Measuring the Possibility of Living in the Earth-Sheltered Building Type between Egypt and Japan

Heba Ismail[1,*], Takafumi Arima[2], Aly Ahmed[3], Yasunori Akashi[4]

[1, 3] *Department of Architecture, Faculty of Industrial Education, Beni-Sueif University, Egypt.*
[2]*Department of Architecture and Urban Design, Graduate School of Human-Environment Studies, Kyushu University, Japan*
[4] *Department of Architecture, Graduate School of Engineering, Tokyo University, Japan*
** Corresponding author. Tel: +20 1140565588, Fax: +20 822241932, E-mail: hassan_kamel77@hotmail.com*

Abstract: The Earth-Sheltered building type has been widely spread all over the world. And the most effective performance for this kind of buildings was found to be with harsh climate. However, recently it is neither used in Japan nor in Egypt. The research is discussing the possibility of dealing with the Earth-sheltered building type with analytical and statistical point of view. Therefore, it is divided into two parts with different methodologies (analytical method and statistical method). It started by analyzing the benefits and drawbacks which are related with this type in general. Afterwards, discussing the motives of applying this kind of building at both Egypt and Japan as well. Then it is discussing the application constraints, which might hinder the optimal performance of these buildings at both countries. On the second part of the research, it used the questionnaire survey method to assess the architects' attitudes towards this kind of building as a living space, from different aspects. Finally, the research recommends some applicable architectural design aspects to be considered for application at the hot-harsh climate like Egypt case, and others at the cold-humid climate like Japan case.

Keywords: *Sustainable Development, Environmental Design, Earth-Sheltered Buildings, Hot- Harsh Climate, Cold- Humid Climate.*

1. Introduction

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

The energy problem at Egypt is growing higher every year, especially the electricity consumption from the residential sector by comparison with the Industrial sector. It could be noticed clearly every ten years by studying the future scenario at 2020 Fig. 1 [1]. It is expected to grow up to extreme level, if we did not control such consumption.

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. Like the case at the new village of "Gorna"; designed by the great architect "Hassan Fathy"; which had been immigrated.

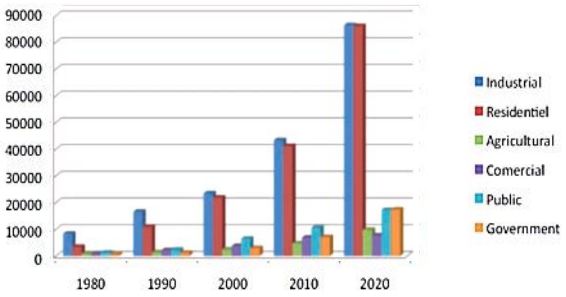


Fig. 1. Electricity Consumption by Major Sectors (MWh).

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. Definition

Earth sheltering: ***"****is the architectural practice of using earth against building walls for external thermal mass, to reduce heat loss, and to easily maintain a steady indoor air temperature"*. [2]

2. Background

It is obvious that any new community would be divided into several land uses. The main land use is usually found to be the domestic one. According to the previous belief, it could be said that: if it is desirable to lower the cost of the urban community as a whole; then we should mainly lower the cost of the housing sector [3].
The previous objective could be reached by the mass production system. Therefore, even if the initial cost of the building is high; it will be economic on the large scale.
Still the question of which kind of building types could be suitable, in the extreme climate! Besides, achieving the objective for the building to be more economic [4].
The research suggests using the Earth-sheltered building system. It is not a new system, nor extinct. It had been used through the history all over the world.
Moreover, it has been reused recently with more modifications to meet the recent necessary needs, Fig. 2, 3. [5][6]

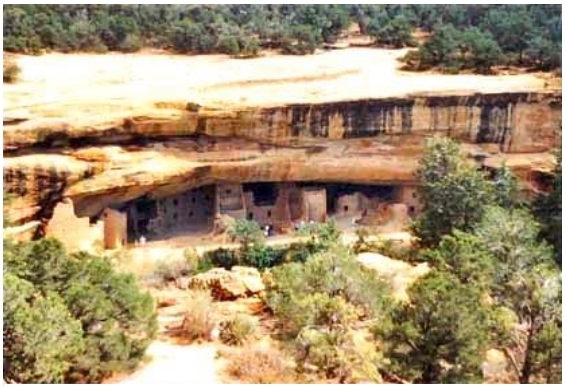


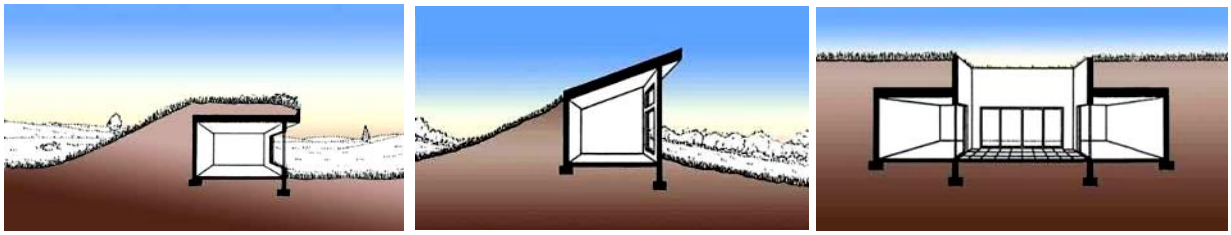
Fig. 2: The hill itself protects Mesa Verdi area and buildings from undesired wind.

Fig. 3: integration with the natural form of the surrounded hillside.

The modern examples use the same concepts used in the traditional vernacular architecture by more developed technology, such as the houses in Spain, Armington and Minnesota in USA, Canada [7].
Recently, it started to depend on electromechanical tools for lighting and ventilation [8].
The Earth-sheltered system had been commonly used worldwide within the housing sector rather than the public one.
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. Also, the air quality was relatively poor [5].
However, Ojima conducted many researches on workers at Japanese libraries; he gained very good results of satisfaction about the working environment [9].
The Earth-sheltered architecture has some special basic characters (its classification, advantages and disadvantages).

- *Classification:* its various types; Bermed, Semi-Bermed, patio type (Underground), Fig. 4 [10].
- *Benefits and Drawbacks:* The research treats most of the direct and indirect potentials and benefits of the Earth-Sheltered system, and presents also drawbacks of this type of building in which we can avoid with good design. With concentration on the main reason of refusing the idea for being underground especially psychologically, and how to overcome these bias.

Recently, this type of buildings has been reused with different treatments and proper design considerations. They differ from one site to another and from climate to another.
In order to optimize the Earth-sheltered architecture, some design considerations should be followed, which are classified into two major categories and other additional sub-categories:



A. Bermed type B. Semi- Bermed type C. Patio type

Fig. 4: Different types of the Earth-Sheltered buildings.

- *Urban considerations:* they include the site selection, climate, soil, hydrology, environmental quality, accessibility and proximity to resources, utilities, shape of urban cells, distribution, composition, and direction to the wind, land uses and the form of urban cells, orientation from sunshine, and vegetation with its effect on sunshine and wind.
- *Architectural considerations:* zoning (distribution, direction priorities of various spaces, entrance design and its relation to the surface). Environmental considerations: with (planning, walls, roof shape, direction, optimum opening areas). Energy considerations: (Earth coating, isolating, frequency of soil temperature, passive solar tools and its suitability). Visual and sound considerations: (visual privacy, visual contact with outside, noise isolation). Construction considerations (soil bearing, water content, materials, walls, roof shapes).

The attempt to apply these perspectives appropriately to our society exceeds the negative effects that hinder its use; by realizing the optimum utilization of subterranean space as a logic alternative to be taken into consideration [11].

Within the Egyptian context, the desert presents about 95% of the country's total area [12]. Although many studies asserted the appropriateness of this building system within the extremely harsh climates [13] [14] [15]; likewise the case at the Egyptian deserts; no contemporary use of such system had been observed across Egypt [9].

Within the Japanese context, the mountains slopes represent the majority of the country's area; but the Earth-sheltered construction is very rare. The researcher believes that it would be more appropriate, if this type of buildings started to spread at the touristic use before applying it at the domestic one. It could be a trial or pilot application, before applying it at a broad range of the housing sector in the new desert urban communities [16].

The research tries to investigate whether the Earth-sheltered construction system would be suitable for usage with the domestic use at the Egyptian desert and the Japanese slopes or not. Therefore, it is going to examine the validity of this hypothesis.

3. Methodology

According to the research nature aimed to identify the Earth-sheltered building characteristics, where it is considered to be unfamiliar scope for large number of Egyptian and Japanese architects, the "Exploratory research type" had been chosen for this study. Therefore, the research is trying to explore the possibility of applying this type on the residential sector at the Egyptian deserts and Japanese slopes within an imaginary scope.

Regarding the way dealing with the research topic; which is going through the general idea (Earth-sheltering) to the specific one (the possibility of applying it to the residential sector at the Egyptian deserts and Japanese slopes); the "Deductive approach" had been chosen.

Testing the research hypothesis; it is based on both (qualitative), and (quantitative) approaches at different stages.

The (qualitative approach) is represented in the stage of examining the architectural criteria for applying the Earth-sheltered buildings at the harsh hot or cold climate.

The (quantitative approach) is represented in the psychological response for both Egyptians and Japanese about living at such buildings, which can be measured by the questionnaire that discusses these topics.
The research is conducting a pilot investigation for the survey. It will be with a group of architecture students to identify any problems the interviewer or respondent may have, for example with understanding of specific questions, before the full application is done. It is noted that the photo-interviewing technique can be particularly helpful for pilot-stage where innovations and enhancement modifications are needed [17], [18], [19].
The Methodology limitations could be represented in:

- None of the proposed sample had lived or dealt with the Earth-sheltered building system, this will make the answers a kind of imagination. Despite of the visual proposed questionnaire, but it would be more reliable and valid if the sample had dealt with this system before.
- This building approach is relatively new within the Egyptian and Japanese context, so there could not be a true experiment test for the internal thermal behavior. It will be only by suggesting architectural aspects, which may not be very typical to the reality.

4. Results

The significant outcomes of this research could be summarized into three main categories: Analyzing the benefits and drawbacks; Finding architectural solutions for some application constraints; and analyzing the questionnaire outcome.

4.1. Analyzing Benefits and Drawbacks

The benefits and drawbacks could be divided into six main categories; each one has its sub aspects. Analyzing the effect of being underground; the site selection issue; the building design and aesthetics issue; economical issues; physiological and psychological issues; and finally the building codes and low issue, Table 1, [20].

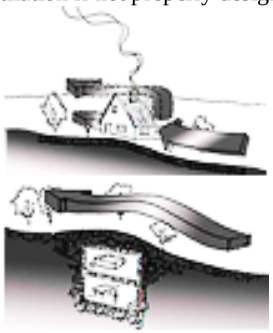
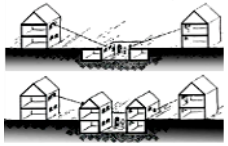
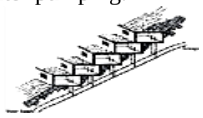
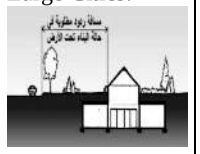
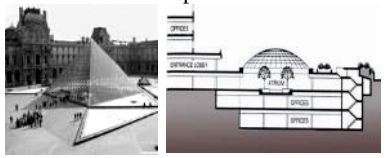
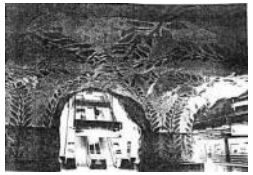
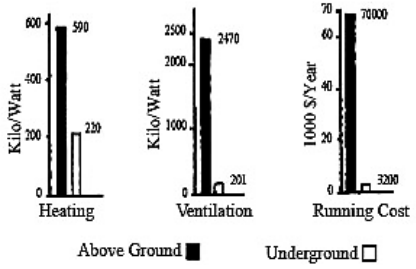
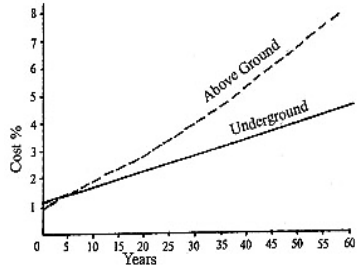
4.2. Applicable Architectural Recommendations

Here are recommendations regarding some application obstacles in detail that might face this type of buildings if applied in Egypt. Beside, suggesting proposals to overcome some of these problems.

4.2.1. Design limitations that affect the performance.

- *Exposure to the accumulation of sand, dust, and floods*: Due to the nature of the desert areas at Egypt and at the heavy rain at Japan; the buildings may be exposed to the accumulation of sand or rain water, Fig. 5. Therefore, the research suggests designing the courtyard to be opened with three sides only, and the level of the surface would be above zero level or designing the building with one façade and direct it away from the wind.
- *Visual features of the urban design:* if the building is totally underground, this may leads to the lack of the skyline and the absence of landmarks. That problem could be eliminated by the integration between buildings up and down, Fig. 6.
- *Dampness:* If the building is not well designed it will suffer from dampness, which may cause the insects habitation, especially at the desert areas, like Egypt case. Therefore, it's suggested to protect the openings with tiny mesh sheets to allow air ventilation and protection from insects if any. On the other hand, dampness can cause the existence of fungus (black or green) at the humid areas, like Japan case. The best action to avoid that is the good cross ventilation, as discussed later.

Table 1. Evaluating Opportunities and Constraints related to Earth-Sheltering.

<table>
<tr><th colspan="3">1- The Effect of Being Underground</th><th colspan="4">2- Selecting Site</th></tr>
<tr><th>Climate</th><th>Natural Hazard Protection</th><th>Security</th><th colspan="2">Topography</th><th>Geology</th><th>Site Planning</th></tr>
<tr><td rowspan="2">Isolation from harsh climate. Poor ventilation if not properly designed
  </td><td rowspan="2">High protection from natural hazards like (earthquakes, floods, sandy storm, fire).
If entrances were not well designed, it will be flooded, buried or smoke confined.
  </td><td rowspan="2">High security at all levels, Poor signals.</td><td>Flat
Easy access, no privacy.
  </td><td>Sloped
Good sewage, difficult water pumping.
  </td><td rowspan="2">Some geological structures are suitable, but others are impossible to build in it.
  </td><td rowspan="2">Needs more in-between distance above zero level, but will be suitable underground at Large Cities.
  </td></tr>
<tr><td>Opened
Good ventilation, open view.
  </td><td>Closed
Poor ventilation, poor view.
  </td></tr>
<tr><th colspan="3">3- Building Design and Aesthetics.</th><th colspan="4">4- Economical Issues.</th></tr>
<tr><th colspan="2">Outdoor</th><th>Indoors</th><th colspan="2">Initial Cost</th><th colspan="2">Long Run Cost</th></tr>
<tr><td colspan="2">Reserving historical site theme, but if entrances not designed well, will give very bad impression.
 
  </td><td>Enables creative environment to designers, but if poor designed, will give very bad impression.
 
  </td><td colspan="2">Is very high, but if we can use the mountain Rocks as a building material; it will lower the initial cost.
  </td><td colspan="2">Is very low compared with Conventional buildings, but if poor designed it will raise maintenance cost.
  </td></tr>
<tr><th colspan="3">5- Physiology and Psychology.</th><th colspan="4">6- Building Codes and Low.</th></tr>
<tr><td colspan="3">- Physiologically, poor ventilation affect air quality, 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.</td><td colspan="4">The 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.</td></tr>
</table>

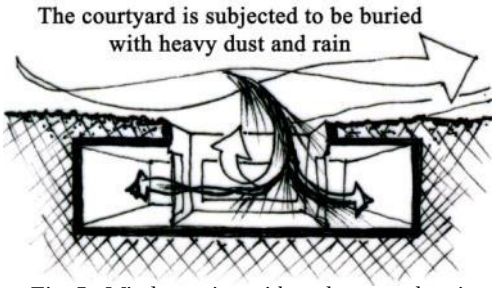


Fig. 5. Wind reaction with underground patio type Earth-Sheltered building.

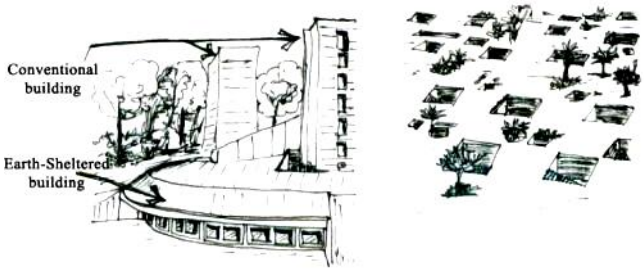


Fig. 6. Not recommended to be totally underground, the integration is more preferable.

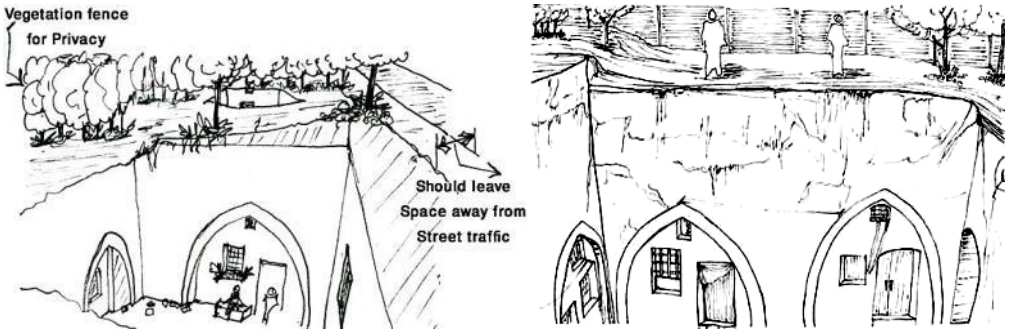


Fig. 7. When a House is Next to the High Way, it should be considered the Existence of Fence to Maintain Privacy and Prevent things to drop in the Patio.

- *Privacy:* There are different types of Earth-Sheltered construction, not all of them provide good privacy to the users. It is very important to the Egyptian people. The patio type of the Earth-sheltering, especially when it is located totally underground, has very week privacy. Unless, protecting the unit from the street dust and the vehicles noise and harmful vibrations to the building unit, Fig. 7.
- *Construction at Humid Areas:* Special concern should be subjected to ventilation especially at the humid areas, like the Japanese case. It's better to be cross ventilation rather than the normal one. If the design couldn't afford the normal cross ventilation; it's recommended to use forced ventilation, like light mechanical fans and shafts for air suction, Fig. 8.
- *Construction in mountainous areas:* To build on the steep slopes; it has some applicable limitations, that can be avoided by good design guidelines, if well applied:

- The steeper the slope, the more need to use stronger water supply pumping system

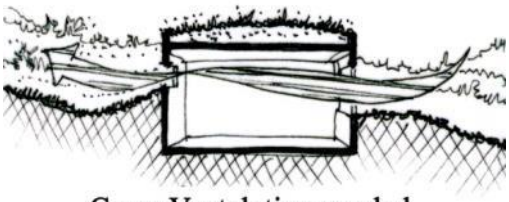


Fig. 8 Earth-Sheltered considerations at the Humid Climate

- The higher the site would be, the higher the cost for constructing roads would be. To lower the accessibility cost it's highly recommended to use the mass construction system, which contributes in making the road cost more economical.
- Some sites with open geomorphologic formations at the mountains could suffer from strong wind or rain, and may be subjected to erosion and landslides, or internal cracks with soil. Therefore, these places should be avoided from the beginning to build on it.

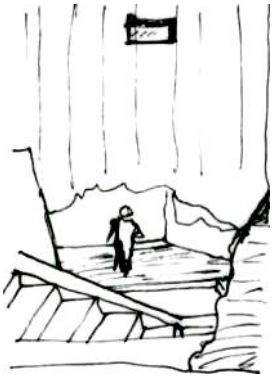
4.2.2. Psychological bias

The main psychological bias that is expected to occur with the Earth-sheltered buildings, especially with Egyptians:

- The relationship between being under a ground cover and the negative image related to death and burring, where it's difficult to adapt people with the closed environment underground without direct visual contact with the open sites like conventional buildings. Moreover, the fears of confinement during fire or during earthquakes like Japan.
- The research suggests to overcome this problem that people experience this kind of buildings as an experimental period of time with a good designed model, like small sized clusters of worker villages, or nice hotels or motels, which avoids the previous defects. This may help to accept the idea little by little, and remove the negative image deep rooted in the minds.
- There are some design guidelines to be considered; which may help in accepting the living in an Earth-sheltered building:
  - The entrance to be upstairs not downstairs, Fig. 9.
  - Having normal building façade like conventional building.
  - The existence of focal reference points with the outside environment, Fig. 10.
  - The natural light to reach every point on the building unit even if direct light was not available, Fig. 11.
- As mentioned earlier, those are not all the potential problems; these are the most expected ones. The real problems could be measured after the real experience, at least an experimental model as a start, as an essential step before the real application takes place with the residential use.

4.3. Questionnaire Design and Outcome

Regarding the Egyptian architects reactions, this research is conducted to ask them more specialized questions. This purposive sample was architecture university students, they went through the questionnaire in one place in the Arabic language, they responded to 23 questions in total. Their age's ranged from 19- 22 years, 33% were males and 67% were females, 50% had a prior knowledge about the Earth-sheltering system, and the other half had not.



Fia. 9. Bad Entrance Downstairs

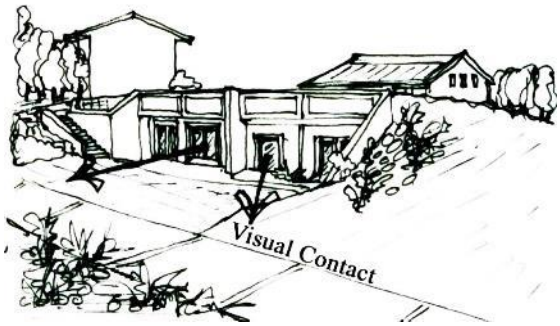


Fig. 10. Visual Contact Improves the Psychological acceptance of these Buildings

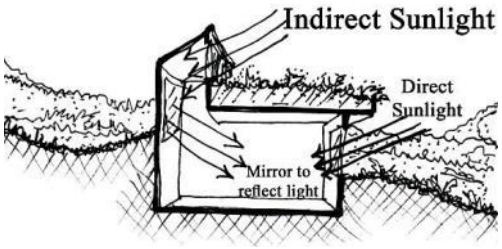


Fig. 11. Top openings to catch Sunlight and ventilation

Questions and hypothesis of each one and the research analysis of the respondent outputs are summarized as follows:

1. The output of the first question helps to construct design strategies to overcome the most negative adjective related with the "Earth-Sheltered" buildings, Fig. 12.

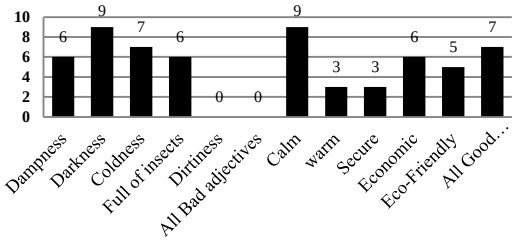


Fig. 12. Background Image w/t pictures

2. In a question about attitudes towards Earth-sheltered interiors, table 2. The research is trying to prove the hypothesis that: the negative psychological bias against these buildings is related only to its' name, according to the beliefs settled at the back mind that: any building has the name of "earth-sheltered"; must be "underground", but we can simply prove the opposite by this question, fig. 13.

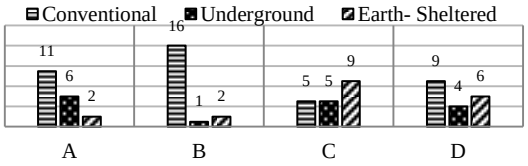
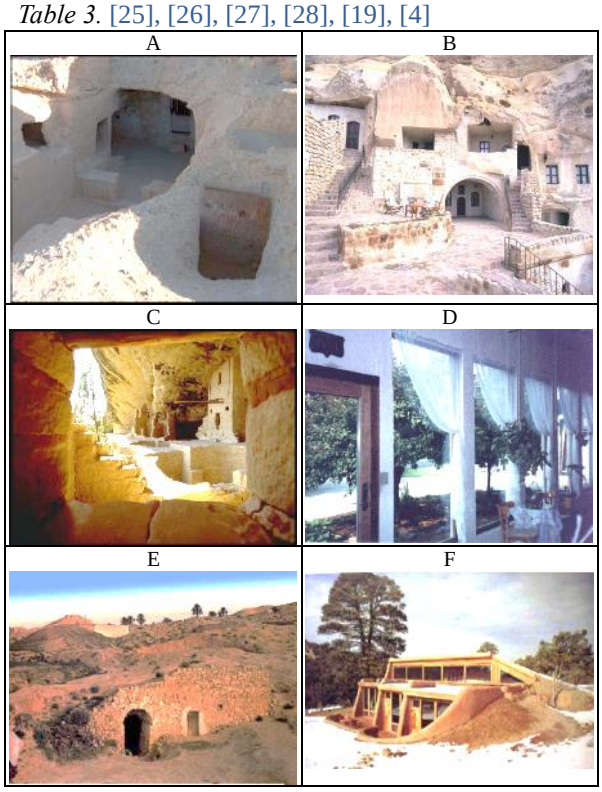


Fig. 13. Attitudes Towards interiors

3. This question is supposed to deal with the mental image deep-rooted in the mind. It presents historical experiments versus contemporary cases, each one with its equivalent at the design strategy system, and its reverse in the way of application at the contemporary cases, Table 3. The hypothesis of this question is that: people will not choose any one from the new cases. In an attempt to know what are the beliefs at the peoples' back mind, which we can create design strategies based on them. For example, it would be preferable entering the building unit upstairs, not downstairs; how to design the building façade to be very far from the most one that gain undesired back mind image, Fig. 14.
4. In a question about which type of usage the respondent wishes to deal with, (residential or touristic), Table 4. We found 37% of them liked to be his home (residential), but 63% wanted to use it as a trial period in a touristic motel.

Table 2. [21], [22], [23], [24]

Table 3. [25], [26], [27], [28], [19], [4]



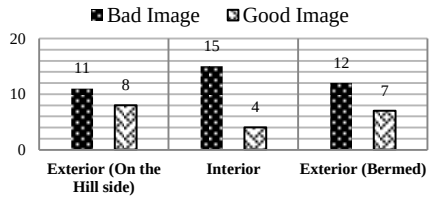


Fig. 14. Background Image with pictures

Table 4. [19], [5]

5. A question about adjectives that people think it is related with pictures at Table 5. Their attitudes are found at Fig. 15.

Table 5. [19], [29], [18]

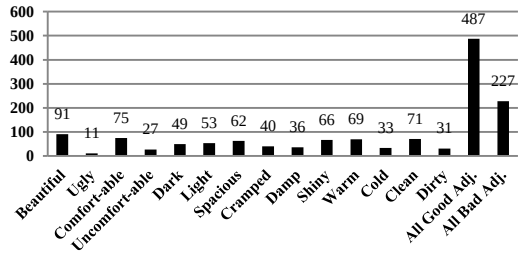
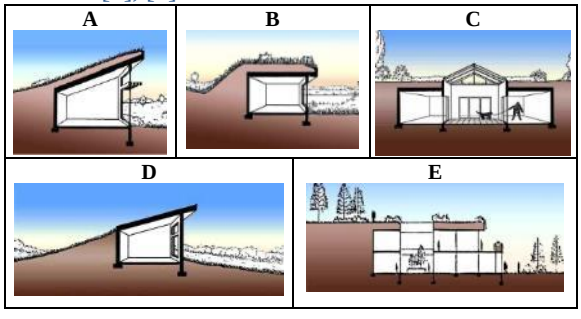


Fig. 15. Attitudes Towards Pictures

6. In a clear question about architectural cross section classification, Table 6. The research hypothesis is that: most of the architects do not know much about this system and choose wrong classification.

Table 6. [5], [8]



In fact, all of them are "Earth-Sheltered". A,B are "Earth-Covered", D is "Bermed", C is "Underground", and E is "Semi-Subterranean", none of them is "Conventional". People may select D or E as "Conventional", as they may have a conventional appearance at the façade. The results, Fig. 16, was interesting and chocking at the same time with some cross-sections like "C", as it is very clear that it is underground, but most of them chose it as "Bermed". This will drive the way to the necessity for holding an Informatics' seminars on the architectural level, in order to enlarge the base for future architects to use this system as an energy-efficient alternative solution.

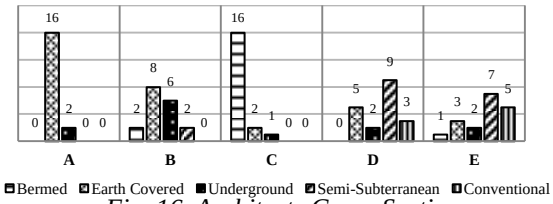
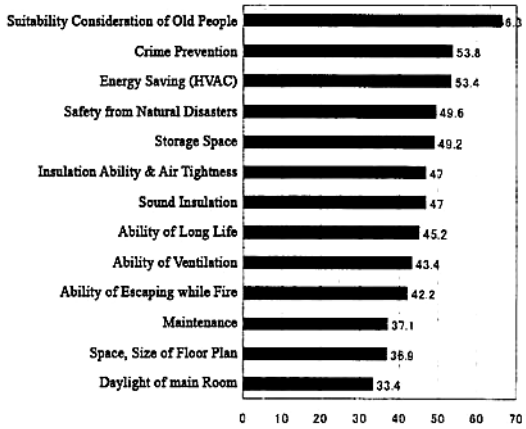
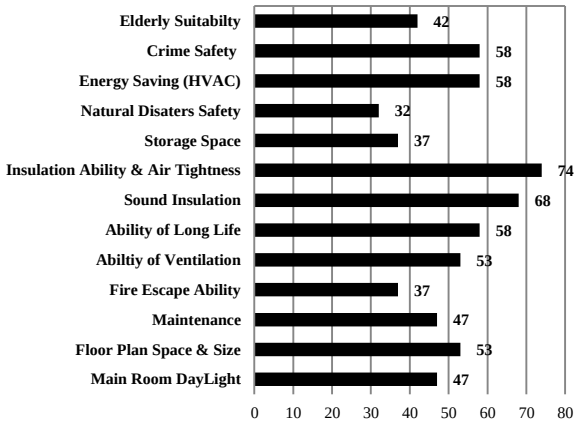


Fig. 16. Architects Cross-Sections Classification

7. There were 13 questions comparing attitudes between Egyptian and Japanese people, relying on a previous study with the Japanese [30]. The most important item measured was the energy saving (HVAC), the ability of ventilation, and the day lighting of main room, Fig. 17, 18.
8. The most important questions were the last two, about their point of view of the Basement and the Earth-sheltered usage, if they were provided with very high thermal comfort. But, even after the interviewees already had knowledge about them from the questionnaire pictures, people didn't prefer to use the earth-sheltered as a domestic use, Fig. 19, 20.



■ *Fig. 17. Japanese Attitudes towards Basement*



■ *Fig. 18. Egypians Attitudes Towards Basement*

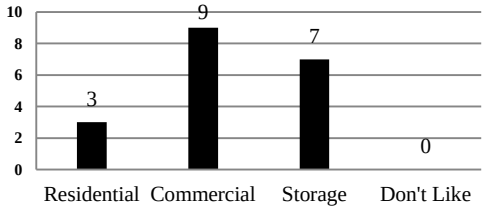


Fig. 19. Basement use preferences

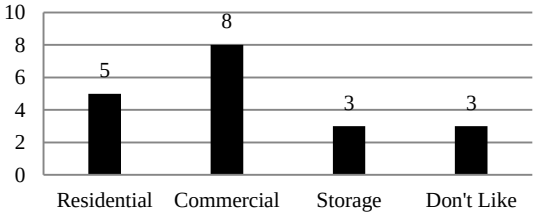


Fig. 20. Earth-sheltered use preferences

5. Conclusions

1. Thinking of application on the touristic facilities and workers villages, at the new developed areas, where both public and domestic use, which motivates individuals for application at their own buildings, as a good alternative to achieve complete thermal comfort, aesthetics, and environmental design.
2. It is recommended to use this system at the hill-side beside the shore bank; like the old "Gurna" village; or at the coastal regions, and reserve the flat land for farming and agricultural purpose.
3. To consider planning the geo-space on slopes and underground as an integral part of the design process for new projects, by the Planning Authority.
4. The most important benefit that could be gained from the Earth-sheltered construction is the internal thermal comfort with a steady state and very little fluctuation during both day - night, and summer - winters.
5. The most important drawback related with this kind of building is its name, which is deeply related in minds with undesired image of death and burying.
6. Not all architects know about these buildings yet, this makes the thinking of the application on a wide range, a kind of imagination and hope.
7. This research maybe not very accurate about Egyptians and Japanese attitudes towards the Earth-sheltered buildings, because almost none of them had lived or dealt with these buildings before. That makes their answer a kind of imagination, despite of the visual questionnaire. To gain more reliable results at the future work, there should be seminars with presentation about this kind of buildings, before asking people who didn't know it about their attitudes.
8. There should be an emphasis on compensate the lack of expertise, by making seminars, lectures, conferences, and classes on the educational level about the great environmental benefits of this type of building.
9. At the future work there should be another two similar questionnaire for two other purposive samples [31] (Egyptians and foreign tourists).

Their attitudes and point of view should not be neglected if we planned to apply these buildings with the touristic use.

10. For further research, it is recommended one of the following points:
    - 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.
    - 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.
    - Deep simulations to reach the optimum thermal comfort guidelines for an energy saving model at the hot-arid and the cold-humid regions.

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