RESEARCH ARTICLE

European Journal of Architecture and Urban Planning
www.ej-arch.org

Bermed Structures' Thermal Function on Kish Island

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ABSTRACT

Bermed plans which are categorized as subterranean provide overall cooling and daylight accessibility of the building all-sided. The factuality of bermed structures are investigated closely for deriving particular data for discussion, from the influential role of outdoor temperature to the maintenance and sound proofing, proportionate perspective and natural damages regarding contemporary buildings. The angular space in bermed constructions leaned upward to cover the roof so that it can support the whole building. Such a feature lets the sun radiate from the south and heat inside. Besides, the structures are earth-sheltered, economical and environmentally friendly at the same time, as with the cooling systems and sunlight. The bermed structures can fulfill the predicted decrease of construction energy utilization and provision of thermal comfort excessively. This study evaluates the impact of bermed structures energy consumption and thermal comfort on Kish Island where ventilation systems and electrical charges are remarkably high. Kariz is a part of Kish Island with high concern. Kariz is the subterranean city of twelve-meter depth below the ground and eight meter high. It holds three aqueducts and two hundred and seventy four wells including recreational resorts and touristic locations available for visitors of archeological aqueduct of Kish Island. Some factors like geometry, building materials and climate are major issues to concern in case of energy and thermal function. Kish Island obviously is in need of productive measures taken for perfect ventilation in order to reduce the consecutive application of cooling systems which are crucial in saving energy and amending the thermal comfort.

Keywords: Bermed Structures, Energy Consumption, Soil Structure, Thermal Comfort.

Published Online: June 13, 2023

ISSN: 2796-1168

DOI: 10.24018/ejarch.2023.2.2.28

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I. Introduction

An archeological practice in earth sheltering traces back into archaic history. Nowadays, its merits have presented innovative descriptions for this practice. Earth shelters are considered as structures composed of earth mass against the construction walls as outdoor thermal mass lowering heat loss and maintaining indoor temperature constantly. Earth sheltering found a significant perspective in residential areas so that the dwellings could somehow be like caves with traditional context requiring modification in the construction of earth dwellings worldwide. The primitive builders were unschooled and with no academic architectural plans or extraordinary techniques in such a way that they simply used soil for shelter, heat and security. (Dharek, *et al.*, 2017).

The underground space usage by the general public and the process of developing the subterranean living environments is considerable. Apparently, there are evidences of underground structures particularly for residential use but they weren't absolutely approved by modern plans. Meanwhile, the comparison between earth-sheltered residences and above ground constructions in terms of energy indicates less energy requirements of the underground structures with remarkable decrease of building expense.

In case of energy, the underground structures are indicative of various outputs. As for the surface, a certain construction is supplied to give off energy efficiency regarding high features and qualities. The subterranean housing architecture have been specific and empirical. There were no criteria for their construction maintenance.

Underground structures are privileged enough to decrease energy consumption in response to the increasing demands. The bermed structures can overly supply thermal comfort. This study evaluates bermed structures' thermal function on Kish Island.

II. Theoretical Underpinning

Despite the fact that long disputes resulted in the idea of accepting the bermed-structured constructions as a housing type which is environmentally friendly in itself, people are always neglecting its benefits. Using the bermed-structured housing design in various climatic areas, some potentiality of this type of plan either environmental or ecological viewpoints were seen. The issues that the world faced today involve great consumption of the non-renewable energy source pollution and the depletion of natural perspectives as well as topography because of the damages resulted from human activities. Nobody can deny the role of contemporary constructions particularly those of high energy use and pollution than all other kinds of buildings. In this way, bermed-structured housing is a means of alleviating energy consumption (Mirrezaei, 2015).

Energy efficiencies for various climates deal with elevational-type and bermed-structured houses. Specific information about a bermed structure is concerned with energy reduction valuable in estimating the actual cost and charges. It is entirely related to its special characteristic, partial embodiment in the ground which leads to indoor temperature regulation (Terman, 1985).

Bermed-structured constructions are inspected mostly because they reduce energy supplies and enhance security. Hence, these structures are investigated through a vast spectrum performance which consists of energy use and security under various catastrophic events such as earthquakes, fire, blast, radiation, and storm conditions. The performance stages regarding ecological effect, life cycle charges and mental impact are matters of concern. There are some General policies and appendices consisted of bermed structures' mobilization and suggested earth-sheltered counties. People's attraction towards this type of constructions and their utilizations are the main topics of discussion. Actually, inhabitants welcome the excellence of these buildings, parks, locations, and atmospheres (Moreland Associates, 1981).

Bermed-structured building projects under the severe conditions of hot lands like Sahara necessitate their designs in such areas. Some urban architectural designs are offered as to remove the obstacles in such climate (ISHED Conference, 2012).

A method used to evaluate the amount of heat carried and saved in the soil was two-sided leading to fluxes for the ceilings, walls and floors of underground and bermed-structured houses. The evaluated heat fluxes emitted from both subterranean and bermed-structured constructions with the consideration of soil cover deepness and thickness of insulation in various climates (Colliver *et al.*, 1982).

Daylight technique in the underground dwellings is implemented by the patterns of either contemporary or innovative daylighting systems in subterranean structures. (Ashraf Ali Ibrahim Nessim, 2005).

III. Methodology

The method of description is the core of this research trying to submit an analysis of the bermed structure of Kariz which is mentioned as rivalry to the contemporary structures on Kish Island. The purpose is to show the deficiencies of other normal buildings and bermed underground structures based on the elements of moisture and thermal comfort.

From metropolitan point of view Kish Island encounters some crucial issues of which solution seems to be the bermed structures. Thus, this study is emphasizing on the bermed structures and the contemporary ones located on Kish Island on the basis of thermal performance, construction materials, environmental effects and energy consumption.

We made an attempt finding ways to focus on the inexorable forces of wind and use it to modify the thermal conditions and increase the comfort indicators of the contemporary buildings on Kish Island which has certain weather conditions such as long- hour sunshine, sea breeze blowing on land and local winds.

The historical bermed structure, Kariz, is examined as for the parameters needed to specify the mass around the drilling areas. Then, the analysis related to the determined area are studied in order to figure out the sensitivity of the resistance parameters of the present masses, preliminary stress conditions, modulus of flexibility and various coatings.

IV. Results and Discussions

The study of Kish Island climate shows that in this design, we are facing critical issues coping with high humidity and heat. Hence, the role of climatic factors in finding appropriate construction structure on Kish Island is obvious enough. It is necessary to have any construction that is currently taking place on this island put into effect with respect to the local architecture and climate design criteria.

The matter of concern for the designs in this area is proper ventilation of the building. On the other hand, due to the crisis of energy shortage, we'd better attempt to have appropriate and sufficient ventilation by designing in concordance with the climate of the region, naturally and without using non-renewable energies.

From the view of construction material, the following approaches have been used by builders on Kish Island:

- Use of reinforced concrete structures in all buildings.
- Use of high strength two-dimensional shear walls.
- High quality and durable materials against moisture and erosion.

Due to the location of Kish Island in a very hot and humid climate and the establishment of weather conditions for most of the year, it is inevitable to pay attention to the climate and adapt to it. The common features of the structures of Kish Island are:

- Shading by two-dimensional shear walls and sloping canopies.
- Placing the building in the direction of the dominant west and northwest wind (north-south direction of the building) and making maximum use of air drafts and creating natural ventilation.
- Choosing light colors in all buildings in order to reduce absorption and penetration of heat into the building.
- Low building density and creating a good view.
- Creating extensive green space between buildings.

In order to have natural ventilation as much as possible, it can be said that the following points must be observed in the architecture of Kish Island:

- Construction of the building in a way that minimizes the absorption of solar radiation, including the use of white materials, reducing the sun exposure levels by properly orienting the building, using curved roofs and design the windows in certain directions which is the maximum amount of sunlight (such as the east and west directions in summer).
- Creating conditions to facilitate the air flow: for this purpose, giving the northwest-southeast direction to the building not only reduces the solar radiation energy in the hot season, but it can limit the air flow that is in the western and eastern directions. Deviation of the 45-degree angle of the building from the east or west direction where the wind flow has a high speed, reduces the wind speed so that it is suitable for comfort. Building construction on a high platform for better use of air flow, using windows in the north-west and south-east directions, and covering the windows with awnings so that the air flow inside is facilitated using materials, a porous building with openings that minimizes heat transfer inside the building. We can mention materials such as clay blocks and AAC also known as Autoclaved Aerated Concrete (is a type of porous concrete). Using trees to improve the microclimate of the island and houses due to its shading.

Previous discussions maintain that the proper ventilation system of the building is the priority of the design on Kish Island. Another vital factor is the stability of building structures on this beautiful island. In this study, we focused on the bermed structures on Kish Island to investigate on the stability of bermed structure in this area, we chose Kariz underground city as the unique exemplification on Kish Island for case study.

Considering Kish Island circumstances, the digging and construction of the historical bermed structure, Kariz, in the marl mud layer emphasizes on the importance and value of this aqueduct much more. The two-thousand-year-old aqueduct of Kish Island with a maximum height of forty-five meters is unique in itself and has a length of 15 km, along two lines from Safeyn area and the airport to the current location of the tourist cultural complex of the underground city of Kish Island, turns into three lines, and from this place leads to a single line and flows into the old city of Harire. These days, the aqueduct has been transformed into an attractive underground city, which is more than 10,000 square meters in size, and it is considered as one of the must-see touristic places on Kish Island.

Along the route of these old aqueducts, there are many wells for gathering water, which supports the fact that the water in this aqueduct was still flowing and moving in the direction of the aqueduct. The water of this aqueduct was used for irrigation of the green spaces, drinking purposes of the residents, and simultaneously, trading the water of Kish Island for consumption and sale or exchange with other commodities in the Persian Gulf countries. Sweet water is gained out of the island's seasonal rains, which passes through the corals as a natural filter and flows in the marl mud layer.

The outstanding feature of the bermed structure, Kariz, on Kish Island is the cool air that constantly blows and does not change throughout the year, so it does not matter what season of the year you're willing to visit this place because it is always cool. This mild weather has caused the water to stay at a tolerable temperature and maintain its drinking quality.

Rocks in the crust of the earth are under a state of in situ stress. When the underground structures are dug in the rock, the state of existing stresses are changed and redistributed in the vicinity of the excavation wall. Meanwhile, the stress distribution around the excavations in the rock can be calculated in advance and the state of the stresses must be determined before the excavation. Based on the results of stress measurement at different depths and various parts of the world, Hoek and Brown showed that the initial vertical stress is 7.2. The coefficient K, which is the ratio of horizontal to vertical stress, is one of the parameters that must be measured carefully. On the other hand, the influence of the hole created in the rock is a local impact that reaches its initial value at a distance of 3 to 4 times the radius of the circle and the value of the created stress with the minimum size of the model should be twice the largest dimension of the underground structure of the model.

According to the results of the geotechnical studies of the area near the bermed structure, Kariz, and several points of the island, it is observed by the consultants under the supervision of the Kish Civil Engineering Organization that the layering on the island is almost the same at different points and only the depth of the coral layer varies.

Supplementary tests were conducted to know the parameters of the mass around the excavations and check its space by visit the project site. On the basis of the observations and local samples from the marl layer, the required tests were performed on this layer. In this section, the results of the tests like soil classification, as well as uniaxial and triaxial CU tests are reviewed.

By the fact that the desired soil passes through sieve number 200 and having Atterberg limits, the name of the soil according to Unified and AASHTO (American Highway Administration) classification is:

1) Classification A-7-5(31): AASHTO clayey soil - inappropriate for road construction

2) Unified classification: MH - OH uniaxial test is required to check the stability of marl walls. For this purpose, several samples were tested from a depth of about 11-13 m (the average depth of the walls). The results of the uniaxial tests are: Uniaxial strength $\sigma p = 0.32$ (MPa)

Also, the triaxial test of Consolidated Undrained (CU) was performed on the marl sample to obtain the values of C, φ (adhesion and friction). In the CU test, the saturated soil sample is first consolidated by all-round confining pressure $\sigma 3$. The value of $\sigma 3$ is about the same all-round pressure as the average depth of the walls, in this case the drainage valve is open. After the excess pore water pressure is removed, deviate stress ($\Delta\sigma$) is applied to the sample up to the breaking point. At least two tests are required to draw the rupture cover.

By using the rupture cover or the relationship between the maximum stress $\sigma 1$ and the all-round stress $\sigma 3$, the soil resistance parameters are determined as: C = 0.17 (MPa) = 170 (KPa), φ = 24

According to all the above cases, the necessary parameters for the analysis of the stability of the underground spaces in the bermed structure, Kariz, for the coral limestone layer and the marl layer are considered as described in Table I.

TABLE I: VALUES OF DESIRED PARAMETERS FOR ANALYSIS AND DESIGN

Resistance Parameters	Coral Limestone	Marl
Angle of Internal Friction φ	38	26
Coefficient of Adhesion C	1.3 MPa	0.2 MPa
Apparent Specific Gravity γ	1900 Kg/m^3	2000 Kg/m3
Resilience Coefficient E	270 MPa	60 MPa
Poisson's Ratio ν	0.3	0.3
Uniaxial strength σ_p	4 MPa	0.32 MPa
Tensile Strength σ_1	22 MPa	-

Analytically, the fact that changing the resistance parameters of soil and rock until a large part of the mass has not reached the plastic state and then fails, does not have much effect on the distribution of stresses and their values. The important thing is that proportionate to the reduction of the resistance parameters of the soil or rock, the reliability coefficient against failure decreases. Another point is that in calculating the reliability coefficient, due to the uncertainty of the resistance parameters, the results of the uniaxial test of the marl layer - during the current research - and the tensile test of the rock based on the available reports were used. Also, highly lateral pressure coefficient causes a remarkable increase in the imbalance and instability of the walls. In short, we can say we have the coral roof and the marl wall. Also, the overhead on the ground surface has been calculated as a sidewalk with an overhead of 3 KN/m2. Boundary conditions have been applied by closing the displacement in the X direction for the vertical boundaries and closing the displacement in the x, y direction for the lower boundary along with applying the gravitational acceleration. The lateral pressure coefficient of the soil is considered about 0.43 and there is a plane strain state for the elements. The coral roof is stable at all stages and has at least a reliability factor of 0.3. However, the condition of the marl wall is inappropriate and have a stability problem, that's why it seems necessary to create a barrier system. For this reason, a concrete coating of 20 and 35 cm thickness was considered for the walls, floor and ceiling.

V. CONCLUSION

Broadly speaking, bermed structures are bright ideas that guarantee extensive decrease in building energy consumption level and the thermal comfort supply. It is archaically experienced to take shelter in the core of the earth and use the thermal characteristics of the soil as one of the fruitful methodologies used in most climates of Iran. Inspection through the soil behavior interaction between the ground and the building embedded in various climates of Iran considered as significant gaps which should be worked on quantitatively and qualitatively. This research has worked on the thermal function of these buildings in hot and humid climate of Kish Island from different angles. The vital direction in the field of passive construction design and advancement is closely related to the kind of response these buildings may illustrate in various climatic and physical situations of Kish Island.

It is worth mentioning that the architectural structure of bermed structures is of some instinctive characteristics. Each has got some specific features which are allotted to itself rather than et al. prevalently, one of the features of these constructions is the energy efficiency, the major cause of intake decrease and control of incoming air. A building embedded in a pile of soil behaves much differently from a building placed in the open air. Thus, bermed structures no matter are they completely or semi-completely built in the soil, can be in close interaction with factors and aspects that impact its performance. As a matter of fact, besides the issues that are essential for common buildings, some features are much more important in this kind of architecture. The most important ones are orientation, natural light and ventilation.

The other factor that affects the thermal behavior of the construction is the physical feature of the soil of which parameter can change the heat transference. The increase of humidity and volumetric mass can directly control the coefficient of thermal conductivity. Due to this relationship, the coefficient of thermal conductivity and heat transfer has a crucial effect on the amount of heat transferred through the soil.

Acknowledgment

I, hereby, want to gratify my respectful supervisors Asst. Prof. Dr. Özgün Arın and Assoc. Prof. Dr. Seyhan Yardımlı and big up to my family for all their support throughout my higher education. This article presents a perspective in architecture which provokes innovative views and practices.

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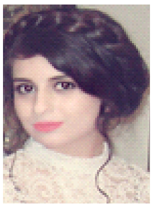

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