The Possibility of Applying the Earth-Sheltered Building Type for Housing Projects between Humid and Dry Climates - Case Study Egypt and Japan -

Hassan Ahmed HEBA
Doctoral Candidate, Department of Architecture and Urban Design, Graduate School of Human-Environment Studies, Kyushu University; Teaching Assistant, Department of Architecture, Faculty of Industrial Education, Beni-Sueif University, Egypt; hassan_kamel77@hotmail.com

Yasunori AKASHI
Professor, Department of Architecture and Urban Design, Graduate School of Human-Environment Studies, Kyushu University.

Ahmed ALY
Associate Professor, Department of Civil Engineering, Faculty of Industrial Education, Beni-Sueif University, Egypt.

Takafumi ARIMA
Associate Professor, Department of Architecture and Urban Design, Faculty of Human-Environment Studies, Kyushu University.

Daisuke SUMIYOSHI
Assistant Professor, Department of Architecture and Urban Design, Graduate School of Human-Environment Studies, Kyushu University.

The research is discussing the Earth-Sheltered building type with analytical point of view. In this context, it started by a brief definition 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. Then, the research makes a brief explanation for some case studies of this building type at both Egypt and Japan. The research 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, and Japanese slopes with its humid climate, through arguing that Earth-Sheltered housing would be more appropriate in those areas or not. Besides, it examines the adaptation of the existing application constraints of this type in both Egypt and Japan. 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, and Japanese slopes for better environment.

Keywords: *Earth-Sheltered Buildings, Environmental Design, Harsh Climate, Humid Climate.*

1. Introduction

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 (Carmody J., 1993). In addition, it can be considered environment friendly as it protects the Earth cover against desertification (Charles, G. Woods, 2000).

2. Background.

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 G., 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 (A. Al-Temeemi, 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, James, 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 G. & Toshio Ojima, 1996; Carmody J. & Sterling R., 1993).

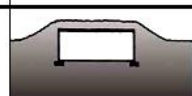
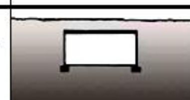
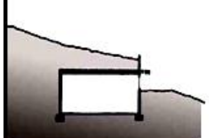
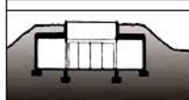
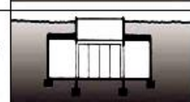
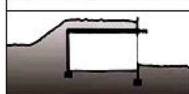
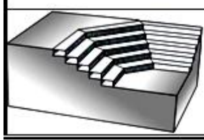
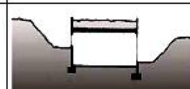
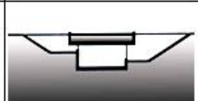
2.1 Brief Definition and Types.

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 is usually existed above zero level but is covered with a soil layer.

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).

So, studying the types and classification procedures is very important before going deep though the research in order to see the possibility of taking advantage of the geo-space for the design purpose either functionally or aesthetically, table 1.

Table 1 Classification of the Earth-Sheltered building type. (Hassan Ahmed, Heba, MA. 2009, P. 7)**.**

(On the Hillside)	(Bermed)	Underground or Earth-covered	← Relation to surface / ↓ Kind of opennings
			(Chamber)
			(Atrium)
			(Elevational)
			(Penetrational)

2.2 Opportunities and Constraints.

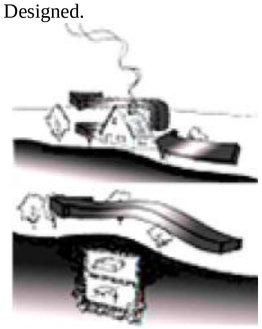
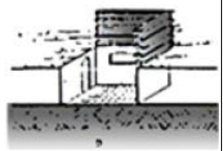
There are many opportunities of the Earth-Sheltered building system we can make use of it. On the other hand, the drawbacks of this building type which we can avoid with good design, are focused on the main reason for refusing to be underground specially (psychologically and physiologically), and how to overcome these bias, table 2.

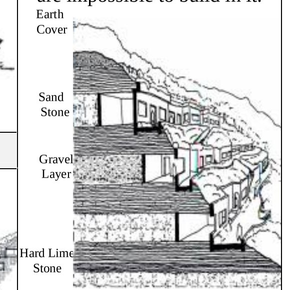
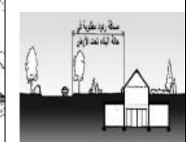
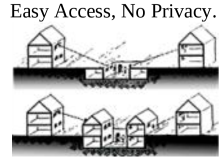
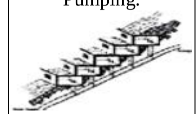
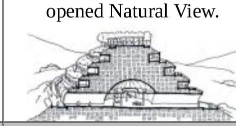
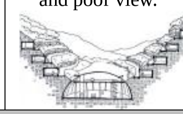
2.3 Quick Overview of Contemporary Use

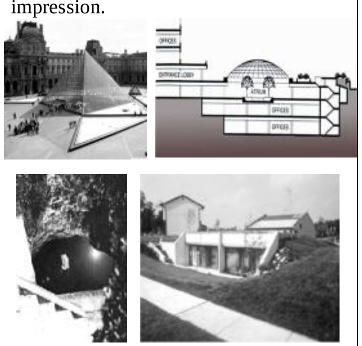
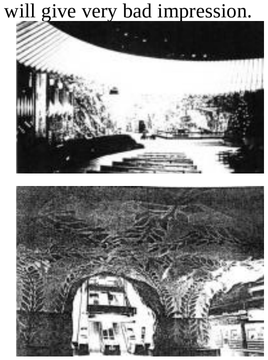
The Earth-Sheltered Architecture has been commonly used worldwide within the Housing sector rather than the public one (Carmody J. & Sterling R., 1985).

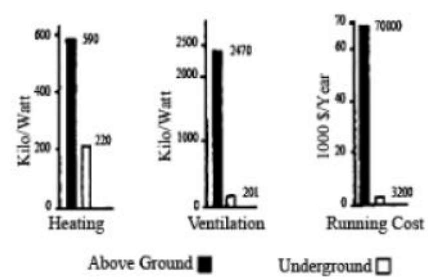
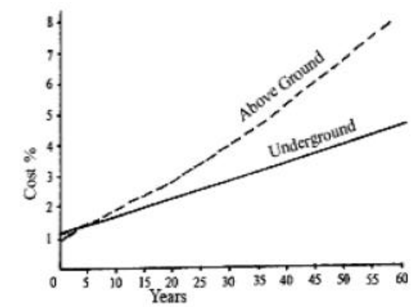
Sterling supports this note, when he made several studies on workers at factories, libraries and governmental buildings.

Table 2 Evaluating Opportunities and Constraints related to Earth-Sheltering. (Source: Golany G., 1983& 1996, Carmody J. 1993, Hassan H., 2009)

1- The Effect of Being Underground		
Climate	**Natural Hazard Protection**	**Security**
Isolation from Harsh Climate. Poor Ventilation if not Properly Designed. 	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. 	High Security at all levels, but Poor signals.

2- Selecting Site			
Topography		**Geology**	**Site Planning**
Flat	Sloped	Some Geological Structures are more Suitable, But others are impossible to build in it. 	It needs 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. 
Easy Access, No Privacy. 	Good Sewage, difficult water Pumping. 		
Opened	Closed		
Good Ventilation and opened Natural View. 	Poor Ventilation and poor view. 		

3- Building Design and Aesthetics.	
Outdoors	**Indoors**
Keeping Historical places site theme without big change, but if Entrances not designed well, it will give very bad impression. 	It enables creative environment to Designers, but if poor designed, it will give very bad impression. 

4- Economical Issues.	
Initial Cost	**Long Run Cost**
Is very high, but if we can use the Mountain Rocks as a building material, it will lower the initial cost. 	Is very low compared with Conventional buildings, but if poor designed it will raise maintenance cost. 

5- Physiology and Psychology.	6- Building Codes and Low.
- Physiologically, poor ventilation affect 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.	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.

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 (Carmody J. & Sterling R., 1993).

However, Ojima conducted many researches on workers at Japanese libraries, he gain a very good results of satisfaction about the working environment they are working at (Golany G. & Toshio Ojima, 1996).

This paper will concentrate 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, such as the one discussed below.

Fig. 1 Eric Earth-Sheltered Home.

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 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. 1, (http://www.joe-davis.com).

3. Method

The research methodology can be divided into Analytical and Statistical, Qualitative and Quantitative. This kind of research is Analytical research (Qualitative type). So it will concentrate on analyzing case studies about the Earth-Sheltered construction from different climates (Egypt and Japan), to measure the application possibility and suitability.

3.1 Earth-Sheltered buildings at Egypt

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 dugging it into the mountains like Abu Simple and Hatshepsut temples Fig. 2.

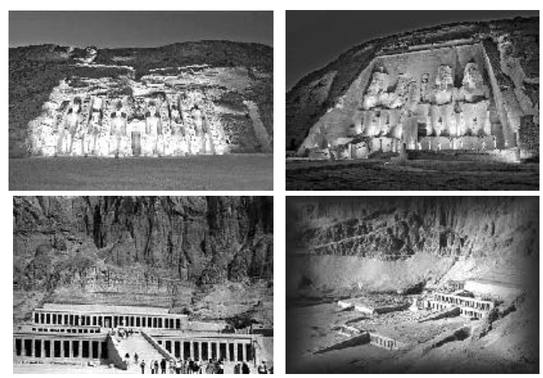


Fig. 2 Abu Simple above, Hatshepsut under.

Pharoses understand that it will be cooler than the outside atmosphere at this very hot city (Luxor). Later on, Egyptians found other tombs at Siwa city. But, they did not found dead people at it. So, they used it later as homes. It is called the Death Mountain (Gebel El Mawta) Fig. 3 (http://lexicorient.com/egypt/siwa05.htm).

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

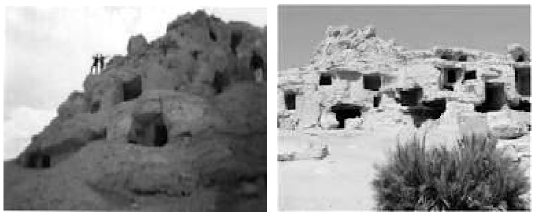


Fig. 3 Mountain of the Death, Siwa, Egypt.

But, people refused to live at the new village, as it is similar in style to the tombs. Unfortunately, now there is no one at both villages Figs. 4, 5 (http://www.waseda.jp/prj-egypt/sites/Qurna/)

Fig. 4 Old Qurna village, carved into rocks.

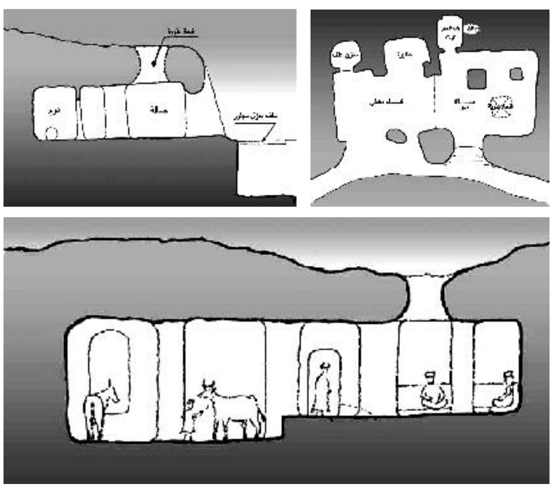


Fig. 5 Cross-Section and plan of old village.

The researcher believes that it would be more suitable from the climate change situation and the energy saving aspects, to apply the Earth-Sheltered building style at Egypt with its new contemporary appearance. But, this step needs a lot of studies before starting, like energy saving extent, people perception acceptance, ability of application, and choosing the appropriate place for application. These studies need a research tools like a survey questionnaire, and using simulation programs to measure the thermal loads and energy saving extent. This will be done at further research.

3.2 Earth-Sheltered buildings at Japan

We can find Earth-Sheltered construction at Japan, but it is very rare. The researcher noticed that, although it is used, but it is not used alone. In other words, it is integrated with above conventional buildings. This means that, there is no complete self-standing Earth-Sheltered construction at Japan; they only use it as basement or a complementary part with the home. As a result, although there is no negative psychological attitude to live underground like Egyptians do towards the Earth Shelter; the wrong use and application created negative attitudes from Japanese people towards the Earth-Sheltered construction. The Japanese use the basement part of the building as a complementary part of the home, while it is forbidden at Egyptian building low to live at the basement; they only use it as a storage areas or parking, sometimes commercial use, but not for living.

Back to Japan, people living at basements suffer from high humidity level, darkness, dampness, and miss feeling of time according to the isolation feeling, (Kazumori & Yuske, 2004).

For example, one case study has basement as a living room and dining above ground, Fig. 6. (Mariko et. al., 1999).

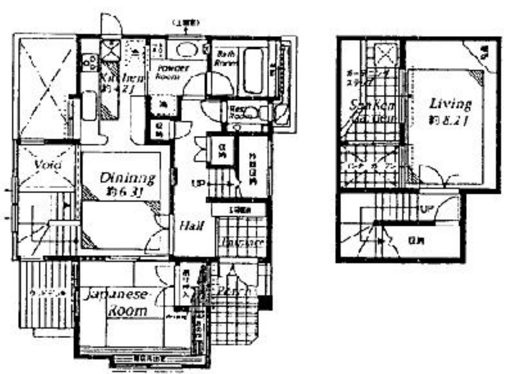


Fig. 6 Japanese Room and Dining with Basement.

This building suffers from dampness and high humidity level, especially at summer season.

The researcher suggests magnifying the cross ventilation at the basement, for instance opening the intermediate wall between the sunken garden and the stairs, this will maximize air movement and reduces the humidity level in order.

The cross ventilation effect can be noticed in another example; Fig. 7, where the spiral stair makes an air circulation movement inside the building. Therefore, it contributes in reducing the humidity level. As a result, people at this house are feeling sufficient environment to live there, (Mariko et. al., 1999).

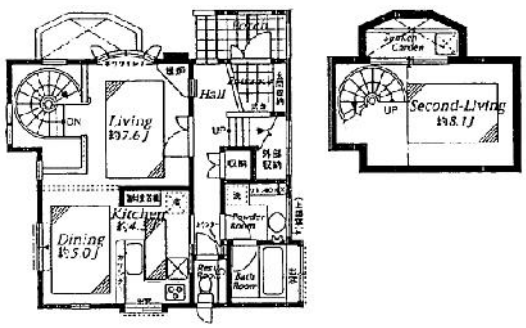


Fig. 7 Living and Dining with Basement.

Kazumori made a questionnaire with Japanese people to measure their attitudes towards basements after they have been living in it for a period of time, Fig. 8. (Kazumori & Yuske, 2004). The most important item measured was the energy saving (HVAC), the ability of ventilation, and the day lighting of main room.

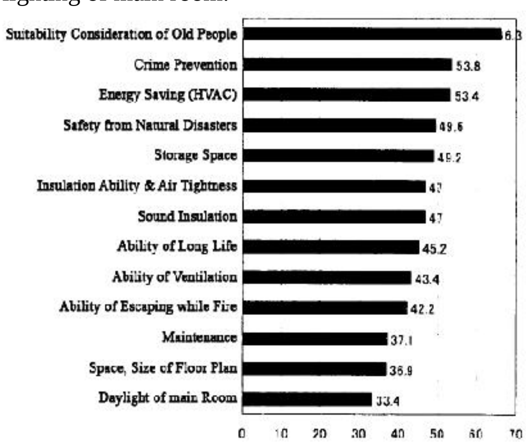


Fig. 8 Questionnaire Results for Attitudes Towards Basements.

To analyze this; the researcher thinks that if we can maximize the ability of ventilation and day lighting of main room; this will gain more sufficient attitudes. This can be obtained if the Earth-Sheltered construction is stand-alone building; not as a basement. In other words, if the building is above zero level not underground, with using of complementary architectural ways of cross ventilation, or passive ventilation like Shafts; this will contribute on better thermal performance, and better people acceptance.

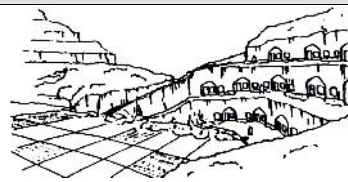
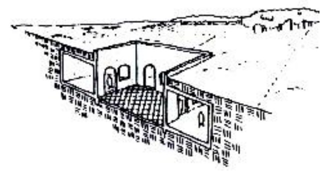
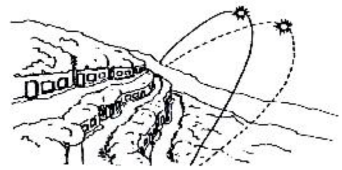
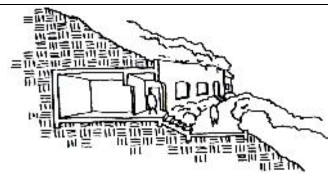
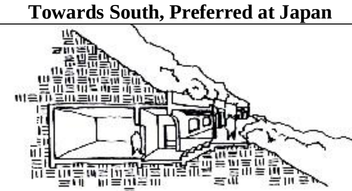
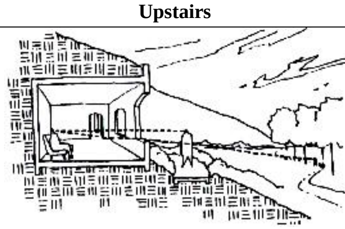
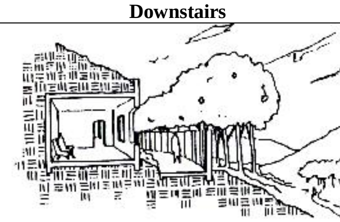
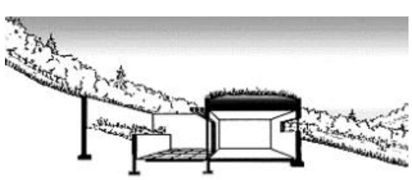
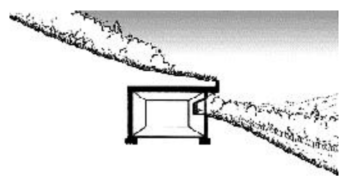
4. Results

4.1 Recommended Adaptation

The research recommends some placements and design guidelines for architects, when building an Earth-Sheltered construction, Table 3:

- About selecting the site to build on; it is preferable to build on slopes rather than flat sites. Slopes have many advantages related with 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. At 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 Natural View and eye contact; it is preferred to have direct eye contact with outer environment; the closed view raise the confinement feeling.
- Natural Ventilation is very important issue, especially at Japan case. If it is not available; they can use negative ventilation by suction effect, but to count on one façade it is not good for ventilation.

Table 3 Adaptation Design Guidelines for Architects. (Source: Golany G., 1996, Carmody J. 1993, Hassan H., 2009)

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

4.2 Application Possibility Guidelines

In order to measure the application possibility, there are many aspects that architects should measure each one as a very important issue, in order to gain realistic view. Al-Temeemi had listed some steps (A. A. Al-Temeemi, 2004). But, the researcher thinks that there are more to measure:

1) Accessibility, it can be measured by studying urban maps and choosing the appropriate site which is near to natural resources and infrastructure.
2) Geology should have been measured through studying the Soil structure maps. Because, wrong decision to choose a site with inappropriate soil structure; could lead to a catastrophe. Like what happened at Muqattam Mountain, 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 at Sep. 6, 2008, (Nadin, Al-Masry Al-Youm newspaper, 2008).
3) Acceptability should be measured by making a survey questionnaire; in order to measure people's attitudes towards these buildings.

4) Thermal Comfort can be measured by simulation programs. And, the sense of thermal comfort is different from country to another; according to people's perception of heat and cold.
5) Energy Saving can be measured by Energy monitoring and calculating the actual Energy saving; in comparison with conventional buildings. If the Earth-Sheltered building is not existent; the Energy saving extent can be measured also by simulation programs.

5. Conclusion

The Earth-Sheltered Architecture is not a new style of buildings; it has been used long time ago. Nowadays, architects are reusing the same concept with new appearance. The application at Egypt has many obstacles, mainly the psychological one. On the other side of the world at Japan, the application has one big problem; which is the high humidity level if not properly designed. In an attempt for application at both countries; there must be extensive studies to measure the success extent, using different tools like survey questionnaire and simulation programs to measure thermal load at both countries. The research created application guidelines for architects to measure the application possibility anywhere. Also, it demonstrates recommended adaptation for better performance.

Acknowledgment

This research is a part of fulfillment for PhD. Degree work about measuring the suitability of applying the Earth-Sheltered buildings at different conditions; case studies Egypt and Japan.

The researcher would like to give deep thanks to Ritsuko Imai, undergraduate student, Kyushu University, and Satushi Ueda, master student, Kyushu University, for their sincere help in providing the research with Japanese case studies, and with translation of some parts into English. Without their help, this work would not be done.

References

A. A. Al-Temeemi, Harris, D. J., (2004). A guideline for assessing the suitability of earth-sheltered mass-housing in hot-arid climates. *Energy and Buildings* ***36***, 251-260.

Carmody J. & Sterling R.,
i. (1985). Earth Sheltered Housing Design, The Underground Space Center, University of Minnesota, Van Nostrand Reinhold. NY.
ii. (1993). Underground Space Design*: A Guide to Subsurface Utilization & Design for People in Underground Spaces.* Van Nostrand Reinhold. New York.

Charles, G. Woods, (2000). A Natural System of House Design, An Architect's Way, MC. Graw-Hill, New York.

David Vaughan, Fall (2009). Earth Sheltering; *A Precedent for the Desert.* Thesis, Committee: Dr. Chalfoun (chair, Architecture), Brittain (Architecture), and Gerstle (Architecture).

Golany, G.
i. (1983). Earth Sheltered Habitat: *History, Architecture & Urban Design.* Van-Nostrand Reinhold Company. New York.
ii. & Toshio Ojima, (1996). Geo- Space Urban Design, John wiilly & Sons Inc., New York.

Hassan, H. (2009). Analytical Study of Earth-Sheltered Construction and its Suitability for Housing Projects in the Egyptian Deserts. Thesis, Committee: Dr. M. Nabawy, Dr. M. Ajmy (Architecture, Egypt).

Kazumori, S., Yuske, N., (2004). Research and study about the environmental performance of living in the basement. *Kanto's (Eastern part of Japan) branch-office report. 4025 Japan Architecture Meeting.*

Mariko, A., Tomoda H., Taguchi Y., (1999). Design Method of Basement in Housing and its Significance, *Some findings on the three dimensional space Cosmopolitan of Housing, 5.*

Nadin Q., Al-Masry Al-Youm newspaper, (2008). (http://today.almasryalyoum.com/article2.aspx?ArticleID=180312).

Wines, James, (2000). Green Architecture. Taschen. London. New York.

http://www.joe-davis.com

http://lexicorient.com/egypt/siwa05.htm

http://www.waseda.jp/prj-egypt/sites/Qurna/