4.14. Measurements comparison between different building structures.
Showing the stable thermal conditions with basements, compared with the conventional buildings.

4.3.2. Ground temperature and basement comparisons

The Iteration results between the (Basement preprocessor) and the (DesignBuilder/EnergyPlus) software, shown in (figs. 4.15, 4.16), are the output of the process described in the flow chart (Fig. 4.7).

We changed some of the uncertainty inputs to obtain the best-fit curve compared with the measured period.

The most sensitive input was the ground temperature, the natural ventilation, and the air-tightness infiltration rate. The comparison results are shown on chart (Fig. 4.17). Putting into consideration the uncertainty parameters of the actual building ex., (infiltration rate, activity level, no. of users, openings schedule, zone usage schedule) + the sensor measurement sensitivity.

The customized inputs were the best to give precise outputs as it showed agreement between the measured and the modeled data, with correlation of 99%, and errors with Mean Bias Error (MBE), Root Mean Square Error (RMSE) and Normalized Root Mean Square Error (NRMSE) of -0.78, 1.30 and 7.0%, respectively.

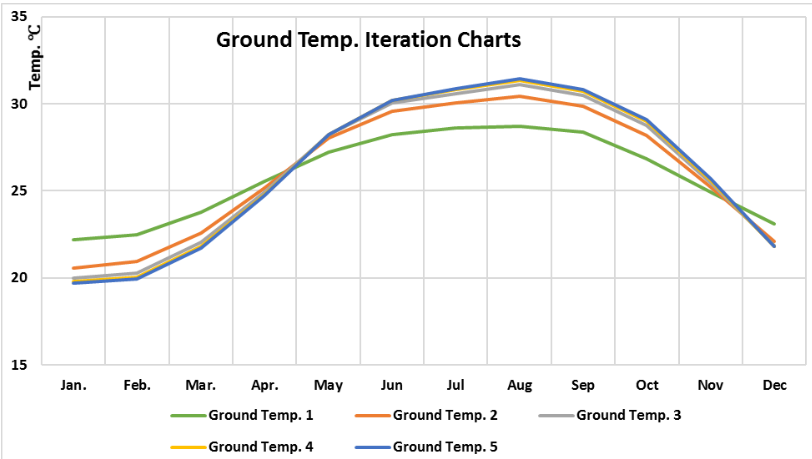


Fig. 4.15. Ground temperature iteration chart, (output of Basement preprocessor) simulation.

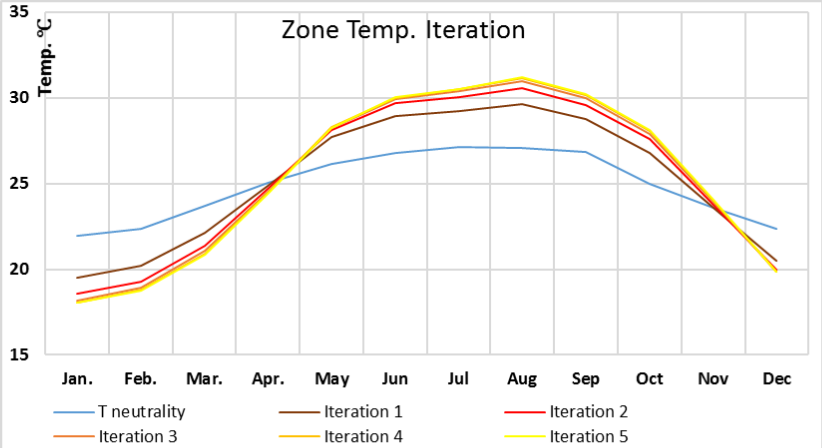


Fig. 4.16. Zone temperature iteration chart (output of DesignBuilder/ EnergyPlus) simulation.

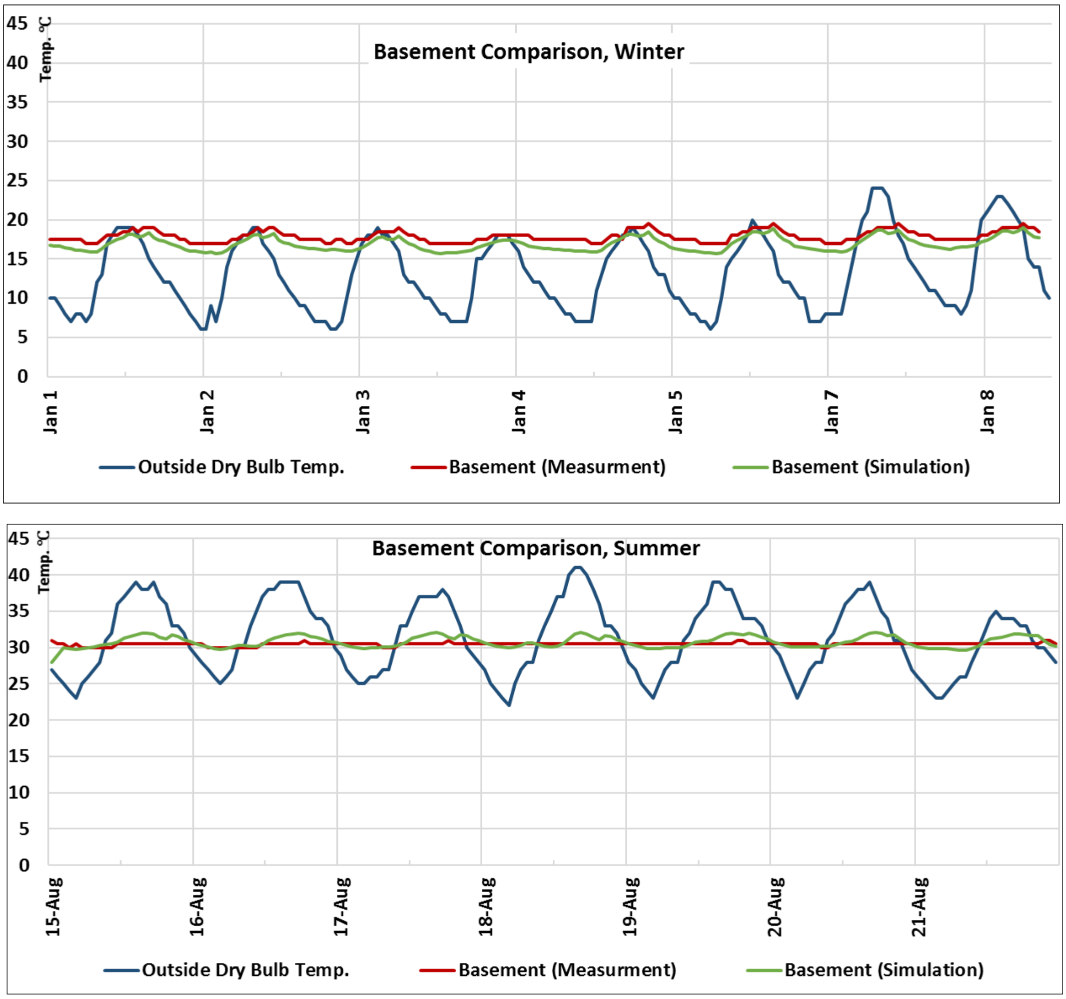
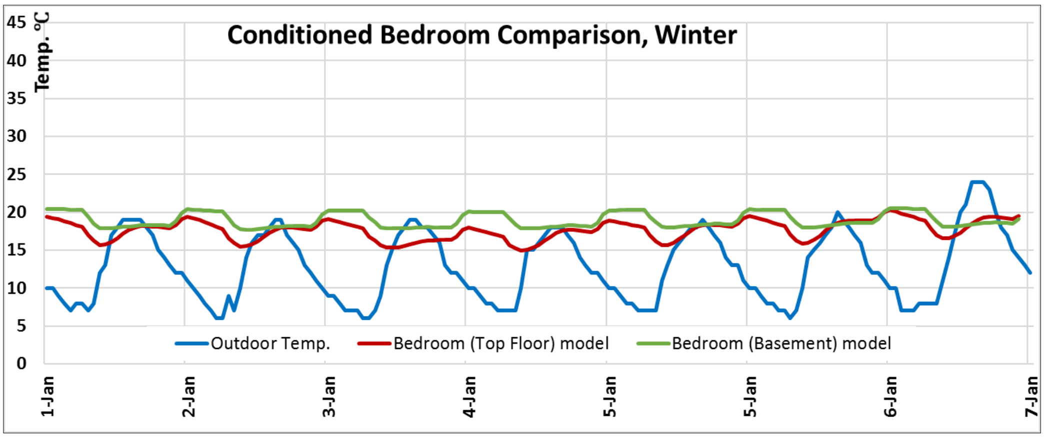


Fig. 4.17. The basement comparison process,
using the ground temperature from the iterative approach.

4.3.3. Thermal comfort analysis and comparisons

After the basement and the top floor comparison, we conducted comparisons between the two hypothetical units; the model (two zones, conditioned and non-conditioned), and a hypothetical (same two zones, conditioned and non-conditioned) if located underground, using the same simulated inputs and usage schedules; one on the top floor level and the other one on the basement level, (Figs. 4.18 ,4.19).

The measured conditioned bedroom zone was set to cooling only.



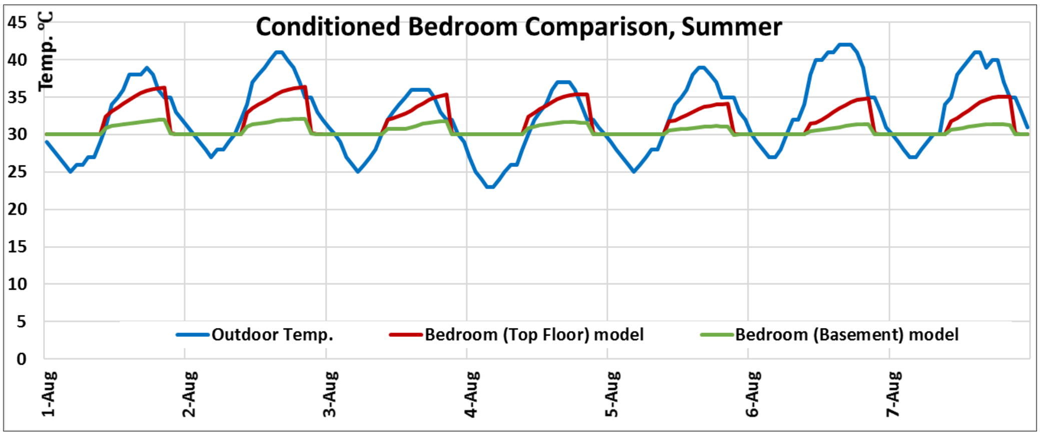
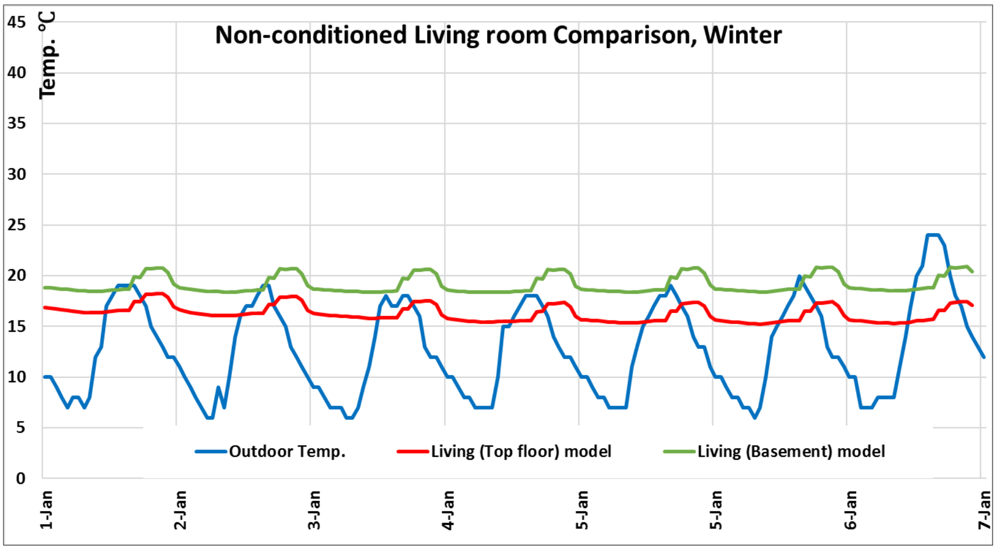


Fig. 4.18. A comparison between the conditioned bedroom zone at roof and underground levels.



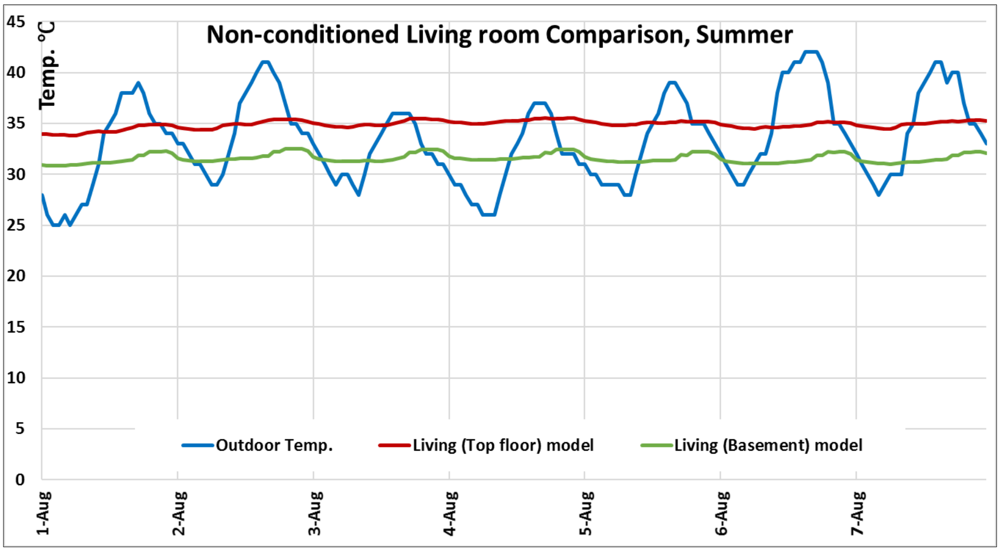


Fig. 4.19. A comparison between the unconditioned living zone, at roof and underground levels.

After the comparison, we changed the HVAC system to a proposed hypothetical (heating and cooling) to compare the heating and cooling loads at the top floor level compared with the proposed basement level, as shown in (Fig. 4.20).

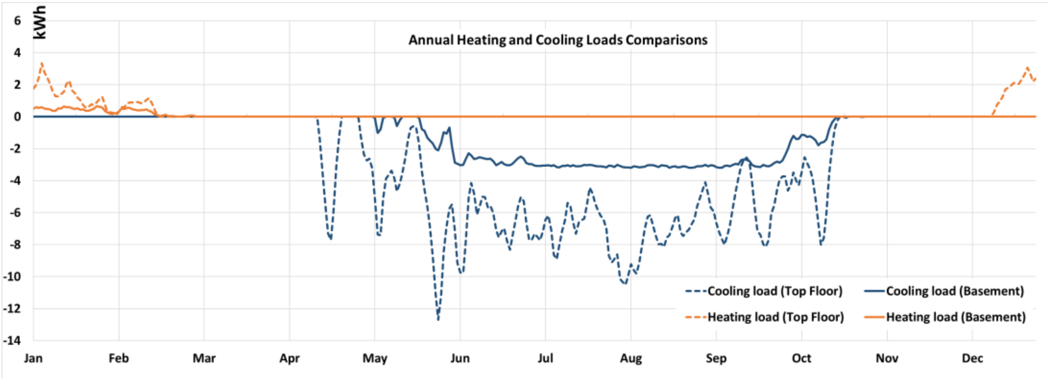


Fig. 4.20. Heating and cooling loads for top floor vs. basement level of the conditioned bedroom zone.

We analyzed the thermal comfort by Fanger model which is divided into the range of (+3: -3) of the Predicted Mean Vote (PMV). The ideal comfort sensation according to Fanger is (zero). We chose the Fanger analysis, because this building was highly sealed, and the infiltration rate was very low, and the building was at the steady state condition. The thermal comfort sensation at Egypt has wider range, and could be reached with a simple ceiling fan (Attia and Carlucci 2015). Therefore, it might be in the comfort range as acceptable until the range of (+2: -2). According to this approach we calculated the thermal comfort hours within this range, (Fig. 4.21).

The top floor unconditioned living zone thermal comfort within this range was (5035 hrs., 57%) of the year. However, the proposed perspective underground zone was (8655 hrs., 99%) of the year, which means an increase by 58% of comfort hours.

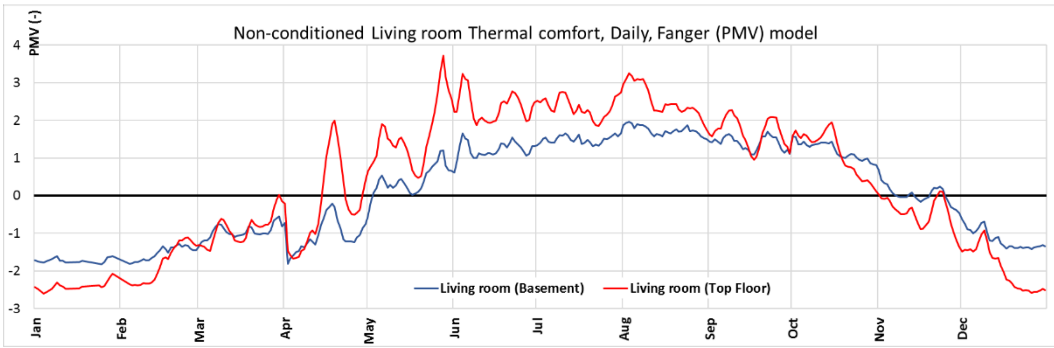


Fig. 4.21. Thermal comfort comparison between top floor and underground floor of the same living zone, showing the stable thermal conditions with basements, compared with the conventional ones.

4.4. Discussion.

The Earth-sheltered buildings are considered to be very good passive solution for saving energy. The big dilemma related with it, is usually how to simulate it precisely. Whereas, the most sensitive input is the ground boundary temperature, and the 3-D thermal bridging effect.

There are two methods for simulating the 3-D thermal bridging effect and ground coupling in EnergyPlus; the first method is the "Basement preprocessor" through the (GroundHeatTransfer:Basement) object related with the iterative approach which we introduced it in this chapter in details, and the other method is by integrating the (Site:GroundDomain:Basement) object inside the EnergyPlus. However, the second integrated approach has predefined inputs to calculate the soil surface temperatures. Therefore, we considered the first iterative approach in our research to calculate the local customized inputs to gain accurate soil boundary surface temperatures around the year.

After the comparison process, we compared the thermal comfort of the top floor and an underground floor living zones. It is known that the thermal comfort sensation depends on the nature of each country and on the people's acceptance of different extreme climate change. In Egypt, people tend to use a ceiling fan or stand-type fan as a first choice to enlarge the thermal comfort zone. Afterwards, they use the AC. units as a second choice, and only during narrow range of the extreme hot weather months, in order to save energy. Consequently, we enlarged the (PMV) sensation range from zero to $\pm$ 2 level. That range could be easily reached by a ceiling fan rather than the AC. units.

This research is not introducing the basements for the living purpose, rather than trying to simulate it as an approach for an early design stage of the earth-sheltered buildings at hot-arid climates, as a passive way for thermal comfort. We discussed in chapter 3 a parallel research to measure people's acceptance to live in earth-sheltered buildings (Heba Hassan et al. 2016; Ismail et al. 2013).

4.5. Conclusion.

In this chapter, we compared between three construction types' thermal performance (Reinforced concrete; Traditional 50 cm. thick wall; Basements) in comparison with the outdoor measurements. Moreover, we provided a detailed simplified way to localize the inputs of the building materials' thermal properties. The research introduced the iterative approach between EnergyPlus and the Basement preprocessor "GroundHeatTransfer:Basement" to gain the precious ground boundary temperature.

The iterative approach and the precise local customized inputs, contributed in high agreement curve with the actual measurements, with correlation of 99%, and errors with Mean Bias Error (MBE), Root Mean Square Error (RMSE) and Normalized Root Mean Square Error (NRMSE) of -0.78, 1.3 and 7.0%, respectively.

The Fanger model is adopted in this research using the (PMV) to evaluate the basement versus the top floor levels' thermal comfort of the same living unconditioned zone. The earth-contact effect in the underground level increased the thermal comfort by 58% of comfort hours, compared with the top floor of the perspective zone.

Finally, this chapter is not a call to live underground, rather than introducing the innovation of the Earth-contact effect on the buildings, as an approach for the modern type of the earth-sheltered buildings' implementation.

Chapter 5

5. PARAMETRIC OPTIMIZATION STUDY FOR EARTH-SHELTERED BUILDINGS

In parametric optimization, Genetic Algorithms (GA) are used to search for optimal design solutions, much more efficiently than is possible with parametric analysis when more variables are involved.

This chapter focuses on the parametric optimization analysis of the previously calibrated residential unit. In order to measure the extent of the Earth-contact on the building, and the best climate conditions to gain the best Earth-sheltering performance for implementation. That two hypotheses were measured for two objectives; the least net site energy consumption and the least discomfort hours per year.

Variables to be measured to reach the parametric optimization's two objectives were, the window wall ratio (WWR%), orientation, location template, soil thickness, and heating and cooling set points.

For deeper analysis, we compared between the optimized solutions at the top level and the optimized solutions of the underground level, to measure the Earth-contact effect and covering the roof with soil extent, on the energy consumption and the thermal comfort.

We found that, the effect of Earth-sheltering was highly effective at hot and hot-arid climates, and less effective at the moderate or warm climates.

5.1. Genetic algorithm approach

The genetic algorithm is a mode of machine learning which derives its behavior from a metaphor of some mechanisms of evolution in nature. This is done by the creation within a machine of a population of individuals represented by chromosomes, a set of character strings that are analogous to the base-4 chromosomes that we see in our own DNA. The individuals in the population then go through a process of simulated "Evolution".

Genetic algorithms are used for several different application areas. As an example, is the multi-dimensional optimization problems in which the chromosome's character string could be used to encode the values for the different parameters being optimized.

Therefore, in practice we can implement this genetic model of computation by having arrays of bits or characters to represent the chromosomes.

Simple bit manipulation operations allow the implementation of crossover, mutation and other operations. Although a substantial amount of research has been performed on variable-length strings and other structures (Deb 2002; Luke 2013), the majority of work with genetic algorithms was focused on fixed-length character strings.

We should focus on both of these aspects of fixed-lengthiness and the need to encode the representation of the solution being sought as a character string, since these are crucial aspects that distinguish genetic programming, which does not have a fixed length representation and there is typically no encoding of the problem.

When the genetic algorithm is implemented it is usually done in a manner that involves the following cycle, (Fig. 5.1):

- Evaluate the fitness of all the individuals in the population.
- Create a new population by performing operations such as crossover, fitness-proportionate reproduction and mutation on the individuals whose fitness has just been measured.
- Discard the old population and iterate using the new population.
- One iteration of this loop is referred to as a generation.

There is no theoretical reason for this as an implementation model. Indeed, we do not see this punctuated behavior in populations in nature as a whole, but it is a convenient implementation model(Luke 2013).

The first generation (generation 0) of this process operates on a population of randomly generated individuals.

From there on, the genetic operations, in concert with the fitness measure, operate to improve the population.

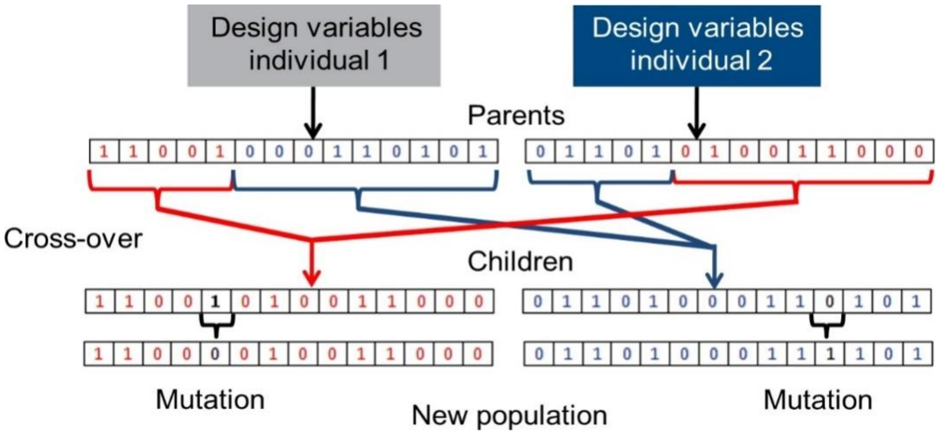


Fig. 5.1. A schematic diagram showing a generation's one cycle process. Source: (Design Methods 2010)

Figure (Fig. 5.2) is showing that the changing of the structure of a gene, resulting in a variant form that may be transmitted to subsequent generations, caused by the alteration of single base units in DNA, or the deletion, insertion, or rearrangement of larger sections of genes or chromosomes.

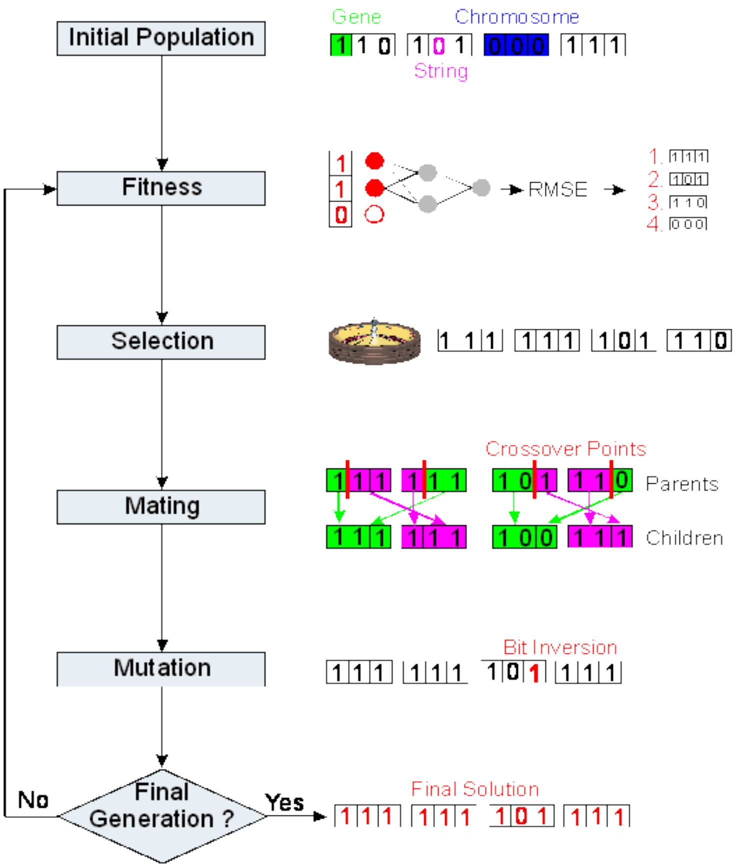


Fig. 5.2. A schematic diagram showing the mutation process through one generation cycle. Source: (ocatfroninod.ga 2017)

5.2. Optimization.

Optimization is a technique for efficient searching and identifying design options that best meet key design performance objectives. it is similar in many ways to parametric analysis, a more well-known technique for analyzing how design performance varies with changes in the building configuration using the design curves.

A parametric analysis would usually consist of one, two or three design variables being adjusted in a systematic way to illustrate trends and find designs with the most favorable characteristics (e.g. low energy consumption, best comfort etc.).

With parametric analysis, a maximum of three variables is normally used because of two main reasons:

a) the results of more than three dimensions to a design problem are difficult to visualize.
b) the large number of simulations required with four or more design variables would take too long to complete.

For example, a designer might want to investigate the impact on carbon emissions of variable levels and types of glazing. The results would be displayed as a series of parametric design curves.

This may be a very useful way to visualize simple comparisons over a limited range of design options, but is of less use for wider studies and for optimization as only a few variables and one key performance indicator can practically be included per analysis.

In DesignBuilder optimization, Genetic Algorithms (GA) (aka Evolutionary Algorithms or EA) (DesignBuilder 2016; Li et al. 2013) are used to search for optimal design solutions, more efficiently than with parametric analysis when more variables are required.

5.3. Methodology

In this chapter we used the parametric optimization tool provided by DesignBuilderV.4.7, based on the EnergyPlus software to reach the optimal performance of the building with the best combination of design variables.

DesignBuilder uses a Genetic Algorithm (GA) based on the NSGA-II method (Deb 2002), which is widely used as a "fast and elitist multi-objective" method providing a good trade-off between well converged and well distributed solution set. It works as follows, (Fig. 5.3):

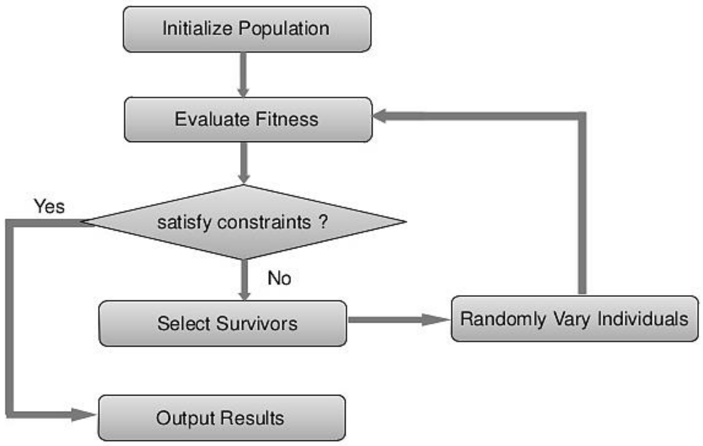


Fig. 5.3. The general scheme of an Evolutionary Algorithm (EA) as a flow-chart.
Source: (Othman 2010)

1. First, the population is randomly initialized.
2. Chromosomes (design variables) are sorted and put into fronts based on Pareto non-dominated sets. Within a Pareto front, the chromosomes are ranked based on Euclidean distances between solutions or I-dist. (term used in NSGA-II) (Deb 2002).

Generally, solutions which are far away (not crowded) from other solutions are given a higher preference in the selection process to help create a diverse solution set and avoid crowding. i.e. the formula for calculating the distance between each of the three individuals as shown in (Fig. 5.4) is Eq. 5.1 (Technical Whitepaper 2005): where the difference between two persons' scores is calculated, squared, and summed for (V) variables.

$$d = \sqrt{\sum_{i=1}^{v} (p_{1i} - p_{2i})^{2}} \quad \text{..................... Eq. 5.1}$$

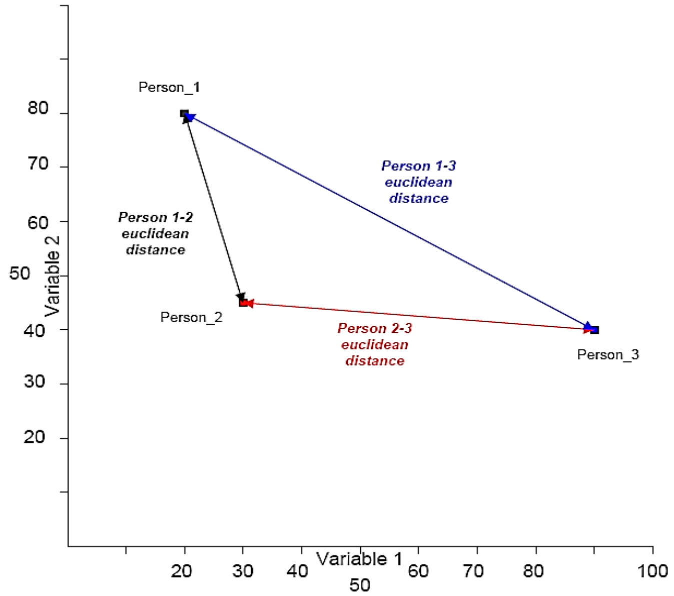


Fig. 5.4. the scores of three individuals on two variables.
Source: (Technical Whitepaper 2005)

3. The best designs are picked from the current population and put into a mating pool.
4. In the mating pool, tournament selection, crossover and mating are carried out.
5. The mating pool and current population is combined. The resulting set is sorted, and the best chromosomes are passed into the new population.
6. Go to step 2, unless maximum number of generations have been reached.
7. The solution set is the highest ranked Pareto non-dominated set from all populations.

Eiben and Smith described in detail regarding the evaluation function (fitness function), that it forms the basis for selection, and facilitates improvements. (Eiben and Smith 2015). In DesignBuilder, up to ten design variables could be included in the analysis in combination with up to two objectives, such as "Minimize net site energy consumption" and "Minimizing discomfort hours per year".

Comfort and energy consumption are a frequently used as pair of objectives in building design optimization analysis because they allow a study of the trade-off between comfort and energy consumption impacts for a large range of designs.

For example, an optimization study might involve a base design which is to be optimized for comfort and energy consumption with building orientation, wall and roof construction, glazing amount and type, degrees of shading, and HVAC system type can vary.

The results might be displayed graphically with discomfort hours per year on one axis and the energy consumption on the other. The performance of each design option that is tested as part of the procedure is plotted on the graph.

The designs with lowest combinations of comfort and energy consumption form a "Pareto front" of optimal designs along the bottom-left edge of the data point "Cloud".

In another example, "Minimize Carbon Emissions" and "Minimize Discomfort Hours" are often used to analyze the trade-off between carbon emissions and the degree of comfort provided by the design. In the example output shown in (Fig. 5.5) the control parameters of a changeover mixed mode natural ventilation model is being optimized based on carbon emissions and discomfort (DesignBuilder 2016).

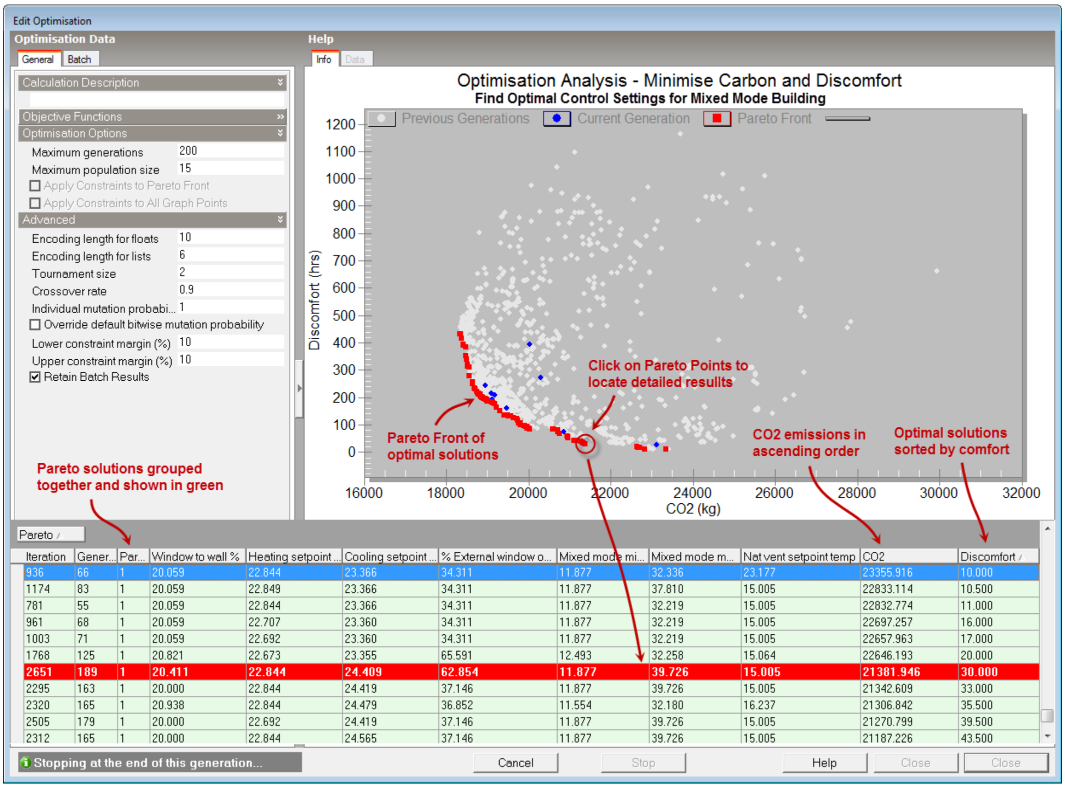


Fig. 5.5. The parametric optimization trade-off cloud style process at DesignBuilder.
Source: (DesignBuilder 2016)

5.3.1. Calculation model

We used the same (Top floor) level of the residential unit that we simulated in chapter 4. However, this time we not only placed the unit in the underground level, but also, we covered the roof with Earth, in order to gain the maximum protection with the earth-contact effect. Therefore, we got two zones; conditioned bedroom and unconditioned living room with the ground adjacency as shown in (Fig 5.6).

In our model we compared the top floor level and the basement level's optimized solutions' "Best-fit-so-far" cases. In (table 5.1), we demonstrated the inputs of the optimization settings for both levels; roof and underground. Afterwards, we described each category in detail in the following sections from 5.3.2 to 5.3.4.

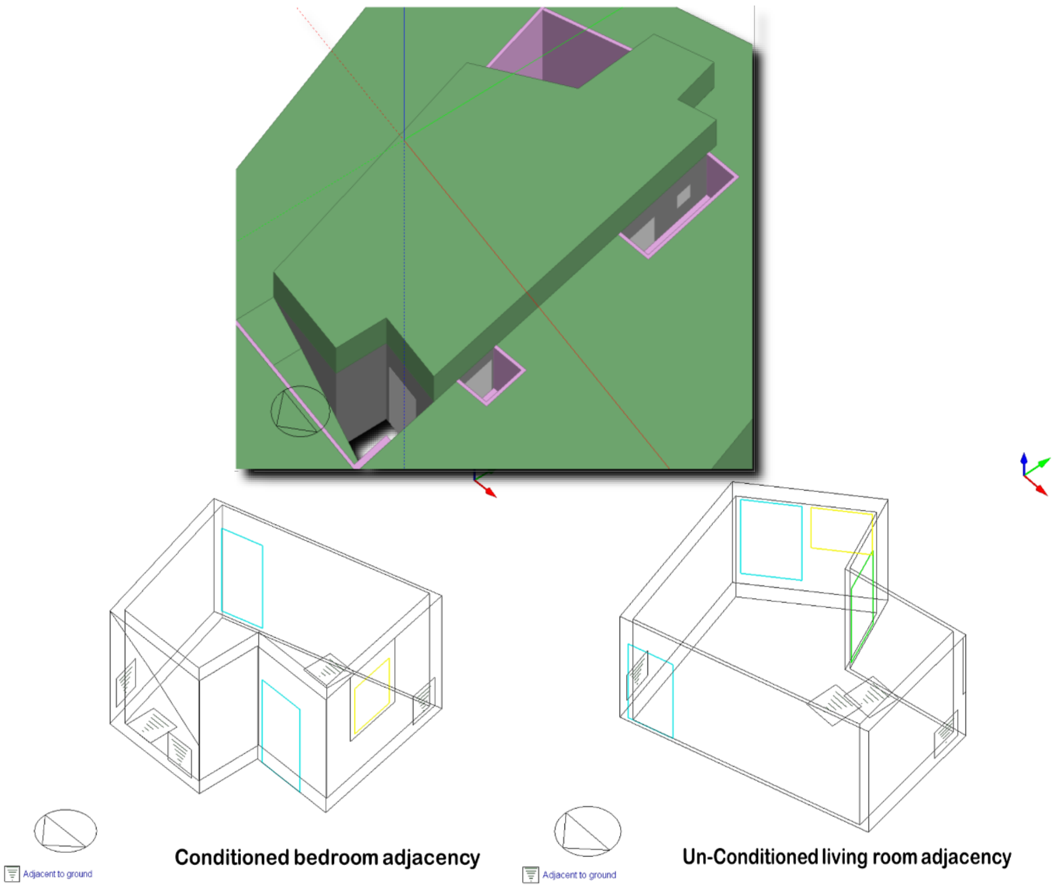


Fig. 5.6. The adjacencies of the two calculated zones of the model to be optimized.

Table 5.1. Optimization settings for both of the roof and underground level's cases.

Objectives	Minimize Net Site Energy Minimize Discomfort Hours, "Discomfort Summer ASHRAE 55 Adaptive 90% Acceptability"					
Constraints	"Discomfort Summer ASHRAE 55 adaptive 80% acceptability" must not exceed 1000 hrs./year					
Variables	**Variable**	**Original position**	**Allowable range**	**Step Optimization**	**No. of Cases**	**Target Objects**
	WWR %	30%	10-50%	5%	9	Building
	Cooling set-point	27°C	20°-28°C	1°C	9	Bedroom zone
	Heating set-point	24°C	18°-24°C	1°C	7	Bedroom zone
	Orientation	180°	0°-315°	45°	8	Building
	Location Template	Al Minya	Ismailia; Sharm El-Sheikh; Al Minya; Marsa Matrouh; Kharga		5	Building

The outputs indicate the control options which resulted in minimal discomfort hours while at the same time having the lowest energy consumption are discussed in section 5.4, 5.5, and 5.6.

5.3.2. Objectives

The most important point about objectives is how to define the best objectives of the analysis, what constitutes a "good design".

In the objectives section we can define how the "success" of a particular design could to be measured. This is done by defining either one or two objectives for the analysis. Typical settings here might include two objectives to investigate the trade-off between two conflicting objects, to reach the trade-off between them.

Our objectives, was to reach the trade-off between minimizing the "Discomfort Summer ASHRAE 55 Adaptive 90% Acceptability", and minimizing the "Net Site Energy Consumption", which typically conflicts, as shown in (Fig. 5.7).

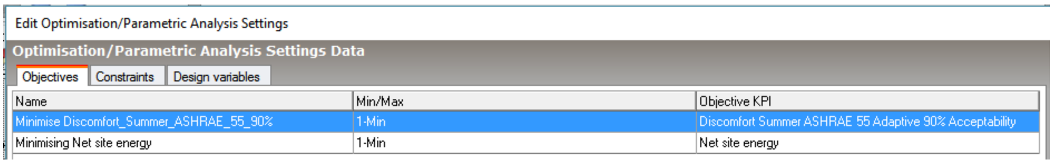


Fig. 5.7. The research objectives trade-off selection settings.

5.3.3. Constraints

Constraints are considered to be any limits to be imposed on the building performance. As an example of constraint that might be applied to an optimization analysis in our model, we excluded the high discomfort hours from the results, choosing only the cases with no more than (1000 hrs./year), “discomfort summer ASHRAE 55 adaptive 80% acceptability”.

More than this hour’s number, we considered them as failed constraint cases. "Discomfort hours must be less than 1000", either over-heating or over-cooling, as shown in (Fig 5.8). As mentioned in Chapter 4, that Egyptians tend to bear high rates of discomfort hours, and they can accommodate themselves with just a ceiling fan (Attia and Carlucci 2015).

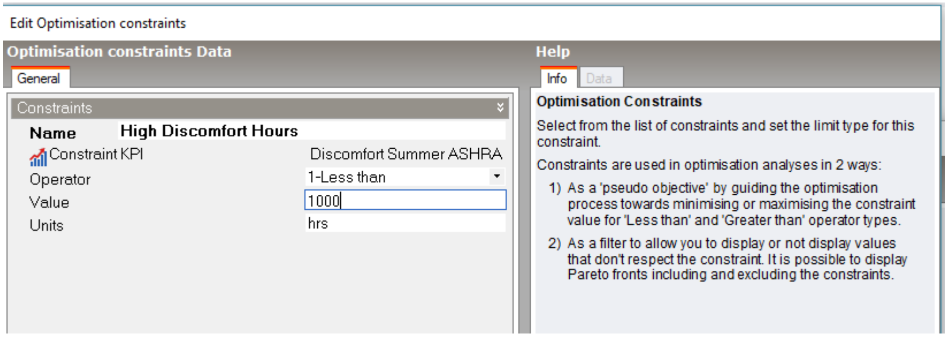
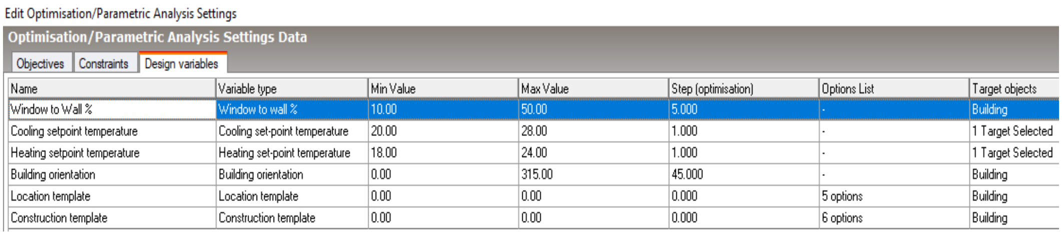


Fig. 5.8. Constraints are limits of the optimization process.

5.3.4. Variables.

The elements of the model that are to be allowed to vary during the optimization analysis and the new values that these elements might take. The variables tab allows us to define the elements of the building design; that could be allowed to vary between the maximum and minimum defined limits per each defined step; that the variable could take on account during the analysis.

Figure (Fig. 5.9) shows this research variable definitions, our design variables were the combination of six aspects:



Name	Variable type	Min Value	Max Value	Step (optimisation)	Options List	Target objects
Window to Wall %	Window to wall %	10.00	50.00	5.000	-	Building
Cooling setpoint temperature	Cooling set-point temperature	20.00	28.00	1.000	-	1 Target Selected
Heating setpoint temperature	Heating set-point temperature	18.00	24.00	1.000	-	1 Target Selected
Building orientation	Building orientation	0.00	315.00	45.000	-	Building
Location template	Location template	0.00	0.00	0.000	5 options	Building
Construction template	Construction template	0.00	0.00	0.000	6 options	Building

Fig. 5.9. Variables are the options for the optimizer to consider performing crossover processes.

- <u>Window/Wall ratio</u> percentage, ranging from 10-50% with 5 steps increment, for the building as a target object.

- **Cooling set-point temperature,** ranging from 20-28°C with 1°C step increment, for the conditioned bedroom zone as a target object.
- **Heating set-point temperature,** ranging from 18-24°C with 1°C step increment, for the conditioned bedroom zone as a target object.
- **Orientation,** ranging from 0°-315° with 45° steps increment, for the building as a target object.
- **Location template,** with 5 options of the cities' weather files inputs (Ismailia, Sharm-El-Sheikh, Al Minya, Marsa-Matrouh, Al Kharga), for the building as a target object, (Fig. 5.10).

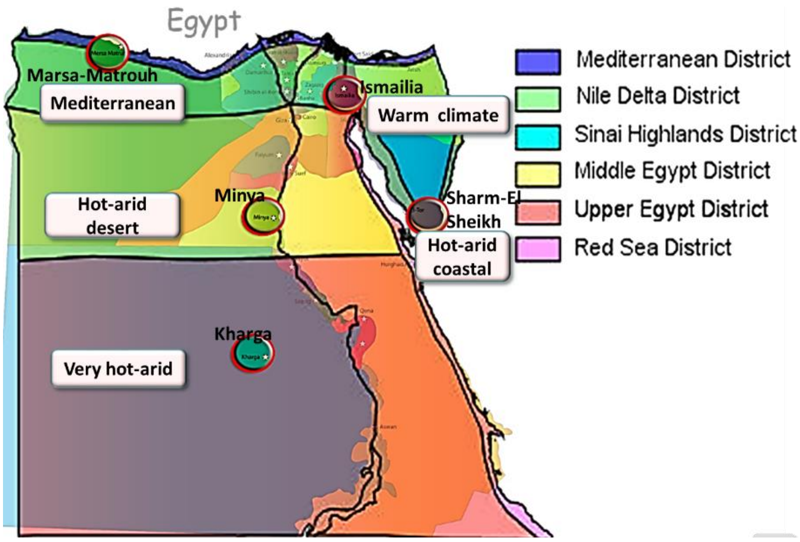


Fig. 5.10. Egyptians governorates' borders map, and the location of the five selected cities.

5.4. Earth-sheltered Optimization Results

We performed the parametric optimization analysis on the underground level at the beginning, as it is the target of our research. The results of the tested cases are plotted in a scatter plot to obtain the "best-fit-so-far" for the underground level, in order to make weighing between the two objectives. The trade-off is weigh between the "Net site energy consumption" and the "Discomfort hours", as shown in (Fig 5.11).

After the parametric optimization process, we chose the optimal design variables' combination, as a guide for the design guidelines recommendations, in chapter 6.

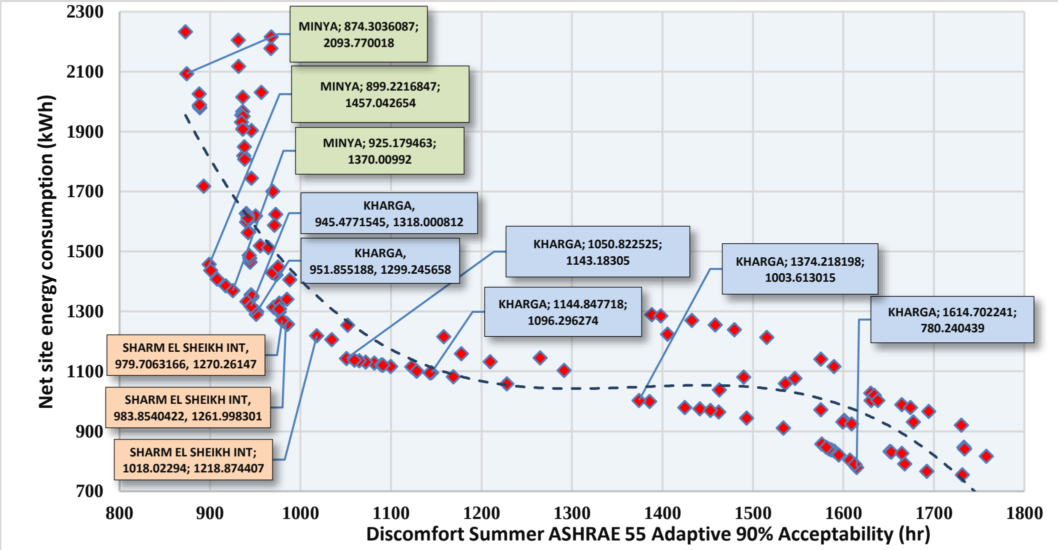


Fig. 5.11. Minimize discomfort summer ASHRAE 55 adaptive 90% acceptability & net site energy consumption at the underground Level.

5.5. Top floor Level Optimization Results

At the top level's optimization chart, Marsa-Matrouh city showed the best solutions for the designed objectives (Fig. 5.12).

That is according to the moderate weather of the city, regardless if it is earth-sheltered or not. Followed by Sharm El-Sheikh city, also has moderate weather around the year.

Therefore, we found that the other three weather files have a problem in discomfort hours at the top level. Their results failed to fulfill the constraint condition.

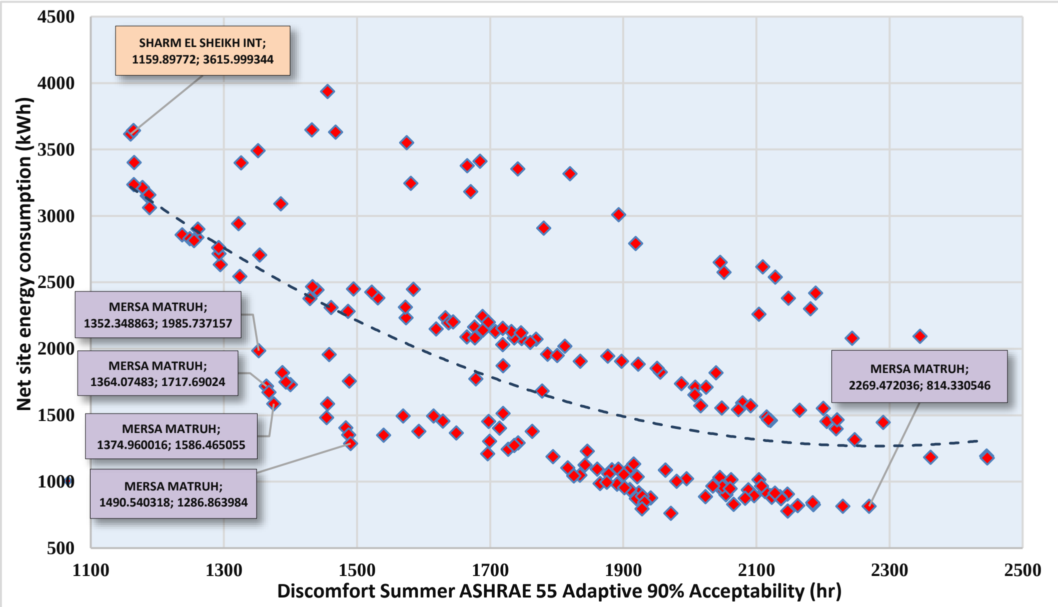


Fig. 5.12. Minimize discomfort summer ASHRAE 55 adaptive 90% acceptability & net site energy consumption at roof level.

5.6. Optimization comparisons.

Going a step further in our research, we compared between the underground level optimized solutions, (Fig. 5.11), and the same zones at the top level's optimized solutions, (Fig. 5.12).

In order to emphasize the importance of the Earth-contact with the building envelope to maximize the thermal comfort, and minimize the energy consumption.

For more analysis, we compared between the two scatter plots' charts, the top level and the underground level, by categorizing the "best-fit-so-far" Preto front optimized results according to each city climate file, then according to the least "Net site energy consumption", as a first objective, and its representative "Discomfort hours" of the same cases are demonstrated, as a second objective, as shown in (Fig. 5.13).

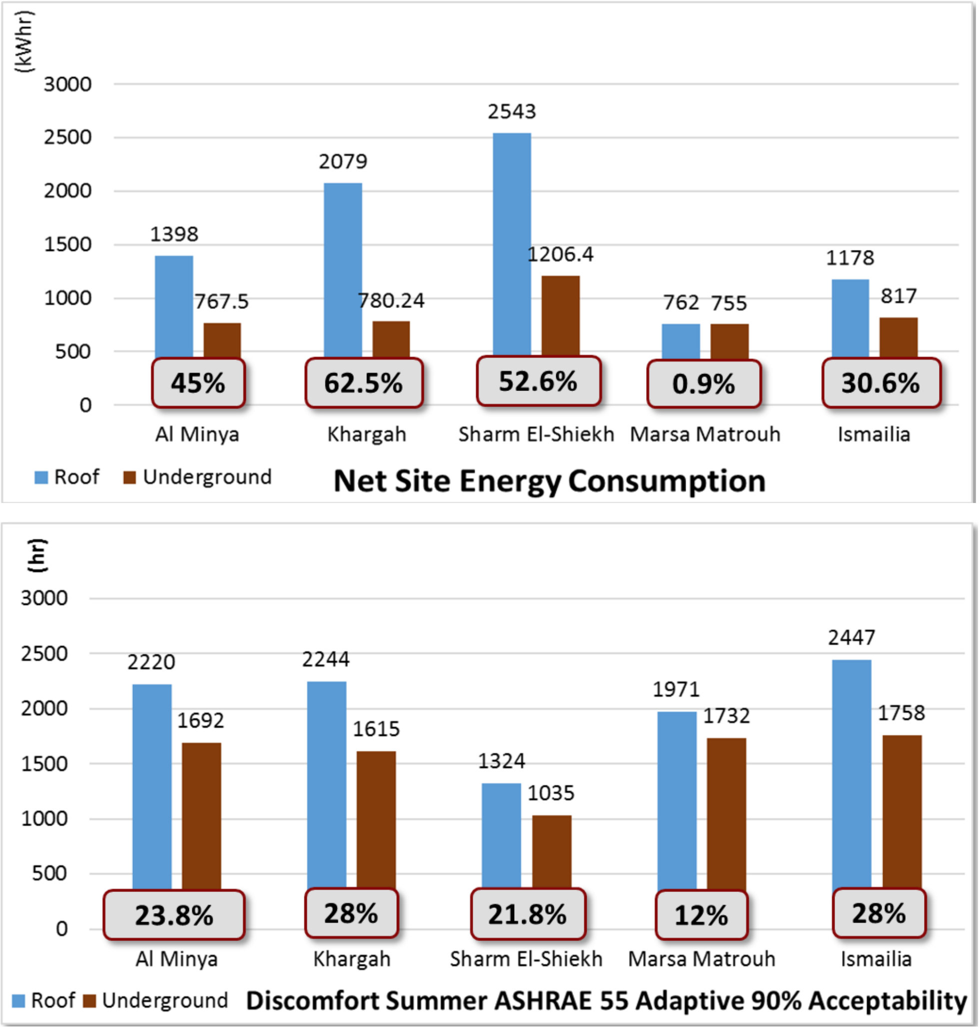


Fig. 5.13. A comparison between the roof and underground level's "best-fit-so-far" cases, to meet the design objectives.

We could gain savings in net site energy consumption at the underground level by 45%, 62.5%, 52.6%, 0.9% and 30.6% at Minya, Kharga, Sharm El-Sheikh, Marsa-Matrouh and Ismailia cities, respectively.

Moreover, we could gain less discomfort hours at the underground level by 23.8%, 28%, 21.8%, 12% and 28% at Minya, Kharga, Sharm El-Sheikh, Marsa-Matrouh and Ismailia cities, respectively.

Moreover, we compared between the top and underground levels' "best-fit-so-far" optimized cases for the best objectives and their representative variables which contributed in that results, as shown in (Table 5.2).

We may notice that, for the Marsa-Matrouh, Sharm El-Sheikh, and Ismailia cities, the improvement in the building thermal performance, the savings of the net site energy consumption, and the less discomfort hours according to the Earth contact is not that much, compared with Kharga and Minya cities.

That is due to the moderate climate of the three cities, compared with the hot-arid climate of Kharga and Minya cities. That results support the hypothesis that, the best performance of the earth-sheltered construction is at the hot-arid climates, rather than the moderate ones.

Table 5.2. A comparison between roof and underground levels' optimization results.

Location template	Subject of comparison	Roof Level	Underground Level
Marsa-Matrouh	Min. Net site energy (kWh)	762.2	755
	Min. Discomfort hours (hr.)	1971.4	1731.6
	WWR %	50	30
	Orientation (º)	135	180
	Cooling set point (°C)	28	28
	Heating set point (°C)	22	19
Sharm L. Sheikh	Min. Net site energy (kWh)	2544	1206.4
	Min. Discomfort hours (hr.)	1324	1035
	WWR %	50	40
	Orientation (º)	315	270
	Cooling set point (°C)	26	27
	Heating set point (°C)	18	18
Ismailia	Min. Net site energy (kWh)	1178	816.8
	Min. Discomfort hours (hr.)	2447	1758
	WWR %	25	25
	Orientation (º)	225	315
	Cooling set point (°C)	28	28
	Heating set point (°C)	18	18
Kharga	Min. Net site energy (kWh)	2079	780.24
	Min. Discomfort hours (hr.)	2244	1615
	WWR %	50	50
	Orientation (º)	0.0	315
	Cooling set point (°C)	28	28
	Heating set point (°C)	22	18
Minya	Min. Net site energy (kWh)	1398	767.5
	Min. Discomfort hours (hr.)	2220	1692
	WWR %	20	25
	Orientation (º)	225	225
	Cooling set point (°C)	28	28
	Heating set point (°C)	20	18

5.7. Post-optimization Results Analysis

To evaluate the pareto front best optimized cases, we created a formula to sort the pareto front cases according to an evaluation number. In order to weigh between the Energy consumption (E) and the thermal Comfort (C), we multiplied each of them with the factor of (0.5), because we seek the balance between the two objectives in our model; minimizing the energy consumption and the comfortableness, both in the same priority.

In other cases, if designers have different priorities between the two objectives, they might change these factors i.e. (0.8 to the side of the energy consumption and 0.2 to the side of comfortableness) for example, to gain different ranking of the pareto front cases according to their priorities. Taking into consideration that the summation of both factors is (1).

Moreover, we divided the (E) and (C) values by the summation of each to get the weight of each of them and to get a unitless numbers, so that we could add both of them together to gain the Evaluation number (EV.), (Eq. 5.1).

$$\left(0.5 * \frac{E}{\sum E}\right) + \left(0.5 * \frac{C}{\sum C}\right) = EV \ldots \text{ (Eq. 5.1)}$$

According to the previous formula we sorted the pareto front case studies to find the best-case variables' combination. The best case according to the evaluation no. was at the iteration no. 123 in the generation no. 8 as shown in (Fig. 5.14). Moreover, we compared between the pareto front cases' net-site energy consumption (Fig. 5.15), and compared between the pareto front cases' discomfort hours (Fig. 5.16).

It could be noticed that best case according to our formula is near to the minimum and making a weighing at the same time between both objectives.

The best-case variables according to each city was: Al-Kharga city climate file with a combination of (WWR%=20%, Orientation= 315°, Cooling set-point= 28° & Heating set-point= 18°) was the best pareto front case. Followed by, Sharm-el-Sheikh city with a combination of (WWR%=50%, Orientation= 315°, Cooling set-point= 27° & Heating set-point= 18°). Finally, Al-Minya city with a combination of (WWR%=35%, Orientation= 315°, Cooling set-point= 26° & Heating set-point= 18°).

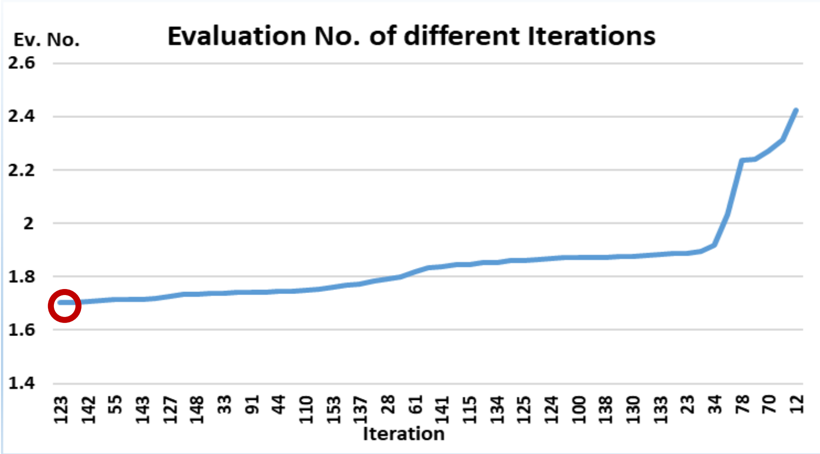


Fig. 5.14. Sorting the pareto front cases according to an evaluation number.

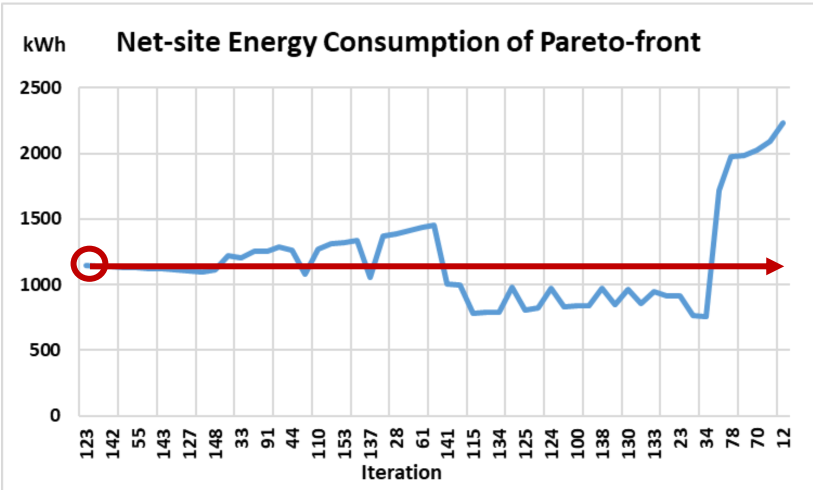


Fig. 5.15. Sorting the pareto-front cases' net-site energy consumption according to evaluation no.

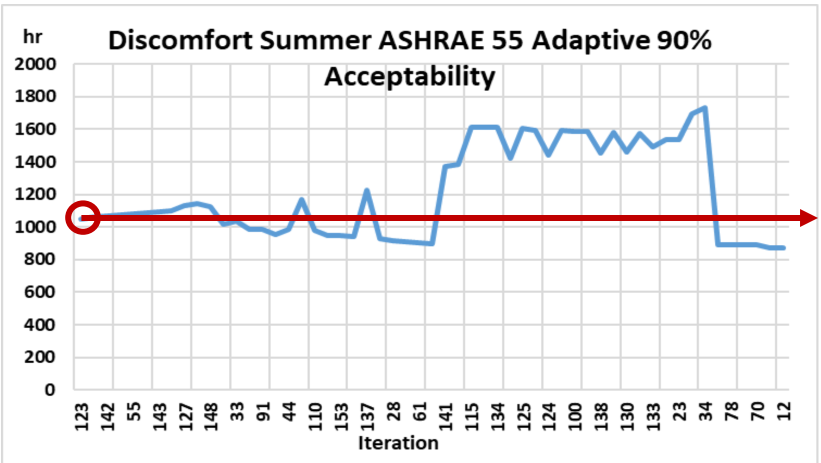


Fig. 5.16. Sorting the pareto-front cases' discomfort hours according to the evaluation no.

However, with deep analysis, we need to grasp the tendency of each variable, i.e. WWR%, orientation, cooling, and Heating set-points for each city, in order to introduce general guidelines for each climate sector where each city is located.

Therefore, we analyzed each variable separately inside each city to get the larger number of each categorization inside each variable. Results are discussed in the next sub-sections.

5.7.1. Window wall ratio percentage (WWR%).

Analyzing the pareto front cases, we categorized them according to each city. To gain the tendency, we counted each categorization number of the window/wall ratio for each city's pareto front cases, (Fig. 5.17).

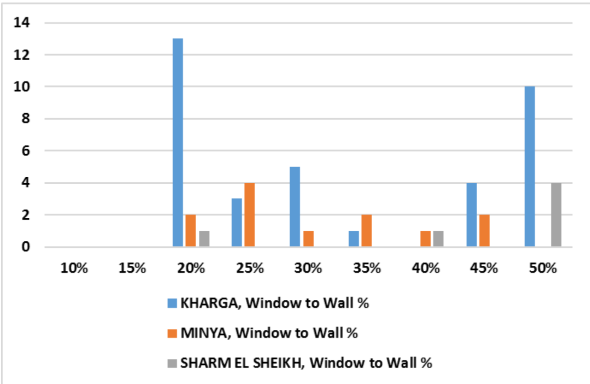


Fig. 5.17. The Window/Wall Ratio% tendency for the pareto front cases at each city.

Therefore, for Al-Kharga city, the window wall ratio tendency was 20%. For Al-Minya city, the window wall ratio tendency was 25%. For Sharm-El-Sheikh city, the window wall ratio tendency was 50%.

5.7.2. Cooling and heating set-points.

Balancing between the two main objectives of the parametric study optimization analysis, as mentioned in 5.3. was to reach the trade-off between minimizing the discomfort summer ASHRAE 55 Adaptive 90% acceptability, and minimizing the net site energy consumption, which typically conflicts.

Therefore, to reach the tendency of the cooling and heating set-points in each city, we counted each categorization number of the cooling and heating set-points for each city's pareto front cases, (Fig. 5.18).

Therefore, for Al-Kharga city, the cooling set-point tendency was 28℃. For Al-Minya city, the cooling set-point tendency was 26℃. For Sharm-El-Sheikh city, the cooling set-point tendency was 27℃.

Moreover, for Al-Kharga city, the heating set point tendency was 18℃. For Al-Minya city, the heating set point tendency was 18℃. For Sharm-El-Sheikh city, the heating set point tendency was 18℃.

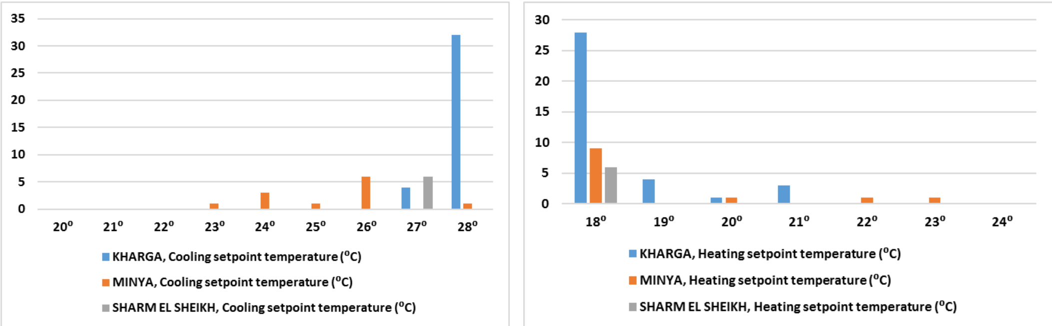


Fig. 5.18. The heating and cooling set-points tendency for the pareto front cases at each city.

5.7.3. Building orientation.

To gain the tendency of the building orientation in each city, we counted each categorization number of the building orientation for each city's pareto front cases, (Fig. 5.19). Therefore, for Al-Kharga city, the building orientation tendency was 315^0.

For Al-Minya city, the building orientation tendency was 315^0. For Sharm-El-Sheikh city, the building orientation tendency was 315^0.

To understand the optimized solutions' orientation, by referring to the building design and shape, the (0^0) is the North orientation, which has the rear part of the unit, and the (90^0) perpendicular to it we can find the openings of the unit is concentrated mainly on this façade.

The optimizer started with the (0^0) façade and give us the recommendation to make it on the (315^0) the North-west. Which means that, the openings' position is to be on (45^0) the North-East direction.

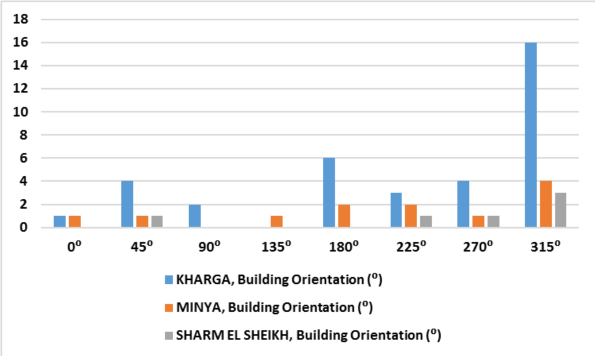


Fig. 5.19. The orientation tendency for the pareto front cases at each city.

5.7.4. Location Template.

Regarding the parametric optimization study, the optimum best solutions of the design variables, went to three weather files as representatives of hot climates, out of five tested weather files.

Sharm-El-Sheikh city as representative of the mild to hot climate, and Al-Minya city as representative of hot climate, and El-Kharga city as representative of hot-arid climate.

The other two climates; Ismailia and Marsa Matrouh; failed to reach the best performance required.

However, to gain the tendency of the location template, we counted each categorization weather file of each city's pareto front cases, (Fig. 5.20).

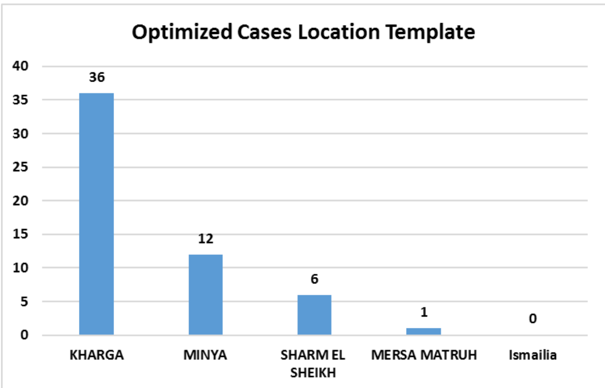


Fig. 5.20. The weather file (Location) tendency for the pareto front cases.

5.8. Discussion

Basements are considered one kind of the Earth-sheltered construction system. Therefore, after calibrating a model in chapter 4, we performed a parametric optimization analysis in this chapter to reach the best combination of the design variables for the best thermal comfort and the best energy savings.

As the main theme of our research is the earth-sheltered buildings, we performed the parametric optimization on the underground level to reach the best design variables as the main purpose of our work. However, to emphasis the Earth-contact effect on the building's thermal comfort and energy savings, we compared between the optimized solutions of the underground level and the optimized solutions of the roof level, as a research contribution to enhance the thermal comfort performance, specifically of the residential buildings.

We chose five weather files of different cities' climates for the parametric optimization analysis, in order to grasp the best earth-sheltered buildings' performance at which weather conditions would be the best. The chosen cities are located at different climatic zones at Egypt; moderate (Ismailia), hot (Minya), hot-arid (Kharga), warm (Sharm El-Sheikh), and Mediterranean (Marsa Matrouh).

From the literature it is known that the Earth-sheltered construction has the best performance at the arid climates, weather hot or cold, because of the large thermal mass with high envelope capacity, it contributes in thermal lag which gives the best performance at arid climates.

We proved that hypothesis in this chapter by the parametric optimization analysis, in which we found that the effect of the Earth-contact on thermal comfort and energy savings, was higher in the hot and the hot-arid climates, rather than the moderate, warm or the Mediterranean. That could be reached through the analysis of section (5.7.4).

Results of this chapter supports the same direction of the research hypothesis which is measuring the suitability of applying the Earth-sheltered construction at Egypt, as a representative of the hot-arid climate weather condition.

5.9. Conclusion

In this chapter, we discussed the effect of the Earth contact with the building, on the thermal comfort and the energy savings issues.

We performed a parametric optimization analysis of an underground level residential unit, for the least discomfort hours, and the least net site energy consumption per year.

The tested variables in which lead to the optimized solutions, were the window wall ratio, the building orientation, the heating and cooling set points, and the weather template of five cities locations at Egypt, for minimum discomfort hours per year, and at the same time minimum net site energy consumption per year. The only constraint was to exclude solutions with discomfort hours more than one month per year.

To emphasis the effect of the Earth contact with the building, we compared the optimized solutions at the roof level; which is subjected directly to the solar gain; and the optimized solutions at the underground level of the same residential unit zones.

The energy savings due to the Earth contact effect, was very high at the hot and hot-arid climates, rather than the moderate or the Mediterranean ones.

We also found a reduction in the discomfort hours per year due to the underground building position. However, the reduction difference was not high at each climate like the reduction difference in the energy savings.

In this chapter we proved the hypothesis that, the effect of the Earth contact with buildings is great for energy savings and for lower discomfort hours, especially at the hot-arid climates, such as Egypt.

Chapter 6

6. EARTH-SHELTERED BUILDINGS, DESIGN GUIDELINES

One of the most effective techniques to achieve the trade-off between thermal comfort and low energy consumption in hot-arid climates is Earth sheltering.

This chapter reports the results of our complete vision from this research, which aims to measure the suitability of applying the Earth sheltering technique at hot-arid climates, in Egypt as a case study. Through several topics; architectural design guidelines, site selection and urban planning guidelines.

Moreover, measuring the balance between the thermal comfort, and energy savings through a parametric optimization analysis.

This chapter presents site-specific guidelines, for architects and urban planners regarding the application of this technique for residential buildings.

6.1. Issues of assessing the suitability

The main purpose of this research is to provide general guidelines about the Earth-sheltered-buildings' implementation for architects and urban planners for the new communities, with emphasis on the thermal comfort.

Besides, measuring the possibility of applying this kind of buildings from many aspects; people's perception, energy savings and thermal comfort.

Therefore, this research scope is focused on creating guidelines for architects, and urban planners who wish to work with the Earth-sheltered building system, especially at new communities of the hot-arid climates.

The main objectives of this research could be summarized in:

- Architectural design guidelines.
- Urban planning and site selection guidelines.

Previous researches mentioned many issues to be evaluated for the application's suitability of the Earth-sheltered buildings. Likewise, economic issues, life cycle cost analysis, natural lighting penetration and glare, etc. (Al-Temeemi and Harris 2004).

In this chapter we focused the evaluation of suitability on two main categories:

- Energy savings potential and thermal comfort.
- Public acceptability.

Al Temeemi and Harris suggested some sequential methodologies for the suitability assessment process. We added another issue to be assessed, although it is not necessarily to be sequential, as shown in (table 6.1).

Table 6.1. Suggested methodologies for the application's suitability assessment process.

Issue to be assessed	Method	The research achievement
Acceptability	Questionnaire.	Done (Visual questionnaire survey).
Urban design typologies	Questionnaire/ Previous studies analysis.	Done (Urban design guidelines according to questionnaire).
Subsurface climate	Temperature and heat flux evaluation.	Done (Basement preprocessor of the EnergyPlus).
Energy consumption	Energy monitoring and/or simulation.	Done (DesignBuilder/EnergyPlus) & monitoring.
Optimization	Simulation software.	Done (DesignBuilder/EnergyPlus) parametric optimization.
Design	Suitable architecture design.	Done (Architectural design guidelines).
Solar penetration	Shading simulation using software.	For future research prospects.
Cost	Life-cycle cost analysis.	For future research prospects.
Geological issues	Simulation software/ Studying historical cases.	For future research prospects.
Structural issues	Simulation software.	For future research prospects.

6.2. Methodology

In this section, we discuss in brief the methodologies done in the previous chapters, which in turn lead to the creation of this chapter.

6.2.1. Questionnaire and Interviews

The questionnaire sample were (n=164) of Egyptians and Japanese, it passed three sequential steps:

- A pilot study photo questionnaire, with a sample of Egyptians' architecture fourth year grade undergraduates, postgraduate architects and architecture's university teachers. Questions were in Arabic language and were moving around their attitudes and reactions. This stage was followed by interviews with the respondents (Ismail et al. 2013).
- The interviews stage was done at Egypt with Egyptian architects, and at Japan with Japanese architects, to measure their attitudes about the Earth-sheltering technique and recommendations about the final questionnaire design (Heba Hassan et al. 2016).
- The internet form photo-questionnaire was the last stage which was designed to measure architecture specialists' attitudes. Besides, their contribution regarding their experience in choosing the most appropriate architecture, site selection and urban design guidelines. The sample was limited to postgraduate students, architecture specialists and architecture university teachers. Questions were designed in a photo comparison way in an internet form. There were two forms; English language for Egyptians, and Japanese language for Japanese. Afterwards, a comparison was made between both of their attitudes and different choices directions, as a representative of different climates and attitudes (Heba Hassan et al. 2016).

Results obtained from the questionnaire responses passed through a chi-square test to be able to generalize the results on the public. We had chosen the significant results only for the design guidelines' contribution.

6.2.2. Simulation Model

As it was noted on previous researches that Earth-sheltered buildings could be above or under zero level (Sahar N. Kharrufa 2008). Therefore, to measure the effect of Earth-contact with the building on the thermal comfort and energy savings, it was recommended to measure a basement model. Hence, we calibrated a basement model in Minya city at Egypt, as a case study of the harsh hot-dry climate.

Using the Basement preprocessor of the EnergyPlus we calculated the heat flux and the soil surface boundary temperature for the 3D heat transfer between the building and the soil. We adopted an iterative approach to reach a convergence of the ground temperature, which was the main sensitive input of the DesignBuilder/EnergyPlus for calibrating the basement model.

Moreover, we calibrated two zones of a top floor residential apartment; conditioned bedroom and unconditioned living in a reinforced concrete building. In order to show the difference between the basement and the top floor, we used the same top floor plan and operating schedules as a hypothetical displacement in the underground level.

This chapter is considered to be the preparation stage for the accurate model inputs for the next step of the parametric optimization.

6.2.3. Parametric Optimization

We performed a parametric optimization study using the genetic algorithm provided by DesignBuilder/EnergyPlus software V4.7 to reach the optimal performance of the building with the best combination of design variables.

- ***Objectives:*** was to reach the trade-off between minimizing the discomfort summer ASHRAE 55 Adaptive 90% acceptability, and minimizing the net site energy consumption, which typically conflicts.
- ***Constraints:*** We excluded the high discomfort hours from the results, choosing only the cases with no more than (1000 hrs./year), discomfort summer ASHRAE 55 adaptive 80% acceptability. More than this hour's number, we considered them as failed constraint cases.

- ***Design Variables:*** were the combination of five aspects:
  - *(Window/Wall)* ratio percentage, ranging from 10-50% with 5 steps increment, for the building as a target object.
  - ***Orientation,*** ranging from 0°-315° with 45° steps increment, for the building as a target object.
  - ***Location template,*** with five options of the cities' weather files inputs (Ismailia, Sharm-El-Sheikh, Al Minya, Marsa-Matrouh, Al Kharga), for the building as a target object.
  - ***Cooling set-point temperature,*** ranging from 20-28°C with 1°C step increment, for the conditioned bedroom zone as a target object.
  - ***Heating set-point temperature,*** ranging from 18-24C with 1°C step increment, for the conditioned bedroom zone as a target object.

After the parametric optimization process, we chose the optimal design variables combination for the design guidelines recommendations, in accordance with the questionnaire results experts' recommendations.

6.3. Results

Results were the outputs of the questionnaire and optimization studies, we recommended the guidelines for the early stage design and application of the Earth-sheltered buildings at hot-arid climates. We categorized them into three main categories: architectural, site selection and urban planning, and finally the climate, city and usage suitability guidelines.

6.3.1. Architectural Design Guideline

Results of this section are derived from the questionnaire statistical analysis and the parametric optimization simulation study.

Hence, we merged and categorized them into the form of an architectural and urban design guidelines.

1. The plan zoning design

According to the questionnaire survey, to overcome the feeling possibility of darkness and dampness, the plan should be opened to the outer environment, from both natural daylight and ventilation aspects, (Heba Hassan et al. 2016).

For bermed or in-hill construction, a recommended plan is to place the living spaces on the back direction of the house facing the hill-side. This provides maximum light penetration to bedrooms, living rooms, and kitchen spaces. Rooms that do not require natural daylight and extensive heating such as the bathrooms, storage, extra rest living room and utility rooms are typically located on the opposite or (in-hill) side of the shelter. This type of zoning layout could be extended to a double level house design with both levels completely earth-sheltered.

This plan zoning has the highest energy efficiency of earth-sheltered homes because of the compact configuration as well as the structure being submerged deeper in the Earth. This provides the building with a greater ratio of Earth contact with exposed wall than a one-story shelter would.

For an atrium earth-shelter, the living spaces are concentrated around the atrium. The atrium arrangement provides a less compact plan than that of the one or two story bermed or in-hill design.

Therefore, it is commonly less energy efficient, in terms of heating and cooling loads. However, the atrium does tend to trap air within it, which is then heated by the sun and helps reduce heat loss.

2. The entrance levels

The preferred access direction is to be upstairs, to prevent water flooding, or sand dunes cover, 65.3% of Egyptians recommended this. (Fig. 6.1. b).

We should also concern about the zero-level entrance, with less priority, to give natural feeling like conventional buildings. (Fig. 6.1. a).

Fig. 6.1. (a) Zero level entrance direction; (b) Upstairs entrance direction.

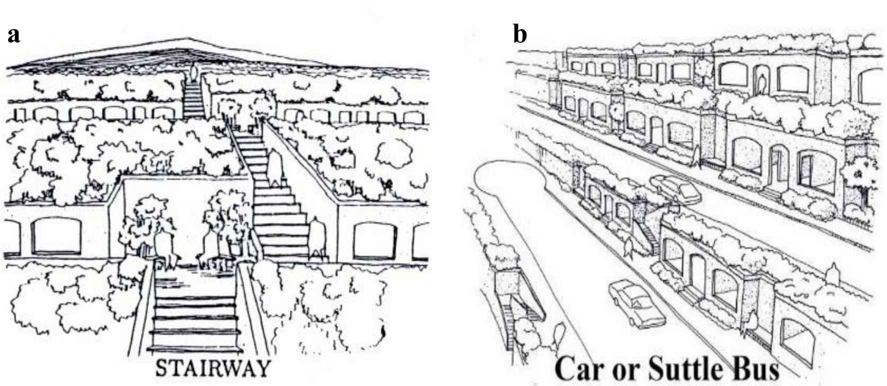


Fig. 6.2. (a) Stairway for mild slopes; (b) Car or shuttle bus for steep slopes accessibility.

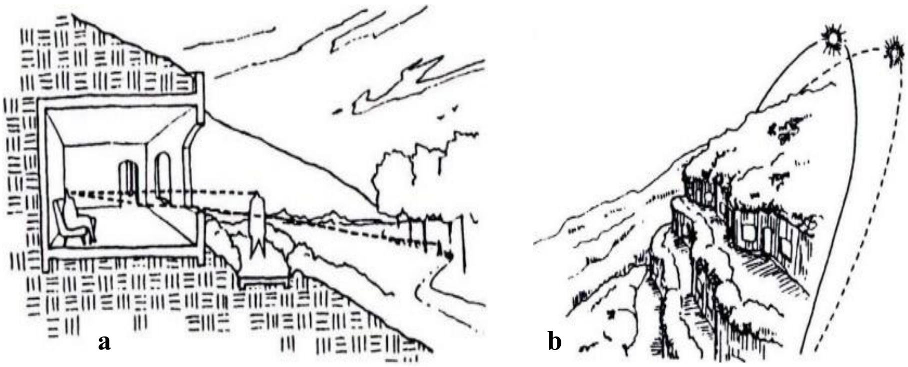


Fig. 6.3. (a) Direct eye-contact is preferred; (b) North direction is preferred by Egyptians.

3. *The unit accessibility*

For the unit accessibility and transition between slopes, 35.6% of Egyptians recommended to use stairways at the mild slopes (Fig. 6.2. a). And 39.6% of them recommended to use a car or shuttle bus at the steep slopes (Fig. 6.2. b) (Golany and Ojima 1996).

4. Eye contact

Although Egyptians and Japanese preferred the direct eye contact, but Japanese liked it more than Egyptians did, 60.4% of Egyptians and 83.3% of Japanese chose the direct eye contact as their preferred choice.

Egyptians tend to like more privacy. Moreover, the hot environment at Egypt makes people tend to close windows, regardless of the outer view. (Fig. 6.3. a) (Golany and Ojima 1996).

5. Building orientation

The questionnaire results pointed out that 72.3% of Egyptians preferred the North direction, to stay far from the direct Sun penetration, (Fig. 6.3. b).

The simulation results are site-specific classified. The best optimized cases were for Kharga city, Al-Minya city, and Sharm-El-Sheikh city. Therefore, the best orientation according to each city was: in Kharga city the recommended orientation is 315^0. In Al-Minya city the recommended orientation is 315^0. In Sharm-El-Sheikh city the recommended orientation is 315^0.

6. Window wall ratio percentage (WWR%)

This section was quantified by the parametric optimization simulation analysis. Therefore, there is no fixed optimum solution for the window wall ratio for the Earth-sheltered buildings for all cities at Egypt, but it depends on many other variables.

The most effective variable is the climate weather file of a certain city. Hence, we categorized them according to the optimum solutions' weather file (city), for each city.

Therefore, for Al-Kharga city, the best window wall ratio was 20%. For Al-Minya city, the best window wall ratio was 25%. For Sharm-El-Sheikh city, the best window wall ratio was 50%.

7. Building cross-sections typologies' suitability

Earth sheltered houses are often constructed with energy conservation and savings in mind. Study of the most efficient application of the earth sheltered principles reveals classifications of the major typologies that are utilized in the construction of earth houses. Anselm categorized these buildings into two major concepts as: The bermed or banked with Earth type and the envelope or true underground type.

The energy conservation values of these typologies also vary depending on climate and physical challenges related to each typology (table 6.2) (Anselm 2012).

Table 6.2. Comparing efficiency values of the earth shelter building typology. (Anselm 2012).

Factor	Earth shelter building type			
	Bermed		Envelope/true underground	
Passive solar potential	Excellent		Less effective	
Thermal stability	Less effective		Excellent	
Natural lighting potential	Effective		Less effective	
Wind protection	Less effective		Excellent	
Noise protection	Less effective		Excellent	
Visual convenience	Excellent (one directional view)		Poor (allows only open sky view)	
Appropriate Climate	Effective for temperate		Most effective for tropical	
Structural cost	Modern design	Vernacular design	Modern design	Vernacular design
	Intermediate	Less expensive	Most expensive	Least expensive

We categorized them according to the relationship with the zero-level into four typologies: Totally underground, at zero level, above zero level, and on the hill-side, (Fig. 6.4).

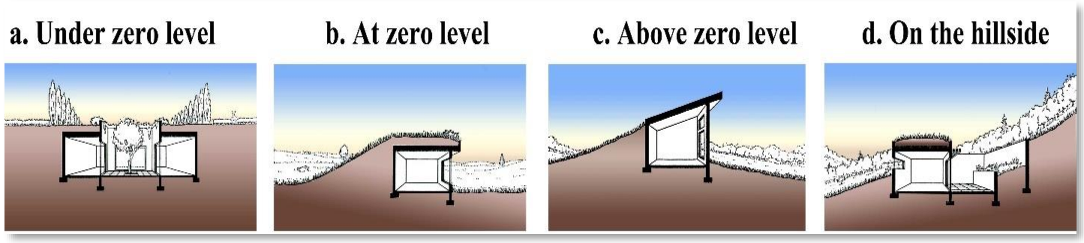


Fig. 6.4. Earth sheltered cross sections' typologies in relation with the zero level.

We measured the experts recommendations about the suitability of each one of them from many aspects regarding implementation possibility; suitability for elderly and disabilities, suitability against crime and robbery, safety against natural hazards, suitability as a living space, suitability for fire escape, easy architectural design, economical use of air-conditioning energy, suitability of long life span and low required maintenance, easy access to maintenance points, economical initial cost and the best structural performance for bearing loads.

By calculating the mean ranking of multiplying the four cross-sections with the suitability factors according to each of the Egyptians and Japanese. We gained different attitudes, but still the trend is the same; the most suitable cross-sections were (B& C); at zero level and above zero level, and the most unsuitable cross-sections (A& D); the completely under zero level and on the hill-side, as shown in the previous chapter 3 (fig. 3.8 and table 3.1) (Heba Hassan et al. 2016).

8. Thermal comfort and energy savings

Balancing between the two main objectives of the parametric study optimization analysis, as mentioned in 6.4. was to reach the trade-off between minimizing the discomfort summer ASHRAE 55 Adaptive 90% acceptability, and minimizing the net-site energy consumption, which typically conflicts.

Therefore, to reach the optimum design solutions, we categorized them according to the weather file. Afterwards, to reach the tendency of the cooling and heating set-points in each city, we counted each categorization number of the cooling and heating set-points for each city's pareto front cases, (Fig. 6. 5).

Therefore, for Al-Kharga city, the cooling set-point's tendency was 28℃. For Al-Minya city, the cooling set-point's tendency was 26℃. For Sharm-El-Sheikh city, the cooling set-point's tendency was 27℃.

Moreover, for Al-Kharga city, the heating set point's tendency was 18℃. For Al-Minya city, the heating set point's tendency was 18℃. For Sharm-El-Sheikh city, the heating set point's tendency was 18℃.

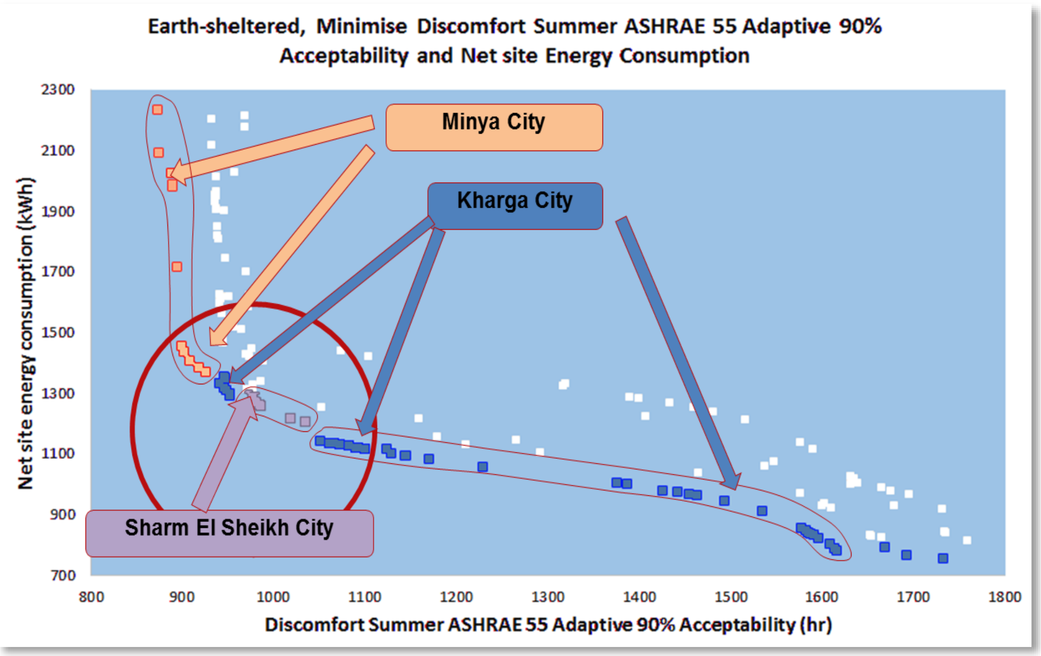


Fig. 6.5. The DesignBuilder parametric optimization study.
best weather choices, according to the combination of many design variables.

6.3.2. Urban Planning Guidelines

Results of this section are derived from the questionnaire statistical analysis, and guidelines from previous studies.

1. Extension direction

Regarding the neighborhood extension; the horizontal extension direction for the urban community is recommended by 51.7% of the Japanese sample, as shown in (Fig. 6.6. a), while two or three levels are recommended by 51.5% of the Egyptian sample, as shown in (Fig. 6.6. b).

Which matches the recommendation of the building plan according to Hoyle for the best energy performance to maximize the soil-building contact (Hoyle 2011). The vertical extension is not preferred (Heba Hassan et al. 2016), (Fig. 6.6. c).

Fig. 6.6. The extension direction possibilities for an Earth-sheltered neighborhood. The horizontal and two or three levels are acceptable

2. Cluster skyline.

The closed (river type) is preferred to avoid wind turbulence and rain erosion. 66.3% of the Egyptian sample preferred the closed river skyline type.

On contrary, the opened skyline (mountain type) which gained 33.7% of votes (Heba Hassan et al. 2016), as shown in (Fig. 6.7) (Golany and Ojima 1996).

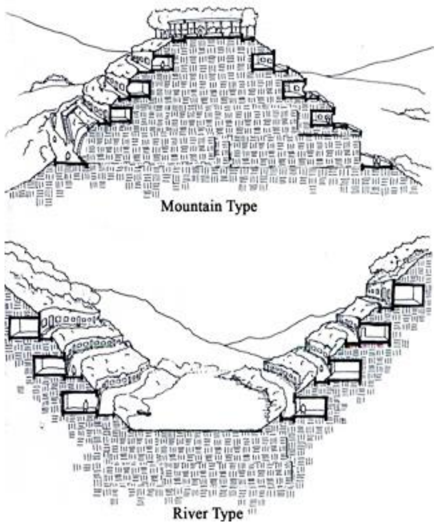


Fig. 6.7. The Closed (River) Type is the recommended for new communities.

3. Slope gradient angle

A percentage of 61.4% of the expert sample recommended the slope gradient angle for new communities as of 30% slope degree (Heba Hassan et al. 2016).

Other three slope degrees, 15%, 60% and 80% are not recommended by experts for this kind of construction, as shown in (Fig. 6.8) (Golany and Ojima 1996).

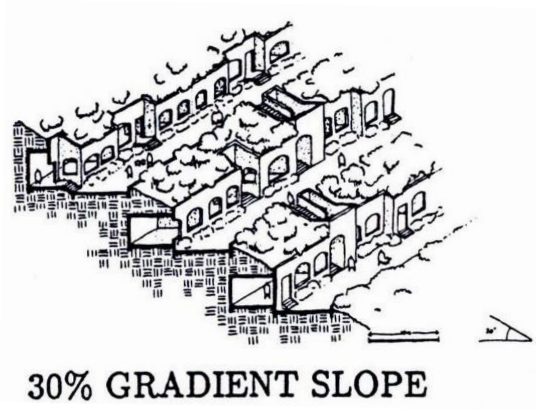


Fig. 6.8. The preferred slope gradient for new Earth-sheltered construction is 30% degree.

4. Urban form (detached/ attached)

Both Egyptians and Japanese preferred the detached form rather than the attached one, concordant with the proposed research hypothesis.

The detached form is recommended to enlarge the heat exchange between the building and Earth contact. 79.2% of Egyptians recommended the detached form for the urban community (Heba Hassan et al. 2016), as shown in (Fig. 6.9).

Fig. 6.9. The detached urban form is recommended for gathering units at new communities of Earth-sheltered buildings.

6.3.3. Site Selection and Usage Suitability Guidelines.

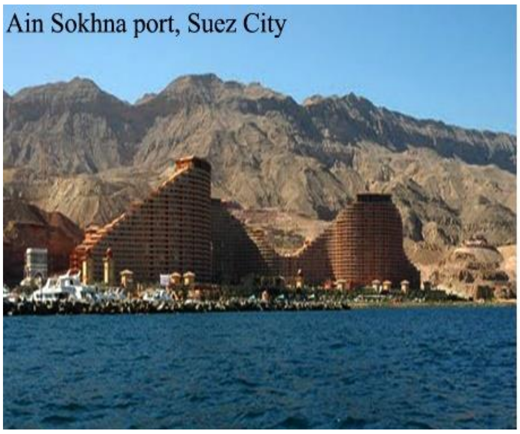
Selecting the suitable climate, usage and city type for new community establishments, can guarantee the best performance to reach the thermal comfort easily. Experts recommended special considerations about each of them.

1. Selecting the city style.

Most of the votes were directed towards the application at a (touristic city with mild climate), 91 out of 164 was the highest number of people whom chose that kind of city, which was represented by (Ain-Sokhnah port) Suez city.

The (beautiful, hot climate) city came after it with high gap lower rank, with 37 votes, which was represented by (Minya) city, (Fig. 6.10). Followed by the (extreme climate) city, and (other) with 25 and 11 votes, respectively.

What is worth to be mentioned here is that the hidden answers for (other) were representatives of extreme climate cities.



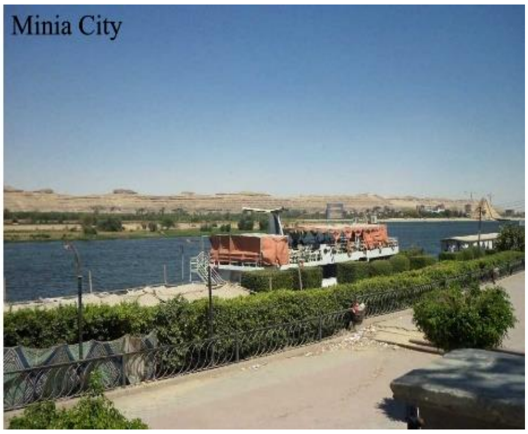


Fig. 6.10. Ain-Sokhnah port vs. Minya city,
was recommended by experts for the Earth-sheltered buildings' application.

2. Recommended usage.

Contrary to predictions; 71 out of 164, the total number of the expert sample, chose the residential usage.

Previous researches outcome argued the unacceptability of living at the Earth-sheltered buildings (Al-Temeemi and Harris 2004; Bartz 1986; Sydney 1981). However, most of them were at the eightieth of this century. Since the pilot study of the research, we investigated about the acceptability of living in or dealing with this kind of buildings (Ismail et al. 2013).

Finally, our research proved the acceptability of residential living as a first choice with 71 votes, followed by 66 votes to the touristic usage, which is also concerned as a representative of the living activity. Two other activities came at a lower rank; the storage and commercial usages by 18 and 9 votes, respectively (Heba Hassan et al. 2016).

3. *Climate's best performance.*

This point we evaluated it through both the questionnaire analysis and the parametric optimization simulation.

Regarding the questionnaire, most of the votes were given to the mild climate 91 votes, followed by the hot climate 37 votes, then the arid climate 36 votes, after grouping the (extreme) and (other) choices. (Heba Hassan et al. 2016).

Regarding the parametric optimization study, the optimum best solutions of the design variables, went to the same three weather files as representatives of those climates, out of five tested weather files. Sharm-El-Sheikh city as representative of the mild to hot climate, and Al-Minya city as representative of hot climate, and El-Kharga city as representative of hot-arid climate. The other two climates failed to reach the best performance required.

However, by analyzing the chart (Fig. 6.5), we can grasp the tendency of the weather file location. The best balance between both the energy saving and thermal comfort was the Sharm-El-Sheikh city, as representative of the mild to hot climate. Afterwards, we recommend the big cases number of the pareto front of the best optimized cases solutions; Al-Kharga city, as representative of hot-arid climate. Finally, Al-Minya city, as representative of hot climate.

The simulation tendency supports the questionnaire results of the experts' recommendation. To apply the earth-sheltered building system at Sharm-El Sheikh city, with mild to hot climate and as a touristic city nature.

6.4. Discussion

Before this research, the background idea about the Earth-sheltered buildings was directed towards the negative attitudes. Therefore, it was very important to measure people's perception and attitudes towards living in or dealing with this kind of buildings.

We proved by statistical tests, that negative attitudes, were only related with the name "Earth-sheltered". It gives the impression of "Underground". Although "Underground" is only one kind of "Earth-sheltered".

Moreover, regarding the research significance, we proved that negative attitudes could easily be changed using the right knowledge and good source of information about the system. Besides, sketches, photos and videos are very important in the questionnaire survey to ensure the right information delivery to the respondent, hence, we can gain the right answers direct on the point.

Besides, choosing the sample for the questionnaire survey was a strike home, because of the experts and university teachers whom provided us with logical answers, and participated in creating the architectural and urban guidelines.

Creating the design guidelines as a single effort work, would lead to errors and uncertainties. Therefore, we counted on creating them according to the tested results from the survey, after passing the chi-square test, and according to the reasonable number of the experts' sample (n=164), we could generalize the resulted guidelines on both communities; Egypt as a representative of hot-arid climate and developing country, and Japan as a representative of cold-humid climate and advanced country.

For new communities, it is better to start with the touristic buildings as a beginning, afterwards, we can enlarge the application scope to the residential sector. That was recommended by experts in this field from the interviews which were accompanying with the questionnaire survey's pilot study. For example; for a certain nation, if people tried using this kind of buildings as a hotel or motel, they may wish to have their homes built with the same style. On contrary, if we, as architects, offered to design their new homes as earth-sheltered, maybe home owners would refuse the idea, as they did not experience it before.

To emphasize the questionnaire results, we performed the simulation tests using the EnergyPlus and its Basement preprocessor as a tool for simulating a basement at Minya city, Egypt; one of the cities chosen by the respondents, as a kind of earth-sheltered buildings. As there is no existence of the earth-sheltered buildings in its modern form at Egypt. Therefore, to assess the thermal comfort and energy savings, we chose a basement.

The parametric optimization results confirmed the questionnaire survey's trend. We used the climate file as one variable to be measured, and the optimized solutions pointed towards three cities out from five cities to be the best recommended for application performance; Minya city, Kharga city, and Sharm L. Sheikh city.

Analyzing the cooling and heating points recommended from the parametric optimization study, we can observe that, the difference between the cooling and heating set points is the least in Minya city, which means that the best thermal comfort performance of the earth-sheltered buildings was at Minya city. On the other side, the cooling and heating points at other cities have big gap between them, which means lower efficiency of the earth-sheltered buildings at those cities. Those results assert the hypothesis which points that the best performance of the earth-sheltered buildings could be gained at the extreme climates, with high diurnal lag. In our case it was Minya city, which also was recommended by experts to start the implementation process.

6.5. Conclusion and Future Prospects

In this research we discussed and analyzed the outputs of research series measuring the possibility of applying the earth-sheltered buildings at hot-arid climates from different aspects; people's perception to live in or deal with it, energy savings' extent, and thermal comfort aspects. Moreover, we created architectural design, urban planning, and site selection guidelines based on the previous possibility measurements' analytical analysis.

Regarding people's perception and reactions about this type of buildings, we performed analytical analysis of the questionnaire survey. It was for proposed buildings and non-occupants' interviewees. However, we used the aid of photos, sketches and videos, to gain precise answers, which could contribute in forming the design guidelines.

Regarding thermal comfort, and energy savings, we calibrated a basement at Egypt, then performed a parametric optimization study to measure the optimum variables which could participate in the design guidelines.

For future researches, it is recommended to monitor the internal thermal environment, and energy consumption at existing modern earth-sheltered buildings, using energy monitoring equipment and simulation programs. Besides, more efforts should be done on the parametric optimization analysis, to add more tested variables related specifically with earth-sheltered buildings.

Moreover, it is recommended to perform deep studies about economics and the life cycle cost analysis.

Regarding people's perception, it is recommended to perform more studies about users at real earth-sheltered buildings, not only proposed questions and their reactions about it.

CHAPTER 7

7. CONCLUSION

In this research we intended to create design guidelines for the effective implementation of earth sheltered buildings.

To reach this goal, we measured the application suitability from many aspects; thermal comfort, energy savings, psychological, architectural and urban aspects.

7.1. Discussion

The research started with a comprehensive literature review studying and analyzing previous researches about the topic.

Then, we tested the suitability of this kind of buildings through detailed simulation tests, and parametric analysis.

Moreover, we tested people's perception extent and benefited from the participation of experts, as questionnaire respondents, on directing the research for creating proper architectural and urban design guidelines.

Because there is no existent earth sheltered buildings at Egypt (the case study country), that constituted a problem for both simulation tests, and questionnaire survey test.

Regarding the simulation aspect, we considered the basement as one kind of earth sheltered buildings, although it is not covered from the roof by earth, but it is covered from the four walls as a building envelope. Therefore, we measured the Earth-contact effect on the basements as a preliminary stage for testing earth sheltered buildings.

Regarding the people's perception aspect, we used the sketches, modified pictures, photos, and videos to gain reliable answers in which we could count on to generalize and extract a guidance to create architectural and urban design guidelines.

We asserted more than once, that this research is not a call to live in basements, rather than only using the same earth-contact concept for testing the thermal performance and energy savings extent.

7.2. Recommendations

The detailed research recommendations could be found at chapter 6. Hence, herein below we will introduce the general research recommendations.

- For the new implementation at the level of small clusters, we recommend starting by the residential or touristic use, in order to give people a chance to try dealing with this style, that would be the best way for convincing people to build their homes like that.
- From the national perspective, the residential sector is the highest to consume electricity after the industrial one. Therefore, in order to lower the energy consumption at the national level, it is better to use passive systems, such as the earth sheltered construction rather than the active ones.
- For site selection preferences, the optimization study proved the hypothesis that the best thermal performance for earth sheltered buildings could be gained at the harsh climates, hot or cold. There are a lot of cases at whole world especially at the cold-arid and cold climate. However, almost no case of the modern earth sheltered buildings at hot-arid climates. Therefore, this research is raising a call to start applying this kind of buildings at the touristic sector first, then people maybe encouraged and apply it their own homes.

7.3. Future prospects

Although we did a comprehensive assessment for earth sheltered buildings from many aspect, but there is still more to be assessed and measured the suitability for application.

- For future researches, it is recommended to monitor the internal thermal environment, and energy consumption at existing modern earth-sheltered buildings, using energy monitoring equipment and simulation programs. Deep simulations to reach the optimum thermal comfort guidelines for an energy saving model at the hot-arid and the cold-humid regions.
- More efforts should be done on the parametric optimization analysis, to add more tested variables related specifically with the earth-sheltered buildings.
- Testing the tradeoff between the energy savings, the degree of earth sheltering, and the sufficient daylight penetration into the unit.
- Conducting deep researches to serve the complementary design methods that help to improve the Earth-sheltered building performance, such as activating methods of natural ventilation, especially in (warm - humid) climates, in an attempt to reach the required good air quality with thermal comfort.
- Economic study in-depth for these buildings excavated within slopes, in terms of initial and long run cost term. Moreover, it is recommended to perform deep studies about the life cycle cost analysis.
- Directing the research to study the physiological effect of living in an Earth-sheltered building, especially at the sleeping period, as the studies in this area are shallow and is not supported by statistics or numbers.
- Regarding people's perception, it is recommended to perform more studies about users for actual earth-sheltered buildings, not only proposed questions and their reactions about it.

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APPENDICES

APPENDICES

I. *Appendices for Chapter 3*

Appendix A: Chi- Square Test According to Nationality and Gender.

	Nationality	Gender
Prior Knowledge	**prior_knowledge** Chi-Square [a] 15.416 df 3 Asymp. Sig. .001 a. 1 cells (25.0%) have expected frequencies less than 5. The minimum expected cell frequency is 2.8.	**prior_knowledge** Chi-Square[a] 15.416 df 3 Asymp. Sig. .001 a. 1 cells (25.0%) have expected frequencies less than 5. The minimum expected cell frequency is 2.8.
Adjectives	**adjectives** Chi-Square[a] 312.107 df 11 Asymp. Sig. .000 a. 2 cells (16.7%) have expected frequencies less than 5. The minimum expected cell frequency is 3.	**adjectives** Chi-Square[a] 9.806 df 11 Asymp. Sig. .548 a. 2 cells (16.7%) have expected frequencies less than 5. The minimum expected cell frequency is 2.8.
Access (Pre-test)	**Accessing_Unit_Pre_test** Chi-Square[a] 1.829 df 1 Asymp. Sig. .176 a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 28.9.	**Accessing_Unit_Pre_test** Chi-Square[a] 2.381 df 1 Asymp. Sig. .123 a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 35.3.
Eye-Contact	**Eye_Contact** Chi-Square[a] 27.671 df 1 Asymp. Sig. .000 a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 19.2.	**Eye_Contact** Chi-Square[a] 17.498 df 1 Asymp. Sig. .000 a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 42.4.
Sun Direction	**Sun_Direction** Chi-Square[a] 571.896 df 1 Asymp. Sig. .000 a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 8.0.	**Sun_Direction** Chi-Square[a] 1.713 df 1 Asymp. Sig. .191 a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 46.6.
Entrance Approach (Post-test)	**Accessing_Unit_Post_test** Chi-Square[a] 21.230 df 2 Asymp. Sig. .000 a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 25.7.	**Accessing_Unit_Post_test** Chi-Square[a] 3.720 df 2 Asymp. Sig. .156 a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 11.3.

***Appendix A** (continued):* Chi- Square Test According to Nationality and Gender.

	Nationality	Gender
Extension Direction	**Extention_Direction** Chi-Square[(a)] 489987.688 df 2 Asymp. Sig. .000 a. 1 cells (33.3%) have expected frequencies less than 5. The minimum expected cell frequency is .0.	**Extention_Direction** Chi-Square[(a)] 1.475 df 2 Asymp. Sig. .478 a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 5.7.
Urban form (Attached-Detached)	**Attached_Detached** Chi-Square[(a)] 7.152 df 1 Asymp. Sig. .007 a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 33.7.	**Attached_Detached** Chi-Square[(a)] 4.327 df 1 Asymp. Sig. .038 a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 19.8.
Slope Gradient	**Slope_Gradient** Chi-Square[(a)] 89986.016 df 3 Asymp. Sig. .000 a. 1 cells (25.0%) have expected frequencies less than 5. The minimum expected cell frequency is .0.	**Slope_Gradient** Chi-Square[(a)] 90004.341 df 3 Asymp. Sig. .000 a. 2 cells (50.0%) have expected frequencies less than 5. The minimum expected cell frequency is .0.
(River/ Mountain) Type	**River_Mountian_Type** Chi-Square[(a)] .172 df 1 Asymp. Sig. .678 a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 32.1.	**River_Mountian_Type** Chi-Square[(a)] .548 df 1 Asymp. Sig. .459 a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 29.7.
Transition Mild	**Transition_Mild** Chi-Square[(a)] 29.692 df 2 Asymp. Sig. .000 a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 16.0.	**Transition_Mild** Chi-Square[(a)] .512 df 2 Asymp. Sig. .774 a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 24.0.
Transition Steep	**Transition_Steep** Chi-Square[(a)] 65.508 df 2 Asymp. Sig. .000 a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 8.0.	**Transition_Steep** Chi-Square[(a)] 10.260 df 2 Asymp. Sig. .006 a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 25.4.
Major	**Major** Chi-Square[(a)] 25.146 df 3 Asymp. Sig. .000 a. 1 cells (25.0%) have expected frequencies less than 5. The minimum expected cell frequency is 1.6.	**Major** Chi-Square[(a)] 14.451 df 3 Asymp. Sig. .002 a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 5.7.

Appendix B: City and Usage Preferences Chi-square test.

Chi-Square		City	Usage
All Sample		**City** Chi-Square[a] 89.561 df 3 Asymp. Sig. .000 a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 41.0.	**Usage** Chi-Square[a] 75.073 df 3 Asymp. Sig. .000 a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 41.0.
Nationality	**EGP.** **JP.**	**Nationality** / **City** **Egyptian** Chi-Square[a,b] 47.545 df 2 Asymp. Sig. .000 **Japanese** Chi-Square[a,b] 9.571 df 3 Asymp. Sig. .023 a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 33.7. b. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 15.8.	**Nationality** / **Usage** **Egyptian** Chi-Square[a,b] 73.139 df 3 Asymp. Sig. .000 **Japanese** Chi-Square[a,b] 13.000 df 3 Asymp. Sig. .005 a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 25.3. b. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 15.8.
Gender	**M.** **F.**	**Gender** / **City** **Male** Chi-Square[a,b] 65.083 df 3 Asymp. Sig. .000 **Female** Chi-Square[a,b] 31.882 df 3 Asymp. Sig. .000 a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 24.0. b. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 17.0.	**Gender** / **Usage** **Male** Chi-Square[a,b] 41.083 df 3 Asymp. Sig. .000 **Female** Chi-Square[a,b] 34.471 df 3 Asymp. Sig. .000 a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 24.0. b. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 17.0.
Specialization	**Specialist** **Not Specialist**	**specialization** / **City** **Specialist** Chi-Square[a,b] 58.571 df 3 Asymp. Sig. .000 **Not specialist** Chi-Square[a,b] 33.900 df 3 Asymp. Sig. .000 a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 21.0. b. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 20.0.	**specialization** / **Usage** **Specialist** Chi-Square[a,b] 38.286 df 3 Asymp. Sig. .000 **Not specialist** Chi-Square[a,b] 36.900 df 3 Asymp. Sig. .000 a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 21.0. b. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 20.0.

Appendix C: Cross tabulation for control variables, access pretest, and posttest

- Major * Prior knowledge Crosstabulation.

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	24.107[a]	9	.004
Likelihood Ratio	25.231	9	.003
Linear-by-Linear Association	14.261	1	.000
N of Valid Cases	164		

a.7 cells (43.8%) have expected count less than 5. The minimum expected count is .47.

Appendix C (continued): Cross tabulation for control variables, access pretest, and posttest

- Specialization * Prior Knowledge Crosstabulation.

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	18.240(a)	3	.000
Likelihood Ratio	19.081	3	.000
Linear-by-Linear Association	17.912	1	.000
N of Valid Cases	164		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 5.37.

- Specialization * Access Pretest Crosstabulation.

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	4.215(b)	1	.040		
Continuity Correction(a)	3.557	1	.059		
Likelihood Ratio	4.235	1	.040		
Fisher's Exact Test				.046	.029
Linear-by-Linear Association	4.189	1	.041		
N of Valid Cases	164				

a. Computed only for a 2x2 table
b. 0 cells (.0%) have expected count less than 5. The minimum expected count is 25.85.

- Specialization * Access Posttest Crosstabulation.

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	11.883(a)	2	.003
Likelihood Ratio	12.530	2	.002
Linear-by-Linear Association	8.513	1	.004
N of Valid Cases	164		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 12.20.

- Major * Access Posttest Crosstabulation.

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	13.412(a)	6	.037
Likelihood Ratio	15.712	6	.015
Linear-by-Linear Association	3.517	1	.061
N of Valid Cases	164		

a. 3 cells (25.0%) have expected count less than 5. The minimum expected count is 1.07.

- Access Pretest * Access Posttest Crosstabulation.

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	45.215(a)	2	.000
Likelihood Ratio	45.321	2	.000
Linear-by-Linear Association	5.795	1	.016
N of Valid Cases	164		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 8.08.

Appendix D: City and Usage choices (χ^2) test with Nationality, Gender and Specialization.

		City	Usage
		Touristic, mild climate / Beautiful, hot climate / Extreme climate / Other	Storage / commercial / Touristic / Residential
All Sample		**City** Chi-Square[a] 89.561 df 3 Asymp. Sig. .000 a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 41.0.	**Usage** Chi-Square[a] 75.073 df 3 Asymp. Sig. .000 a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 41.0.
Nationality	EGP.	**Nationality** / **City** **Egyptian**: Chi-Square[a,b] 47.545; df 2; Asymp. Sig. .000	**Nationality** / **Usage** **Egyptian**: Chi-Square[a,b] 73.139; df 3; Asymp. Sig. .000
	JP.	**Japanese**: Chi-Square[a,b] 9.571; df 3; Asymp. Sig. .023 a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 33.7. b. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 15.8.	**Japanese**: Chi-Square[a,b] 13.000; df 3; Asymp. Sig. .005 a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 25.3. b. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 15.8.
Gender	M.	**Gender** / **City** **male**: Chi-Square[a,b] 65.083; df 3; Asymp. Sig. .000	**Gender** / **Usage** **male**: Chi-Square[a,b] 41.083; df 3; Asymp. Sig. .000
	F.	**Female**: Chi-Square[a,b] 31.882; df 3; Asymp. Sig. .000 a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 24.0. b. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 17.0.	**Female**: Chi-Square[a,b] 34.471; df 3; Asymp. Sig. .000 a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 24.0. b. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 17.0.
Specialization	Special.	**specialization** / **City** **specialist**: Chi-Square[a,b] 58.571; df 3; Asymp. Sig. .000 **not specialist**: Chi-Square[a,b] 33.900; df 3; Asymp. Sig. .000 a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 21.0. b. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 20.0.	**specialization** / **Usage** **specialist**: Chi-Square[a,b] 38.286; df 3; Asymp. Sig. .000 **not specialist**: Chi-Square[a,b] 36.900; df 3; Asymp. Sig. .000 a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 21.0. b. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 20.0.

Appendix E: *Earth-Sheltered Building's Questionnaire, English form.*

* Please help us to reach the goal of the best design of Earth-Sheltered buildings for the touristic use at Egypt.

* Required

*Gender

- ○ Male
- ○ Female

Background Idea

Do you have a prior knowledge about the Earth-Sheltering system before this questionnaire? *

Don't know about it, before this questionnaire.

- ☐ I have little knowledge.
- ☐ I Have some knowledge.
- ☐ I have good knowledge.

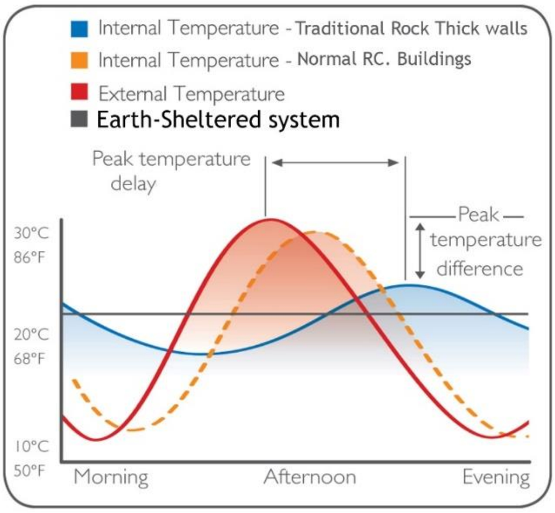
Which of the following adjectives do you think it is related with Earth-Sheltered buildings, (if it exists), Please choose what you think. *

- ☐ Dampness
- ☐ Darkness
- ☐ Coldness
- ☐ Contains Insects
- ☐ dusty
- ☐ All bad adjectives
- ☐ Calm
- ☐ warm
- ☐ Secure
- ☐ Economic
- ☐ Eco-Friendly
- ☐ All good adjectives

Please have a look before going through questions

Earth-Sheltered buildings can preserve natural landscape.

The Earth-Sheltered Building system improves thermal comfort, by delaying the peak temperature, and flattening it.

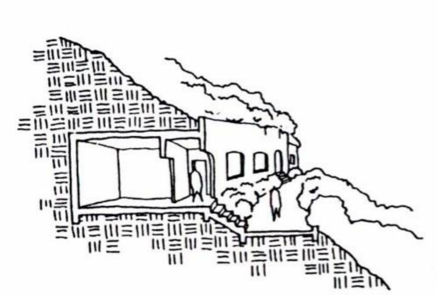


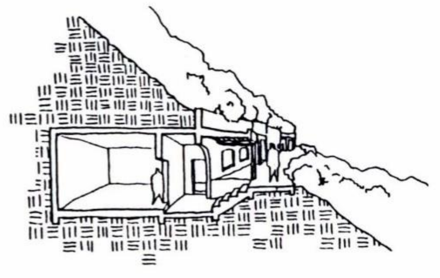
Please watch this 3 Mins. Video for the Earth-sheltering Idea

Earth-Sheltered Home

* If you are supposed to design an Earth-Sheltered building; at the Egyptian (Hot-arid) climate; which of the following design guidelines will you choose for better design!

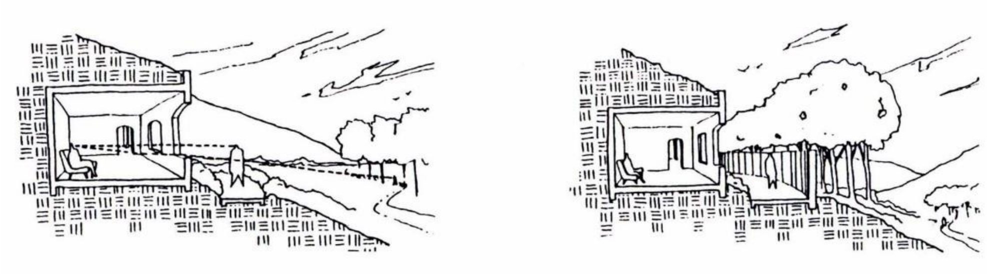
Pictures Source: Golany, Gideon S. Geo-space urban design. John Wiley & Sons, 1996.





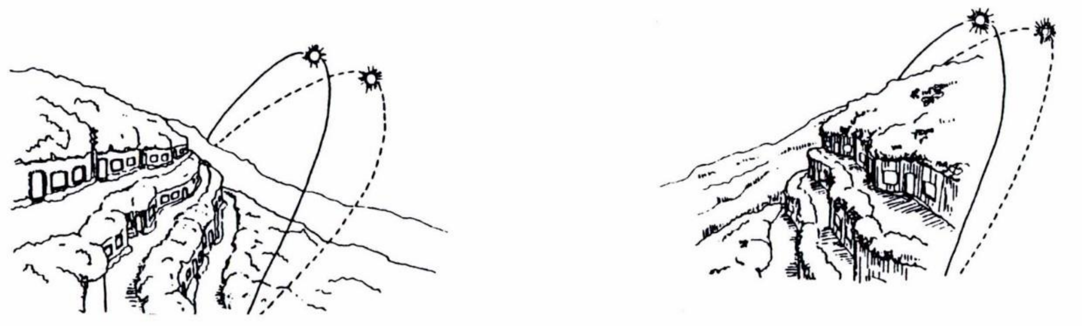
Accessing the Unit. *

- Upstairs.
- Downstairs



Eye Contact *

- Direct eye-contact
- Confined eye-contact



Sun Direction *

- Facing South
- Facing North

*Which entrance approach do you prefer the most?

*a- Downstairs. b- Zero level. c- Upstairs

- Downstairs.
- Zero level.
- Upstairs.

Which extension direction is the most suitable from your point of view?

*a- Vertical. b- Two or three levels. c- Horizontal

- Vertical.
- Two or three levels.
- Horizontal

If architects would apply the earth-sheltered Buildings, for touristic resorts, do you think which is the most suitable, attached or detached type?

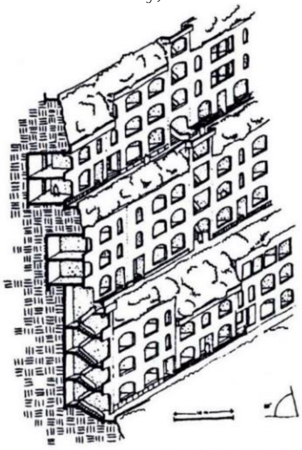
*a- Detached. b- Attached.

- ○ Detached.
- ○ Attached.

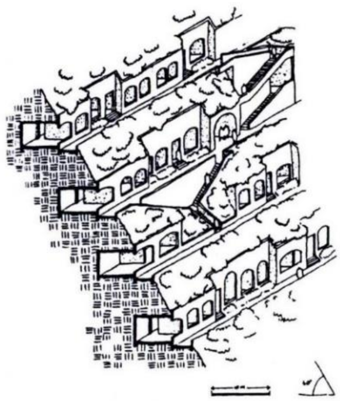
* From your own point of view: A. Which of the following urban composition forms is the most suitable for the environment, and suitable to the movement between levels from the following aspects?

*Note: (there's no right or wrong answer, just measuring people perception).

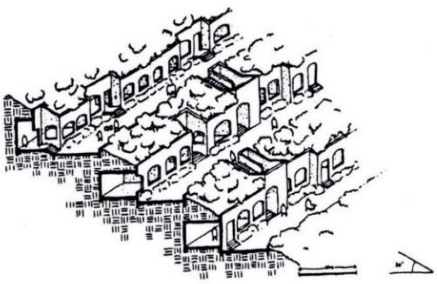
Pictures Source: Golany, Gideon S. Geo-space urban design. John Wiley & Sons, 1996.



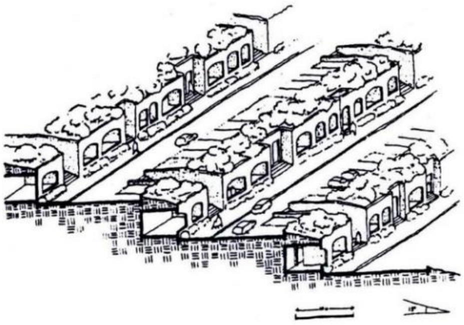
80% GRADIENT SLOPE



60% GRADIENT SLOPE



30% GRADIENT SLOPE

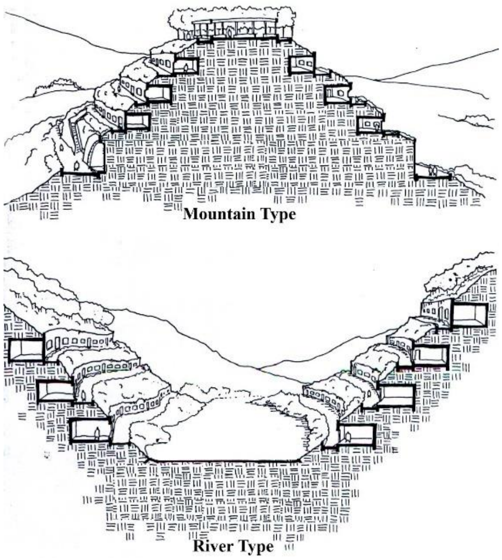


15% GRADIENT SLOPE

- ○ 80% Gradient Slope
- ○ 60% Gradient Slope
- ○ 30% Gradient Slope
- ○ 15% Gradient Slope

B. Cluster Skyline.

* Pictures Source: Golany, Gideon S. Geo-space urban design. John Wiley & Sons, 1996.

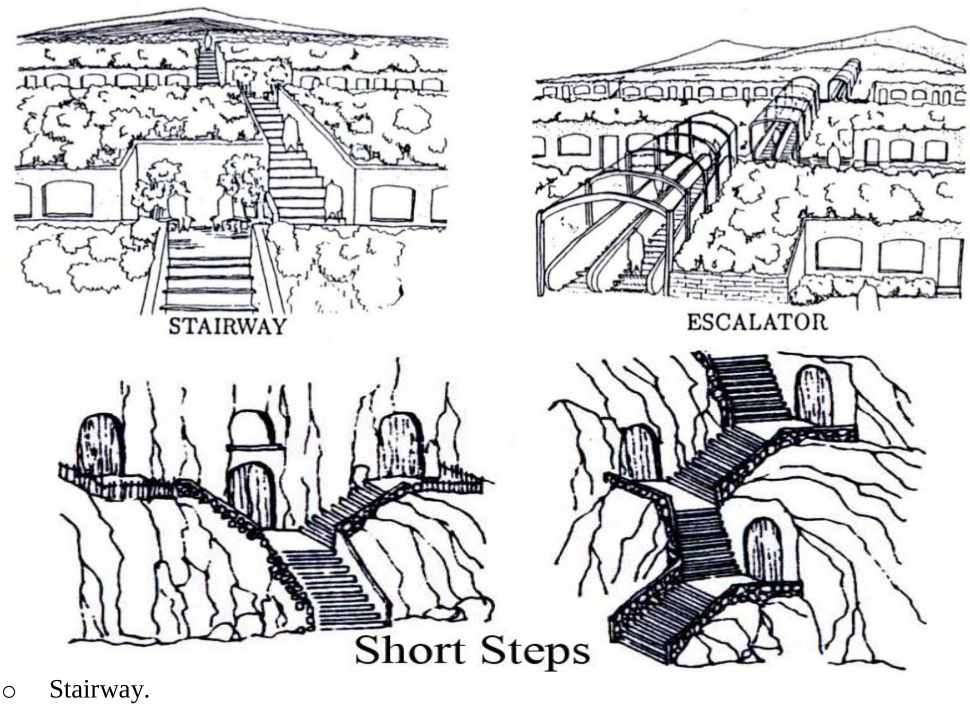


- Mountain Type
- River Type

C. Transition between slopes

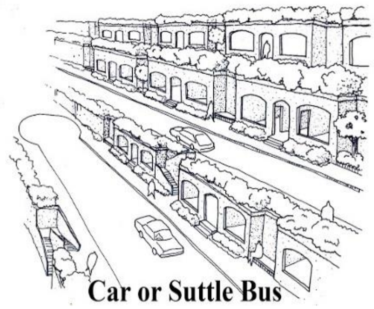
*1. Mild Slope.

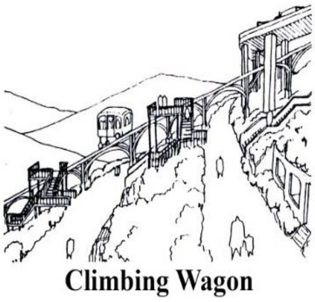
Pictures Source: Golany, Gideon S. Geo-space urban design. John Wiley & Sons, 1996.

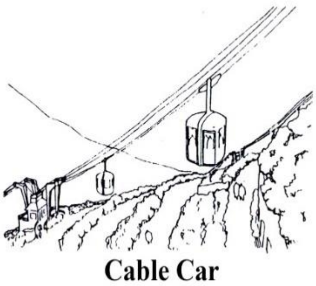


- Stairway.
- Escalator.
- Short steps.

*2. Medium and Steep Slope







- ○ Car or Shuttle bus
- ○ Climbing wagon
- ○ Cable Car

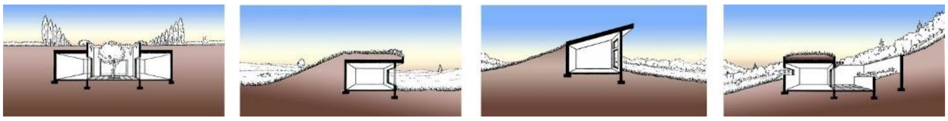
** For the following questions, please tell us about your major?

- ○ Post graduate student
- ○ Architect
- ○ University Teacher
- ○ Other.

* After you have got an idea with Earth-Sheltered Buildings, please take a look to the following cross-sections.

Pictures Source: Carmody, John, and Raymond Sterling. Earth sheltered housing design. Van Nostrand Reinhold Company, 1985.

a- Under zero level. b- At zero level. c- Above zero level. d- On the hillside.



*Please rate each of the previous cross-sections at the best cell, according to the following categories:

- ○ Best Suitable
- ○ Suitable
- ○ Needs special design considerations
- ○ Not suitable

Suitability for elderly and disabilities
(a) Under zero level.
(b) At zero level.
(c) Above zero level.
(d) On the hill side.

Suitability against crime and robbery
(a) Under zero level.
(b) At zero level.
(c) Above zero level.
(d) On the hill side.

Safety against natural hazards
(a) Under zero level.
(b) At zero level.
(c) Above zero level.
(d) On the hill side.

Suitability as a living space
(a) Under zero level.
(b) At zero level.
(c) Above zero level.
(d) On the hill side.

Suitability for fire escape

(a) Under zero level.
(b) At zero level.
(c) Above zero level.
(d) On the hill side.

Easy architectural design

(a) Under zero level.
(b) At zero level.
(c) Above zero level.
(d) On the hill side.

Economical use of air-conditioning energy

(a) Under zero level.
(b) At zero level.
(c) Above zero level.
(d) On the hill side.

Sustainability, long life span, and low required maintenance

(a) Under zero level.
(b) At zero level.
(c) Above zero level.
(d) On the hill side.

Easy access to maintenance points

(a) Under zero level.
(b) At zero level.
(c) Above zero level.
(d) On the hill side.

Economical initial cost

(a) Under zero level.
(b) At zero level.
(c) Above zero level.
(d) On the hill side.

Best structure performance for bearing loads

(a) Under zero level.
(b) At zero level.
(c) Above zero level.
(d) On the hill side.

Suitability for elderly and disabilities

(a) Under zero level.
(b) At zero level.
(c) Above zero level.
(d) On the hill side.

Suitability against crime and robbery

(a) Under zero level.
(b) At zero level.
(c) Above zero level.
(d) On the hill side.

Safety against natural hazards

(a) Under zero level.
(b) At zero level.
(c) Above zero level.
(d) On the hill side.

Suitability as a living space

(a) Under zero level.
(b) At zero level.
(c) Above zero level.
(d) On the hill side.

Suitability for fire escape

(a) Under zero level.
(b) At zero level.
(c) Above zero level.
(d) On the hill side.

Easy architectural design

(a) Under zero level.
(b) At zero level.
(c) Above zero level.

(d) On the hill side.

Economical use of air-conditioning energy

(a) Under zero level.
(b) At zero level.
(c) Above zero level.
(d) On the hill side.

Sustainability, long life span, and low required maintenance

(a) Under zero level.
(b) At zero level.
(c) Above zero level.
(d) On the hill side.

Easy access to maintenance points

(a) Under zero level.
(b) At zero level.
(c) Above zero level.
(d) On the hill side.

Economical initial cost

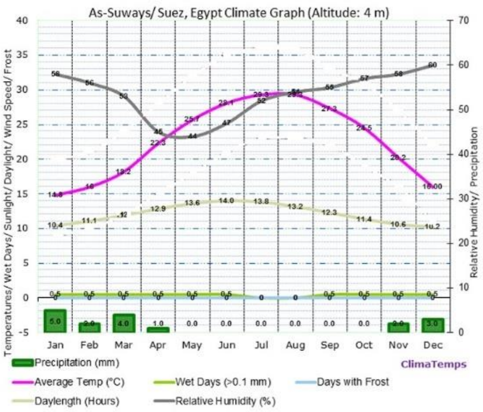
(a) Under zero level.
(b) At zero level.
(c) Above zero level.
(d) On the hill side.

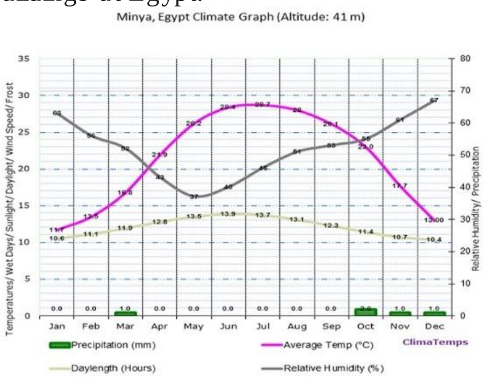
Best structure performance for bearing loads

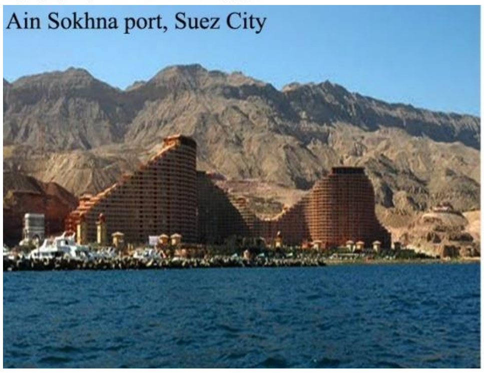
(a) Under zero level.
(b) At zero level.
(c) Above zero level.
(d) On the hill side.

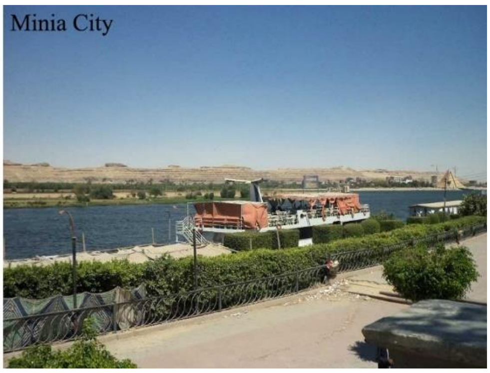
After this questionnaire, now you can decide the location for application:

Recommended Locations for Earth-Sheltered buildings at Egypt.









Ain Sokhnah Port, Suez city. Vs. Minya city.

*Which city do you recommend for better Earth sheltered building performance?

- Suez city, Ain Sokhnah port
- Minya city
- Other:

* If it is supposed that Earth-sheltered building has good thermal comfort all over the year,

*What is the most suitable use for it?

- Residential
- Touristic
- Commercial
- Storage

If you want to add something, or let us know your opinion, please write it shortly.

Appendix F:Earth-Sheltered Building's Questionnaire, Japanese form.

土壌被覆型建築物に関する質問。
観光用の土壌被覆型建築物について最高のデザインを実現するため、ご協力をお願いします。
* Required
性別 *
1- 男性
2- 女性

研究背景

土壌被覆型の建築についてどれくらい知っていますか。 *
1- このアンケートを受けるまで知らなかった
2- 少し知っている
3- 知っている
4- かなり知っている

*「土壌被覆型建築物」と聞いた時、以下のどの項目を連想しますか。 (複数回答していただいてかまいません)。
1- 湿っている
2- 暗い
3- 寒い
4- 虫がいそう
5- 汚れている
6- 上記以外にも様々な悪いイメージがある
7- 静かである
8- 暖かい
9- 安全
10- 経済的
11- 自然にやさしい
12- 上記以外にも様々なよいイメージがある

回答に入る前に一読お願いします。

土壌被覆型建築物は自然風景をそのままの状態で保つことができます。

土壌被覆型の建築様式は気温のピークを遅らせ、変化をゆるやかにすることで、温熱環境の快適性を向上させます。

3 分間こちらの土壌被覆型建築物に関する映像をご覧ください。

土壌被覆型住宅の例

あなたが日本の山で土壌被覆型建築を設計する場合、次に示すモデルのうち適切なものを選んでください。

a- 上り階段 b- 下り階段.
入り口 *
1- 上り階段
2- 下り階段
a- 開けている b- 遮られている
景色 *
1- 視界が開けている
2- 視界が遮られている
a- 南に面している. b- 北に面している

建物の方位 *
1- 南に面している
2- 北に面している

***玄関デザイン。**

a- 下り. b- ゼロレベル. c- 上り
a- 下り. b- ゼロレベル. c- 上り

1- 下り
2- ゼロレベル
3- 上り

集合化した場合のデザインについて
デザインの観点からみると、適切な高さはどれでしょうか？。

a- 高層. b- 2～3 階. c- 平屋
a- 高層 b- 2～3 階. c- 平屋
*
1- 高層
2- 2～3 階
3- 平屋

デザインの観点からみると、適切な集合のタイプはどれでしょうか？。

a- 分散タイプ. b- 集約タイプ.
a- 分散タイプ. b- 集約タイプ.
*
1- 分散タイプ.
2- 集約タイプ.

あなたの個人的視点から、次に続く項目のうち、最も環境に適しており、上下の移動に適していると思われる集合形式を選んでください。

*メモ; 主観的な意見を答えるアンケートであり、正しい答えや間違った答えはありません。

80%勾配のスロープ
60% 勾配のスロープ
30% 勾配のスロープ
15% 勾配のスロープ

B. 集合の形

*
1- 山型
2- 川型

C. 段差の間の移動方式。

1. 緩い傾斜
*
1- 階段の道
2- エスカレーター
3- 短い階段
2. 中ぐらい、急な傾斜。

*
1- 車もしくは往復バス
2- スロープカー
3- ロープウェイ

以下の質問のために、あなたの職業を教えてください。

*
1- 大学院生(建築系)
2- 建築家や建築関係の実務者
3- 大学教員(建築系)
Other

下記の断面図を見てみて、次の質問に回答してください。

a- 地下. b- 地上. c- 地上レベルより高い. d- 斜面上.
a- 地下. b- 地上. c- 地上レベルより高い. d- 斜面上.

***以下のカテゴリに従って最も適する項目を選び、それぞれの断面図を評価してください。**

1- 最も適している　2- 適している　3- 特別な設計の考慮が必要である 4- 適していない

高齢者や障害を持つ人に適している

(a) 地下.
(b) 地上.
(c) 地上レベルより高い.
(d) 斜面上.

防犯に適している

(a) 地下.
(b) 地上.
(c) 地上レベルより高い.
(d) 斜面上.

自然災害に対する安全性

(a) 地下.
(b) 地上.
(c) 地上レベルより高い.
(d) 斜面上.

生活空間に適している

(a) 地下.
(b) 地上.
(c) 地上レベルより高い.
(d) 斜面上.

火災時の避難がしやすい

(a) 地下
(b) 地上.
(c) 地上レベルより高い.
(d) 斜面上.

建築の設計がしやすい

(a) 地下
(b) 地上.
(c) 地上レベルより高い.
(d) 斜面上.

高齢者や障害を持つ人に適している

(a) 地下.
(b) 地上.
(c) 地上レベルより高い.
(d) 斜面上.

防犯に適している

(a) 地下.
(b) 地上.
(c) 地上レベルより高い.
(d) 斜面上.

自然災害に対する安全性

(a) 地下.
(b) 地上.
(c) 地上レベルより高い.
(d) 斜面上.

生活空間に適している

(a) 地下.
(b) 地上.
(c) 地上レベルより高い.
(d) 斜面上.

火災時の避難がしやすい

(a) 地下
(b) 地上.
(c) 地上レベルより高い.
(d) 斜面上.

建築の設計がしやすい

(a) 地下
(b) 地上.
(c) 地上レベルより高い.
(d) 斜面上.

***最後に、日本においてこれらの建物を建てるのに適した都市はどこだと思いますか？**

1- 那覇（沖縄県）
2- 箱根（神奈川県）
3- 札幌（北海道）
Other :

仮に土壌被覆型建築物が年間を通して快適な温熱環境を維持できるとした場合、この建物に最も適した用途は何ですか。 *

1- 住宅
2- 宿泊施設
3- 商業施設
4- 倉庫

このアンケートについて何かご意見やご質問があれば以下にご記入お願いいたします。