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ENERGY CONSERVATION USING EARTH SHELTERING TECHNIQUE-AN APERCU

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Abstract— **Earth sheltering is an age long traditional practice. In modern times its benefits has prompted new definitions for its practice. With the potential thermal conservation qualities and physical characteristics of earth as a building mass, earth shelters can now 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. The popularity of earth sheltering was advanced mostly by research in energy conservation in residential housing. Originally conceived as dwellings developed by the utilization of caves within the traditional context, its evolution through technologies led to the construction of customized earth dwellings all across the globe. These structures in the past were built by people not schooled in any kind of formal architectural design or with identifiable building techniques rather they depended on the cover the very structure of the earth could provide them for purposes of shelter, warmth and security. By reducing building energy consumption a nation can reduce dependency on imported energy and strengthen its strategic position. This paper is aimed at addressing the role played by earth sheltered houses in energy conservation.**

KEYWORDS- Earth sheltering, Energy conservation, Thermal comfort

I. INTRODUCTION

ENERGY conservation refers to reducing of energy consumption all though using less of energy service . Energy conservation not only reduces energy services but also increases environmental quality, national security , financial security and higher savings. It also plays major role in preventing resources depletion.

India is growing and so are its building's energy consumption has seen a drastic increase through decades.

Demand and depletion of resources thus drives for energy efficiency and conservation in buildings. This makes energy conservation building codes mandatory in India. In recent years, the concept of sustainability has attracted increasing attention within building science, for energetic, ecologic and economic reasons. The decreasing fossil fuel reserves warrant a minimized consumption of energy and maximized application of renewable energy sources.

Estimated Energy Capacity in 2030		
	GDP Growth	
Year	6%	9%
2022-2023	316,148	352,778
2023-2024	327,850	371,467
2024-2025	342,316	391,249
2025-2026	354,549	412,212
2026-2027	368,054	434,455
2027-2028	383,630	458,082
2028-2029	397,443	483,211
2029-2030	413,385	509,967

Fig:1 Details showing Energy capacity estimated in 2030.

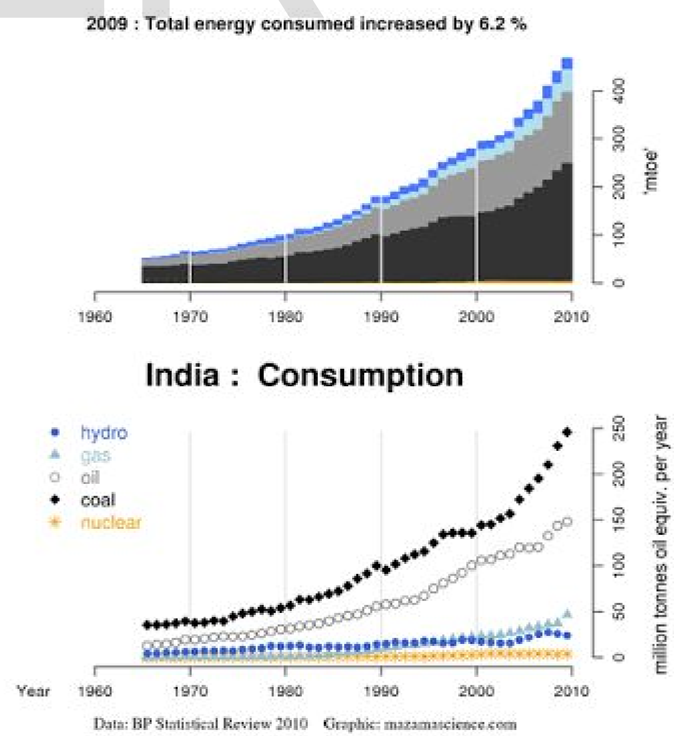

Fig:2 Energy consumption in India in last 50 years

II. EARTH SHELTERING TECHNOLOGY

A potential method to fulfil these requirements for dwellings is the concept of earth-sheltered buildings, which may be simply described as concrete constructions partially covered with soil. The large thermal inertia of the soil cover causes the temperature in the surrounding soil to be higher/lower than the outdoor air temperature during winter/summer. This way, the temperature differences between the interior and exterior are reduced, which means that the heat transmission is lower compared to conventional above-ground houses. The application of soil cover thus potentially cuts the required heating and cooling loads.

When mechanical cooling and ventilation becomes a requirement, pollution hazards and health problems are then unavoidable. Energy planning can mend the quality of our life and the environment in our new level. Its conservation is an essential part of energy planning, helping to economize and reduce the negative environmental impact of any development that uses energy.

The current situation decrees the need for the adoption of technology that is essentially non polluting, simple in principle and socially and culturally acceptable. The compatibility of these prerequisites with the characteristic attributes of earth sheltered housing is obvious. Our ancestors adopted simple, non-energy consuming techniques using earth and masonry as the basic construction materials for their buildings.

Fig:3 Earth sheltered house

III. OBJECTIVES OF THE PRESENT STUDY

1. To understand the existing gap between building performance and energy conservation
2. Study the benefits of earth sheltering technology in building construction.
3. To commend future construction to target and harvest saving potentials.

III. WHY TO GO FOR EARTH SHELTERED HOME?

There are two basic reasons for using earth for thermal comfort one is the cheapest availability and second is that earth-based materials have their excellent sustainability characteristics. By using earth we have many advantages such as efficient use of our resources, minimizing pollution, minimizing waste, etc. It also provides good thermal and acoustic insulation and has a particularly good ability to regulate internal air humidity and quality.

IV. WHAT ARE EARTH SHELTERED HOUSE?

A building can be called earth-sheltered when it has a thermally significant amount of soil or substrate in contact with its external envelope. That dry definition includes having earth against its walls, on its roof, or being underground. Earth-sheltering has a long history. Earth sheltered houses at Keldur in Iceland are amongst the country's oldest buildings, and houses of turf and earth have an ancient history in many parts of the world. A web search reveals the existence of ancient earth-sheltered dwellings in India, China, Africa and Turkey; and if we include caves , earth-sheltering can be considered one of humanity's oldest types of dwelling.

V. HISTORICAL RECAP OF EARTH SHELTERING:

Living underground however is hardly a twentieth century phenomenon. From prehistoric times to the present , people all over the world have built and lived below the surface of the earth. Primeval cave dwellers, seeking warmth and protection from wild animals and severe weather, chose an existing natural earth form-the cave-that provided those needs. In fact, the existence of inhabited cave dwellings in Tunisia, Libya, China and the Loire and Cher valleys of France today provides evidence that, given the proper geology and hydrology, caves can be converted into very comfortable and extremely private spaces, Throughout history, human beings have often turned to the earth for protection against climatic extremes and dangers. Around AD 800 the people of Cappadocia in Turkey carved out underground chambers in spines of soft rock, partially in response to the scarcity of good timber and materials for mortar but mainly to protect the inhabitants from invaders for centuries, residents of Matmata in Tunisia(fig 3) and Ghirian Libya have curved into the soft rock to create atrium houses in which several excavated rooms with 4.5 meter high, vaulted ceilings open out onto a single sunken courtyard .

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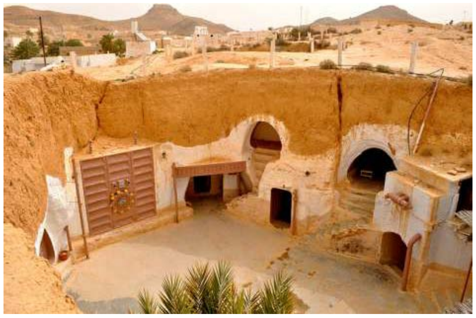

Fig.4 Matmata in Tunisia

These houses are built below ground to protect the inhabitants from the extremes of daytime heat and night time cold, typical of this desert region. In China, the courtyard type houses that dot the landscape were dug into the loose, silty soil to combat the hot summers and bitterly cold winters. The Chinese provinces of Shansi, Kansu and Homan, faced with the need to preserve agricultural land and house their people, have been digging entire cities beneath the land since the 1920's. Today, more than 10 million Chinese live underground, perhaps the largest number of troglodytes ever to inhabit a single region. Buried at depths of up to thirty feet, underground homes are built around courtyards. The atrium-style design offer ample sunlight. Each home is protected from biting winds and temperature extremes. Most importantly, the buried cities offer China the opportunity to put the land to dual use since the soil provides ample crops to feed the millions of inhabitants who live below .

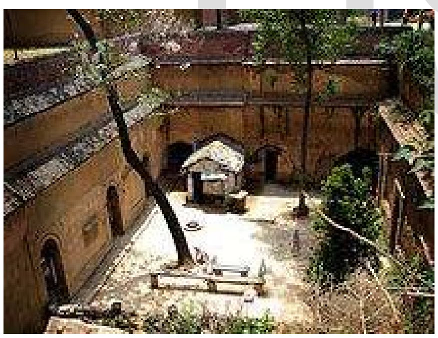

Fig: 5 Sod Houses in America

In the American Midwest, sod houses and dugouts were also built in the 1800's in response to severe heat and cold, as well as the lack of building materials-and fuel. Sod houses are still in use in Scandinavian countries.

VI. MODERN CONSTRUCTION TECHNOLOGY AND DESIGN TOPOLOGY

The structural make up of a typical earth shelter house is made up of the supporting members and the compacted backfills in which case strength and composition can determine the ability to withstand overhead loads of moisture, dead and live loads, the distribution of which depend on the compaction strength of the backfill or supports. However in modern designs, the supports are the parts of the house that brace against the side walls of soil and overlaying roof members that are made of backfills as in the case of underground homes. The design method and material choice will determine the resistance to failure of these structural members. In the traditional construction scenario where the earth-soil is used as building material; its strength is determined by the soil stability, which goes to improve the resistance to wind and in most cases rain erosion. The structural make up of earth homes is mainly made up of the supporting members and the compacted backfills. As earlier mentioned, the strength and composition of the material used as backfill can determine the ability to withstand overhead loads. The supports are the parts of the house that brace against the side walls of soil and overlaying roof members that are made of backfills. The building design method and material choice will determine the resistance to failure of these structural members. In the case where the earth-soil is used as building material, its strength is determined by the soil stability, which goes to improved the resistance to wind and rain erosion. In most earth shelter construction the significant structural areas are the soil, walls and roof area. Apart from serving as a building material, the soil-walls of the shelter trench are regarded as the most valuable structural member of the Earth house structure. It provides the necessary support a normal wall gives in an ordinary house design. Nevertheless, not all soil types are efficient in use for earth sheltered house construction. From studies it is identified that the best soils are granular, such as sand and gravel. These soils compact well for bearing the weight of the construction materials and are very permeable, which means they allow water to drain quickly. The poorest soils are cohesive, like clay, which may expand when wet and has poor permeability. Soil tests, offered through professional testing services, can determine load-bearing capability of soils and possible settlements that may occur after construction.

VII WHAT CAN WE DO:

A building can be called earth-sheltered when it has a thermally major amount of soil or substrate in contact with its external envelope. That dry definition includes having earth against its walls, on its roof, or being underground. Earth-sheltering has a long history. Earth sheltered houses at Keldur in Iceland are amongst the country's oldest buildings, and houses of turf and earth have an ancient history in many parts of the world. A web search reveals the existence of ancient earth-sheltered dwellings in India, China, Africa and Turkey and if we include caves, earth-sheltering can be considered one of humanity's oldest types of dwelling. Technically speaking, there are three kinds of earth sheltered building: earth bermed; in-hill / earth covered and underground or fully recessed. The earth berm or bund consists of earth banked against the walls. This might be one wall (polar facing) or all walls. Traditionally, stones were used too, and/or turf; modern construction calls for insulation and waterproof membranes.

In-hill, or earth-covered construction covers the roof as well. Buildings are set into a slope and normally oriented towards the equator (or with the slope of the hill to take drainage into account - see Mike Oehler's Basic Design, in resources). Underground earth-sheltered buildings can also be called atrium-style because of the common use of an atrium or courtyard to ensure adequate light and ventilation. Some of the most famous subterranean houses are to be found in Coober Pedy, Australia, where underground living is a response to an extremely hot climate. There are low-tech and high tech approaches to this technique. There's a world of difference between concrete and steel earth-sheltered houses which whilst they can be energy efficient in use, have high embodied energy and can cost £1000 per square metre, and hand-dug earth shelters with timber posts and shed-style roofs.

VIII WHAT ARE THE BENEFITS

Earth sheltered buildings have great advantages as following.

- An earth-sheltered building is less susceptible to the impact of tremendous outdoor air temperatures.
- Long life expectancy due protection from external factors.
- low maintenance .
- Fire resistance.

Increased comfort because of minimal temperature swings. Temperatures inside the building are more stable than in conventional building, and with less temperature unevenness, interior rooms seem more comfortable.
Recycled materials may be used in their construction without problem. Because earth covers part or their entire exterior, earth-sheltered buildings require a lesser amount of outside maintenance, such as painting and elevation treatments.
Earth sheltered building "blends" the landscape more harmoniously than a conventional building and as a results provide more space for landscaping. It provides natural safety and security to the building. Space above the earth sheltered buildings remains available as open space. There are also challenges to earth sheltered building design such as day lighting and ventilation etc. which may be overcome by innovative layout planning and design.

IX MODERN APPROACH TO EARTH SHELTERING TECHNOLOGY

Earth-sheltered houses have long been known to be very energy-efficient, with the thermal mass of all that dirt keeping the temperature relatively even all year. However they have often been expensive to build and difficult to make totally waterproof. Florida-based Green Magic Homes have developed a prefabricated system structures made of fiber-reinforced polymers (FRP) for earth sheltered houses. Each structure comes as a modular component that is durable, flexible and waterproof. In addition, the components can be assembled quickly and easily and then covered with the available soil from the area—creating thermal mass for minimal heating and cooling. Each module has smooth interior surfaces and washable walls, rounded corners and arched ceilings. Furthermore, they are impervious to rot, pests and fire and are strong enough to have up to eight inches of soil and plant life on top. While fiber-reinforced polymers are not the most green of materials, this type of architecture could be beneficial to people in hot, dry climates or fire-prone areas because the soil will protect the home from damage. The R value or heat transfer resistance value of a GREEN MAGIC HOME, is approximately 1 per every 10 cm of Earth. A typical GREEN MAGIC HOME has an average of 60 centimeters between walls and deck, which would give an R factor of 6. The use of earth as a large capacity heat storage makes it possible not only to reduce such buildings' demand for heating and cooling energy, but also helps to preserve the local microclimate.

Fig: 6 Green magic buildings

X. COST

Comparing cost factors for building an earth-sheltered house to those for building a conventional house can be like comparing apples and oranges. Costs vary by region, depending on the area's construction activity and cost of materials. Many earth-sheltered houses are built by their owners and are customized in different ways, adding amenities that can dramatically increase final costs. However, when you factor costs, remember to consider important expenses that occur over the life of a house, such as exterior maintenance and utility costs. Greater initial investment can actually mean your ongoing costs, such as heating, cooling, and maintenance, will be reduced. Making the best use possible of natural resources may be one of an earth-sheltered house's greatest advantages. Therefore, in comparison to standard houses, while earth shelters tend to be slightly more expensive to build, these higher initial costs may be offset by the lower energy costs after completion. And while energy savings have been documented by families living in earth shelters, attributing that savings solely to the earth-sheltered design would be difficult, because most earth-shelters incorporate a wide variety of energy efficient features.

XI CASE STUDY 1

Birla Institute of Technology & Science (BITS) is an institutional building located in Pilan. (Rajasthan)

Recently it has come up with new construction of Academic Blocks, based on Earth Sheltering building concept. It was a challenge in front of architect to design “new academic block” at a location given by the client, with a condition that the Saraswati temple (South) should be visible from the existing V.C. Office (North). After working on number of design options, Architect come up with a solution of “Earth sheltered building” with following advantages. To be able to go two stories below the ground, without obstructing the view of temple from clock tower . The complete terrace of the “new academic construction” is available to us for future use.

The challenges of “Daylight & Ventilation “are taken care by berming of land on either side, at some distance from the building. The building is also connected with the existing Hostels at ground floor level. Storm water & toilet waste water is managed with open drains on either sides of the buildings and water is collected in big sumps from where it is pumped out at regular intervals.

Fig: 7 Earth Sheltered building at BITS PILANI Campus

XII CASE STUDY 2

Earth sheltered residence on Kea Island. Location and main design characteristics

The island of Kea is used as a promising location for showcasing an earth sheltered residence. The island’s privileged position, near Athens, makes it a very popular destination. The earth-sheltered construction method was selected as the intermediate step to the development of underground living environments, so as to make the underground space more familiar to the people. The construction method suggested, fits perfectly into the spirit of the Island, as an extension of its vernacular architecture, due to the partially underground houses that can be found at both Kea’s capital city and the countryside. More specifically, in the Ioulida town, the capital city, there are squared houses with tiled roofs which, in total, form a multilevel complex of houses with narrow stone alleys. In the countryside, where a more mainstream vernacular architecture style is represented, the structures and their extensions are incorporated in the landscape and have partial earth-bermed rooms. The climatic conditions are typical of the Cyclades islands weather, with long sunshine duration (annual sunshine duration of 2767.7 h), little rainfall (annual precipitation of 311.6 mm) but quite high relative humidity (annual mean relative humidity of 72.64%), because of sea water evaporation throughout the whole year. Summer temperatures are high, with an average value of 25.4^{O}C and absolute max temperature of 39.4^{0}C in July. Winter temperatures are mild, with average values of 11.2^{O} C and absolute minimum of 2.0^{0}C in February. Even in the winter, the average low temperature remains at relatively high levels, over 6.6^{O}C. This means that it is practically rare to encounter humidity problems in the interior of buildings, since – even without heating systems – the surface temperature of walls is really hard to reach the dew point. This is in line with the existing experience of the partially underground residences located in Kea, having many of their perimeter walls in direct earth contact. The design of an earth sheltered residence, needs to take into account several parameters in order to come up with a sound and modern, easy living underground environment. Such parameters include, site selection, orientation, indoor–outdoor perception, and natural ventilation. The structure was basically shaped according to these parameters and the principles of the bioclimatic architecture in order to provide energy efficiency and modern living conditions. One of the most important parts of the process is the selection of the construction site. Taking advantage of the island’s natural hill sides, the structure is placed in an inclined site of 4000 m^2 in ‘‘Rodacado’’ region. Slopes provide a wide variety of configurations. The natural inclination allows the development of a multiple level residence, maximizing its space availability. Furthermore, easier natural ventilation, unobstructed sunshine and light penetration deep into the house can be achieved, as long as a southern orientation is selected. Extra shading can be provided, if required, with the use of exterior shutters or deep awnings. The southwestern orientation of the specific site covered these prerequisites providing at the same time a spectacular view of the sea and the harbor. In that way, the feeling of claustrophobia is reduced, if not eliminated, by the direct view between indoor habitat and the outdoor lowland environment. In such a setting, the residents can be part of the surrounding environment, and the surrounding environment can be an integral element of the indoor space.

Design details The residence is characterized by elements that relate to the design culture of the island’s vernacular architecture and morphology, while its influence is evident, both internally and externally. The structure follows the lines and the morphology of the site, retaining the lines of the stone walls, but differentiating from them with its modern materials. The goal was to design it in order to show the influences from its environment while retaining its special character by using dynamic formations/. Both the design of the interior and the exterior of the residence came as a combinational result of the need to face the prejudices related to the underground space and create a modern residence of unique esthetics. Every part of the house from its shape to the materials used is designed with high priority to natural ventilation and lighting. The advantages gained from the selection of the inclined site were used as a core of the designing process and a starting point to create the primal shape of the structure. It allowed the implementation of a multi-level design enabling the creation of additional space to be integrated in the main useable areas of the house. The volume of the structure is increased, as the interior space expands both in depth and in height. In this way, every square meter is exploitable and an initial space of 100 m^2 is reformed into a 130 m^2 of built space. Furthermore, the interior's minimum height is set to at least 2.8 m, minimizing any restriction and claustrophobia feelings. Another advantage of the inclined siting of the residence is deriving from its high integration potential into the original topographic relief. Thus, the concrete outer shell is easily covered with soil inflicting minimum visual pollution and attaining an extra thermal isolation layer. The structure therefore becomes a ‘‘hidden house’’, preserving the natural scenery and allowing for the harmonious relationship of the structure with the surrounding landscape. The residence consists of two bedrooms, two bathrooms, a transitional space used as kitchen and living room, an office and an extra guest room accommodating the needs of a four member family. Such arrangements are typically found in Kea's island residences and are adopted in the case of the earth-sheltered house. The layout of the spaces gives certain independence to the bedrooms and the communal facilities. The main materials of the interior are concrete and stone. This combination forms a modern living environment that also keeps the island's character. The only ‘‘exposed’’ part of the structure is the residence's façade. This area of the house, the primary way of contact with the environment, is characterized by the impressive polygonal overhang and the form of the concrete light beams. These elements are aligned so as to maintain the beauty and uniqueness of the house.

XIII CONCLUSION

The above study shows that although there is lot of potential in the earth sheltering buildings but study in quantifiable terms is required. The present work has a focus on evaluating the Thermal Comfort in indoor climates in quantifiable way with respect to energy conservation. The endeavour is to develop innovative layout planning and design options making best use of the advantages of earth sheltered buildings as discussed above and working out solutions for disadvantages such as light, ventilation, etc.

Earth sheltering has been confined to individual buildings/houses built on small scale but this has the potential to develop buildings on larger scales such as housing. If a single building of Earth Sheltering is found to have noteworthy advantages, these advantages can only increase in degree if applied to whole housing development.

We must take a serious look at the idea of the earth sheltered house of the future, while at the same time carefully integrating the design with the cultural heritage and social needs of the people for whom it is being built. A developed site with earth sheltered houses will not disrupt the landscape. On the contrary, it will allow the natural beauty of the land to remain. Such low energy cost houses, noted for their "silence" and quietude, successful for centuries and functionally "inscribed" in the natural and social environment, will continue to be with us for a long time.

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