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Underground Houses - Alternative for Residential Living

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Abstract

The purpose of this study is to determine if earth sheltered housing may be the trend for the future in residential construction.

Underground Houses--Alternative for Residential Living

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Chapter One

Introduction

Since the energy crisis of 1973, the use of and the cost of energy has had a tremendous influence on life styles. Along with the energy crisis, the country is in a time of high inflation. The combination of these two problems has caused a setback in the construction of the single residential home.

Earth shelter housing has the potential of overcoming the obstacles of inflation and energy consumption; however, in the past, there has been some public skepticism about going underground. This resistance is due, in part, to the following:

1. The fact that the earth sheltered technology is new to the general public.

2. The fear of dampness and coldness of living underground.

3. The uncertainty of construction cost.

4. The uncertainty of governmental agencies, that deal with zoning and building codes. (Wells, 1979, p. 85)

Statement of the Problem

The purpose of this study is to determine if earth sheltered housing may be the trend for the future in residential construction.

Limitation of the Problem

Earth sheltered housing for residential units is a fairly new idea, so the technology for this type of construction has not had a long testing period. This study will concentrate on gaining background knowledge in the construction of earth sheltered houses.

Importance of the Problem

The cost of inflation and energy has caused people, who still have the American dream of owning their own home, to look for alternatives in home construction that will be affordable. The most appealing aspects of earth sheltered homes are the low cost of heating and cooling and virtually no extra exterior maintenance.

Until new energy sources are developed, there is a need for the conservation of fossil fuels. This writer feels that any form of construction that may save energy should be studied.

Definition of Terms

The following terms have been added for the benefit of the readers to allow for a better understanding of the paper.

Atrium--A rectangularly shaped open patio around which a house is built. (Webster's New Collegiate Dictionary, p. 72, 1976.)

Bentonite--An absorptive and colloidal clay used as a filler. (Webster's New Collegiate Dictionary, p. 103, 1976.)

Berm--A narrow shelf, path, or ledge typically at the top or bottom of a slope. (Webster's New Collegiate Dictionary, p. 104, 1976.)

Percolation--To cause (a solvent) to pass through a permeable substance for extracting a soluble constituent. (Webster's New Collegiate Dictionary, p. 850, 1976.)

Chapter Two

Historical Background

To document the first time an underground shelter was used by humans would be almost impossible. Undoubtedly, this time would date back to prehistoric times and the use of caves. In comparing the ancient and the contemporary use of underground shelters, there are numerous similarities which are listed below:

--the availability of building materials

--climate (now expressed as energy conservation)

--defensive needs (natural and human antagonists)

--local (sites) circumstance

--intensification of land use (multiple levels)

--aesthetic or formal concerns

--ceremonial, symbolic intentions

--nature conservation (ecological)

--landscape preservation (visual)

(U.S. Printing Office, 1975, p. 10)

Protection from hostile neighbors and the elements were the main reasons for the early use of underground shelters. To go along with these nine considerations is the socio-economic evolution of communities. The unique architectural features of early underground dwellings were "imposed by the religious practices, claimed to be the major factors in the choice of location" (U.S. Printing Office, 1975, p. 11) Rock-cut churches are prime examples of underground space used for ceremonial reasons. Early Christians were one of the groups to use the underground shelter as an escape from religious persecution. (Mason, 1976, p. 18)

Early development of earth sheltered homes in this country was in the Southwest, where various Indian tribes used subterranean rooms called "kivas." Like other builders of earth sheltered homes, the Indians of the Southwest were concerned with ceremonial purposes. In time, underground homes were used more for the family unit. America's development of earth sheltered homes came from early settlements of farmsteads before there was mechanical refrigeration, and there was a need for subsurface root cellars. (U.S. Printing Office, 1975, p. 12)

The first evidence of concern for more technological development of earth covered buildings began in the 1940's, with people going underground for defense reasons. In the 1950's the idea of expanding subsurface area in homes for more comfortable living and more efficient heating and air conditioning was promoted. During this time, more emphasis was placed on "climate control" than on energy conservation. Emphasis on defensive construction lessened for a few years until the late 1950's and early 1960's. At that time concern over the Cold War aroused people's interest again in going underground, with the development of nuclear fallout shelters.
In the early 1960's, alternatives for underground living developed into what could be called "ecological architecture." This period dealt with only the visual aspect of architecture and landscaping, not energy conservation. (U.S. Printing Office, 1975, p. 13)

Only recently has underground construction become more concerned with "conservation architecture." History has shown various alternatives to underground building, and the benefits gained from them. Examples of these benefits would be acoustical benefits, climate, control, defensive shelters, protection from storms, reduction of fire hazards, and land conservation. (Dean, 1975, p. 105) With the current problems of meeting energy needs, this writer feels it would be beneficial for the public to consider the great potential of developing underground living space.

Chapter Three

Review of Literature

Attitudes

People's attitudes towards underground homes in the past have been that underground homes were only for the rich. If the money had been available, people would have had the following concerns: condensation, air getting stale, cold and dark, roof structure holding up, and natural lighting. These concerns were based on their experiences with leaky basements. Another attitude was that prehistoric people moved out of caves and developed better insulation so people could live in the open spaces. (Dempewolf, 1975, p. 42) The question has to be asked: Was man smart in moving out of his natural environment?

In foreign countries more people have been building homes underground than have been in the United States. Building underground in this country has been for defense and aesthetic values. (Mason, 1976, p. 18) To promote the idea of going underground leaders in the field are avoiding the word "underground" and are using geotectures, terratectures, earth-homes, with the most popular being earth-sheltered; however, the name is not as important as the reason for going to subsurface dwellings. This nation went through a time of abundance of most everything, including energy. Now people are realizing the need for "conservation architecture." The reasons to build underground are becoming evident. These reasons are low energy consumption, low maintenance, privacy, structural stability, and preservation of surface space. (Campbell, 1980, p. 8)

Energy Use

One interest in earth sheltered housing comes from the possible energy savings. (Blich, 1976, p. 27) Loss of energy comes from the unwanted heating and cooling of the air around the building. Two main reasons for loss of energy is through ventilation of intake air and the heat transmission through the building walls and roof. (Campbell, 1980, p. 112)

Earth shelters, because of thermal mass, have a great advantage over above ground dwellings. In above ground shelters, the inside air temperature is greatly affected by the local weather conditions. The seasonal temperature changes that occur below ground are not as noticeable several feet underground and take a longer period of time to occur. As one goes deep into the ground, soil temperature responds only to seasonal changes in temperature. In Figure 1 the changes are indicated in soil temperature during a twelve month period at different soil depth.

Heat is transferred into the soil during the summer months by warm water percolation. During the winter, the winter top soil freezes and stops the heat transfer out of the ground. For this reason the soil maintains such a constant temperature that it does not take as much energy to heat or cool an earth-sheltered building. (Blich, 1976, p. 29)

The surface temperatures in the upper Midwest vary from minus 30 degrees Fahrenheit to 100 degrees Fahrenheit, with the soil temperature at 10 feet below the surface staying around 50 degrees Fahrenheit all year long. During the winter, it may be necessary to raise the inside air temperature eighty to ninety degrees Fahrenheit; but in an earth sheltered home, one would only have to raise the air temperature fifteen to twenty degrees Fahrenheit. This would result in a great savings in energy use. (Underground Space Center, 1978, p. 54)

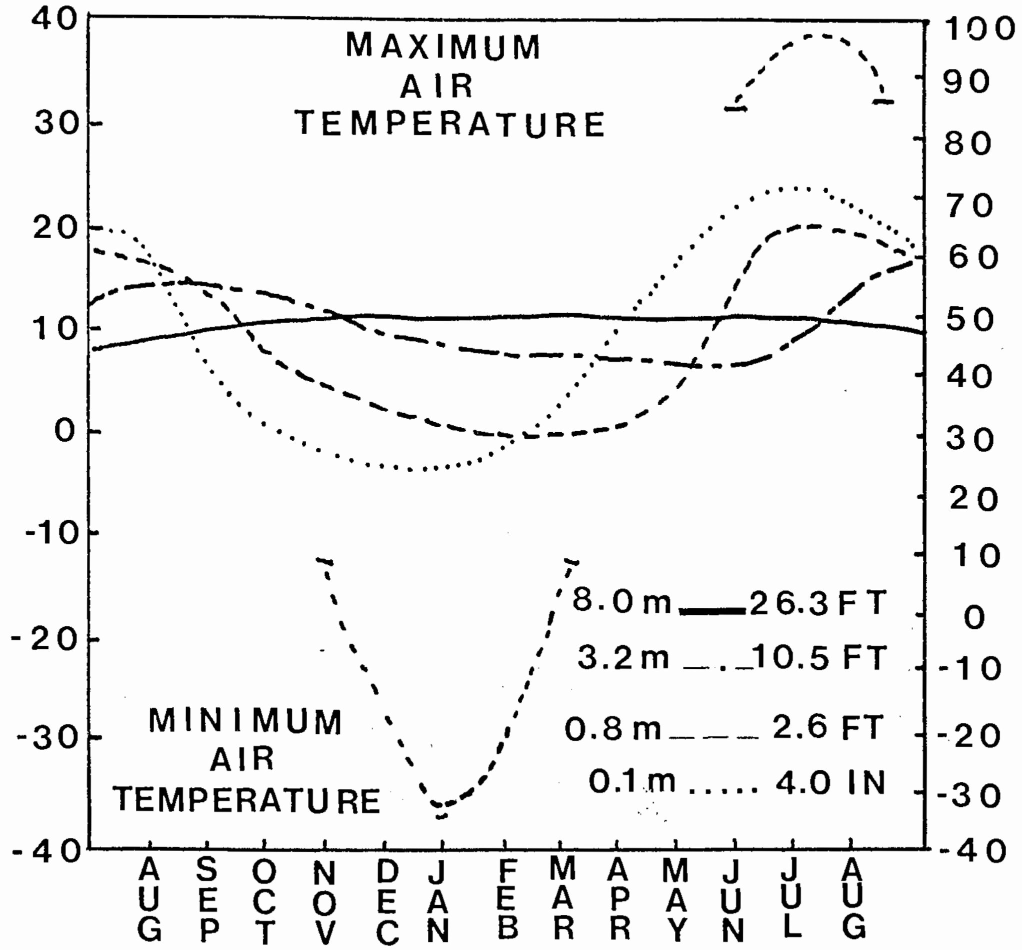

Figure 1. Soil Temperature Distribution (Underground Space Center, 1978, p. 53).

Initial Cost

Since earth sheltered housing is still relatively new, there are several thoughts on the initial cost. On structures that have been built during the past several years, cost has varied from $27 to $45 per square foot. Usually, with any type of innovative construction, contractors will require higher prices because of their unfamilarity with the materials and techniques. Hopefully once contractors have gained some experience with this type of construction, they will be able to lower prices. (Campbell, 1980, p. 39)

Excavation and materials are big factors in the cost of underground construction. More excavation may be involved in earth-sheltered homes than above ground structures, depending on the design. For the most part, concrete is being used in the construction of earth sheltered homes over the use of wood. At the present time, wood prices are escalating faster than the prices of inflation. With the price of concrete escalating at a slower rate, concrete will probably be used more in the future. (p. 40)

Financial

Like all new construction ideas, underground homes will have to go through a period of public acceptance. As pointed out by Manson, financing an earth home will depend on where people are and with whom they talk. Lenders, like other people, are skeptical on something they do not fully understand. Many lenders feel that the resale on earth homes will be low, and that they are only fads. (Underground Space Center, 1978, p. 33)

This type of thinking, however, may change as more and more people build earth homes, and statistics can be gathered to support the benefits of going underground. "Government agencies are being pressed to increase the energy conservation measures in housing" (Campbell, 1980, p. 33). With these pressures, government agencies are reacting with enthusiasm over the idea of earth sheltered homes. With government agencies making new guidelines for lending institutions, these institutions are able to lend money to interested home developers. However, the legislation needed to accomplish this has only begun.

> If the HUD headquarters in Washington would establish a program to specifically underwrite earth sheltered homes, or even if they would just issue a directive that earth sheltered homes should not be considered a novelty, and that if they met the minimum property standards, they should be considered for standard HUD or FHA loans. A rapid change in the financing picture would occur. (Underground Space Center, 1978, p. 173).

Legislation of this type has already been done in Minnesota and has helped the funding problem. (Campbell, 1980, p. 152)

The National Energy Bill, passed by the House of Representatives in August 5, 1977, had an amendment added by Congressman Bruce Vento of Minnesota which required Housing and Urban Development to do a three-year study on earth homes that included building codes, zoning, and financing. (p. 176) When this preliminary study is done, it is hoped that recommendations for the improvement of financing will be completed. It is apparent now that financing earth homes is in an uneasy period, and it will take the time and the cooperation of developers and lenders to work out these problems. (p. 176)

Geographical

In selecting a site for an earth sheltered home, the aspects are quite different from above ground structures. In above ground structures, little consideration is given to the energy saving and the site location. However, in an earth shelter home, if the design is going to be energy efficient, understanding of orientation, vegetation, winds, views, lot size, soil, and ground water must be considered. The following information will briefly deal with each of these areas.

The actual location and orientation of an earth sheltered home in relation to the sun is very important, because of the possibility of using passive solar energy as the main source of heat during the winter. The passive solar technique is to trap the radiant energy of the sun, which enters through the windows. Because of the capital expense of a passive solar system, this system can provide a substantial amount of energy in comparision to an active solar system, without the cost. "According to a recent study on passive solar energy a double glazed window facing south will produce a net energy gain even without the use of drapes or shutters at night" (p. 59).

With the heat gain available from the sun, windows must have a southern exposure. The heat gain is lessened with east-west exposure and with virtually no northern exposure. Normal earth sheltered buildings have three sides covered with earth; however, southern exposure may not always be possible, and alternatives will be needed to maximize the total heat gain from solar energy. An important note is that sunlight is needed for heating but is not desirable for cooling. During the summer months, techniques with the uses of vegetation, overhangs, and shutters will be needed to reduce solar heat gain. (Underground Space Center, 1978, p. 22)

Wind is also a consideration in the orientation of an earth sheltered home. The wind chill affect on above ground structures is tremendous but also will affect below ground structures. To improve energy performance, window and door openings on the north and west sides must be minimized. In the design of earth sheltered homes, diverting the prevailing winds around or over the structure (with the help of the orientation of the building to the ground around it) and the use of vegetation, is possible. This is because the prevailing winter wind is from the northwest in the northern hemisphere. With trying to avoid the prevailing wind in the winter, it is necessary to use the wind in the summer to provide natural ventilation. Unfortunately, the best ventilation would occur with openings to the north, but this would cause heat loss in the winter. Alternatives to this would be vents or skylights on the roof. (Dean, 1979, p. 106)

As in surface structures, the view is important in earth sheltered homes. The major problem in window orientation is if the view is not to the south, there will be a heat loss from solar energy. Another problem to be considered is that the earth sheltered home may be at a lower level than a conventional house causing the view to be blocked. Isolating the surrounding environment by the effective use of landscaping or building on a hillside would be possible. (Wells, <u>The Futurist</u>, 1976, p. 23)

When dealing with the size of a lot, there are three main issues to consider: additional area for excavation, set-back limitations, and structures on adjacent property. Earth sheltered homes, because of their design, may require more land to construct than a conventional home but create no problem in a total below ground development. Setbacks concern zoning ordinances that deal with how close traffic may drive to a sub-surface structure. When considering a lot, "the use of structure on adjacent property which may interfere with views, block sunlight, or simply create an unpleasant feeling of being looked down upon" (Underground Space Center, 1978, p. 164). With some special planning, this problem can easily be solved before a lot is to be developed.

The effect of vegetation can have a great potential for energy savings. One use of vegetation would be planting deciduous trees on the south exposure. During the summer, they would shade the house from solar radiation; and during the winter, when the leaves have dropped off, they would allow the radiation to hit the windows. The use of vegetation can also help in the control of wind. Evergreen vegetation can protect openings exposed to the winter winds. In a study done by the Minnesota Energy Agency in South Dakota, the study compared two identical houses, one with wind breaks, the other without. The study shows the house with wind breaks had a reduction of forty percent in fuel used. (p. 166)

In determining the soil and groundwater conditions for an earth home, more consideration is needed because earth sheltered homes are usually heavier and will need a sturdy base. Before starting to build, a site investigation should be done to determine soil type and water table. There will be a cost involved, but this will be cheaper than expenses involved if the site is found to be unsuitable. Some soils may have poor bearing capacity. Land that has a high water table may cost more to waterproof. An alternative to a site investigation would be to consult local agencies, realtors, and owners of neighboring properties. (Metz, 1979, p. 40)

Public Policy

The standards of design and construction of individual buildings include standards for mechanical, electrical, and plumbing work, which are regulated by building codes. These codes are set up by individual states and localities. The codes are concerned with public welfare, which include health, safety, and protection of property. Codes are not only useful to the developer of the property for his or her safety, but for the safety of people around the property. Building codes that most directly relate to homes are exit provisions, ventilation, and lighting. These concerns can be summarized as follows:

1. Habitable rooms must have glazed areas greater than one-tenth of the floor area.

2. Opening windows of at least one-twentieth of the floor area are required unless mechanical ventilation is provided.

3. Sleeping rooms must have a window or door connecting directly to the outside.(Underground Space Center, 1978, pp. 154-55).

The code on glazed (natural light) has been established for some time, and officials are reluctant to change it. This code does present a problem in earth sheltered housing, but the code can be met with different design. Developers of underground structures agree that living, dining, and kitchen areas need natural light and views to the outside, but disagree that rooms such as studies, dens, and bedrooms need the natural light. (p. 155)

When dealing with ventilation, earth sheltered homes have a little more flexibility. Natural ventilation can be done through vents or skylights. Mechanical ventilation may already be in use if a forced heating and cooling system has been installed.

The code dealing with sleeping areas has been the big design problem for earth sheltered homes. This code mainly deals with fire protection and an easy way to escape to the outside without going through the fire and smoke. With the limited openings, as in an earth sheltered home, considerations must deal with infants, handicapped, and elderly occupying the bedrooms. The argument against this code is that there may be alternatives that will give equivalent protection. The ideas that have worked in parts of the country are walls finished in concrete textures, smoke detectors, open skylight with appropriate ladders, and a back corridor to a back exit. (p. 158)

Occupation Safety Health Administration is not concerned with a design of a house but is concerned for the workers that may be employed to do the construction of the home. With the large amount of excavation in earth homes, O.S.H.A. is concerned with the protection of banks and trenches during construction. This concern comes from large number of deaths each year due to cave-ins.

There are several legal aspects that vary from the above ground structure but not to the point of any great inconvenience. The first one deals with setbacks, which relate to access for the fire department, proper light and ventilation of windows facing property lines, neighborhood, aesthetics, maintenance of exterior walls, and utility easements. With an earth home, there may be a great portion of the lot size used which would normally not be permitted. Building codes require that walls built within three feet of property lines be fire resistant. This would be no problem for a concrete wall underground. (Campbell, 1980, p. 26)

There should not be much increase in legal liability in excavation next to adjacent buildings due to the fact that earth sheltered homes are not much deeper than the conventional basement. If there is a case when deeper digging is necessary, care must be taken to protect the adjacent property. Building codes already provide some protection against this, with regulated distances for cuts and fills next to property lines. They also give procedures for the notification of adjacent property owners. (p. 23)

With solar energy becoming more feasible, questions are being asked if homes using solar energy should be protected from construction and vegetation on adjacent properties which block out solar radiation. Two states have passed solar rights laws, Colorado and New Mexico, with Minnesota considering legislation. The only problem coming from this is that earth sheltered housing is usually lower in the ground than conventional housing, which may limit construction on an adjacent site. (Blich, 1976, p. 29)

Zoning ordinances are local restrictions that control the type, size, and setting of a building. They are designed so noisy factories cannot be constructed next to a quiet residential neighborhood. They also control the design of buildings in a particular neighborhood. Zoning ordinances can vary greatly from city to city. (p. 30)

For the most part, zoning restrictions will not unfairly restrict earth sheltered homes. If there are any problems, the city officials are usually willing to work with the developer. The only problem that may occur in some communities is the "Basement Ordinances" which grew out of a common practice after World War II. Financing was available to build the basement, but not the upper portion of the house until a later date. However, many people never did finish the upper portion of the house and left what some considered an eye sore. (Underground Space Center, 1978, p. 167)

Insurance

As of now, there are only two insurance companies considering reduction of their premiums for earth homes by 30 to 40%. In theory, earth sheltered homes should get lower fire ratings because they are basically made from concrete. Like the financial aspects of earth sheltered homes, there is little in the way of statistics to back up the safety of underground homes. Some insurance officials still argue that ratings depend on the content of a building and not the structure. (Campbell, 1980, p. 37)

Rate reduction for earth sheltered homes is not likely, because housing insurance is class rated. Companies do not feel it is worth their time to inspect each home. Because there are so many homes insured, companies do not feel there is enough difference in the design of the homes to treat them as individual units. There are some modifiers used by companies to effect the premium. The first of those is class of insurance and is described as follows:

1. Fire and extended coverage--Protection from fire, windstorms, and hail loss, etc.
2. Theft--Protection from loss by theft of goods from property.
3. Public liability--Protects from liability to person injured on the property.
4. Tenants Form--Protects only contents.
5. Board Form--General policy including coverage under 1, 2, 3 and providing some additional coverages. (Underground Space Center, 1978, p. 170)

After the class of insurance is determined, it is modified into three major elements which apply to any building. Those are as follows:

1. Type of Construction--House may be split between masonry construction and frame-wall construction.

2. Type of Occupancy--Rate may change according to number of families living in the dwelling and whether the building is owner or non-owner occupied.

3. Exterior Grading--Refer to the quality of public fire protection; for instnace, water availability, water pressure, distance to fire station. (p. 170)

Before the rates for earth sheltered homes drop, insurance companies will have to look at their rating scale. Companies will have to compare well-built earth homes to conventional buildings on their merits.

Maintenance

Once the earth sheltered home is completed, there is very little that will ever have to be done to the home again. It will not have to be repainted or resided, and there will be no shingles to replace. The building will be protected from rapid changes in heat and humidity that wear out most materials. The home will also be protected from the freezing of pipes. There are different estimates on what an earth sheltered home will cost, but even if the initial cost is 10% more, the cost of maintenance and savings in energy will make it worthwhile. In studies done at the University of Minnesota, tests have shown that with the increase in the cost of fossil fuels, earth homes will easily recover the initial cost expenditures over a conventional home. Some tests have shown as much as an 80 to 90% reduction in fuel cost over a period of a year. (Dean, 1979, p. 104)

Chapter Four

Technical Information

Acoustics

A benefit gained from earth sheltered homes is the dampening of unwanted sound and vibration. This is because soundwaves at the surfaces are maximum but will decrease rapidly as they travel downward into the soil. Sheer stress, which causes damage to above ground structures during earthquakes, will cause little or no damage to buildings constructed underground. Because soil has an insulating effect against sound and vibration, the construction of homes near highways, airports, and other undesirable noise sources will be possible. The cost of this land may be less, due to the fact that traditional home builders will avoid these areas. In most cases, unwanted sound is desirable. Because of the greater amount of silence in earth homes, appliances and mechanical systems may seem louder than normal and background music may be needed. (Wells, 1976, p. 21)

Waterproofing

In an earth sheltered home, one the big concerns is for the possibility of moisture problems. This relates back to the problems encountered in basement construction. In the past, because of the moisture problems, basements were not considered as living space but as storage space. Due to better waterproofing techniques over the past years, basements are becoming inexpensive living areas. There will be questions asked about earth homes, because the whole home is underground; and there will be public concern about moisture problems. However, there should be no need for concern if care is taken in selection of a good waterproofing system, and the application of the system is done properly. (Smay, 1977, p. 89)

Waterproofing is going to be a large expenditure, but the cost will be relatively low in comparison to weather-proof siding in a conventional home. An example of a comparison would be that aluminum or redwood siding costs approximately $1.75 per square foot, not including sheathing or insulation. The cost of full waterproofing a below-grade structure will range from about $.50-$1.50 per square foot, depending on the technique used. If any waterproofing system is going to work, a good site must be selected in the first place. Obviously a perfect site will not always be found, but good judgment is needed to channel runoff and control the water table. The following would be a possible solution: Low area flood plains should be avoided with any type of house; however, earth sheltered homes would probably not receive serious structural damage. Sub-pumps would be able to handle normal rainfall but would not be able to handle a large surface flow. In high areas, where heavy rains could cause gullies, the site should be landscaped to avoid erosion. In sites that are sloping, a gravel trench should be built around the earth home to divert water run off. If an area with a high water table is selected, extra drainage pipes will have to be installed. (Underground Space Center, 1978, pp. 131-36)

A complication that is often found in waterproofing is temporary build up of water pressure. If the water pressure is not taken care of, cracks in the wall may occur. This can occur even above the water table, due to water seepage next to the house that cannot run to the natural ground table after a heavy rain fall. Temporary pressure can also occur in the spring, when the warmth of the house melts the frozen ground around the house, but not further away. To avoid this water pressure, free draining back fills must be placed next to the walls. (p. 135)

Another problem that can occur is capillary draw, which is moisture drawing into the wall from the damp earth. Moisture will travel through the wall if the air inside the home is not saturated; this will raise the relative humidity when the moisture evaporates. If the relative humidity is low, moisture may evaporate before condensation takes place on the wall. However, if evaporation is slow, moisture will develop on the wall. One way to cut off this capillary is to apply a good waterproofing system. Another way is to install an air gap or a material that is open enough so that moisture will not travel through it. The use of open weave materials allows the moisture from capillary draw to flow down the material into the drainage system. (p. 135)

Drainage is important, not only for reducing water infiltration, but drainage lessens the need for a heavier structural design of the walls and roof when the soil is saturated with water. In order to lower the water table, drains should be located as low as possible in relation to the foundation. Perimeter drains will not be sufficient in draining an earth home, but they will need additional drainage places under the floor to control the curve of the water table. Figure 2 will show the proper location of drains:

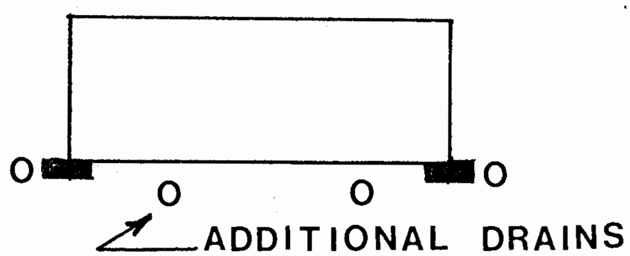

Figure 2. Drainage Techniques (Underground Space Center, 1978, p. 137).

Several methods and materials can be used to waterproof a building. There are several materials that may stop the capillary draw of moisture, but the materials are too thin and would have very little elasticity needed to cover cracks. They also may deteriorate too easily. This report will not list all of the techniques but will explain the materials that had the best results in waterproofing.

Bituthene--This is relatively inexpensive, polyethylene-coated, rubberized asphalt, which has elasticity up to 300% to cover up cracks. If bituthene is covered with backfill after the application is done, the membrane should have a long life. However, bituthene will deteriorate if exposed to ultra-violet light from the sun. (p. 141)

Butylrubber--This material comes in wide sheets, so there is little need for seams, which can cause leaks in the membrane. The membrane can be used on the roof or the walls. However, this material is expensive. (Campbell, 1980, p. 71)

Bentonite Panels--This material is natural, so it is not subject to the deterioration that man-made materials are. Bentonite is a clay that greatly expands when it comes in contact with water. The clay, in dry form, is placed in cardboard panels so that it can be installed. After the panels have been installed, the cardboard will deteriorate leaving the clay. Because the clay has the ability to expand, it will seal small cracks that develop. Bentonite can also be sprayed on walls when mixed with mastic binder. (Underground Space Center, 1978, p. 142)

Insulation

Because soil is not as good an insulator as believed, a need exists for insulation in constructing an earth home. As in any home, there is the need to stop unwanted heating and cooling. In controlling the heat and cooling loss in an earth home, "thermal mass" is an important factor. Thermal mass is the amount of energy required to raise the temperature by 1°C. Earth homes have large amounts of concrete (or thermal mass) which can absorb the heat and release it again. The soil surrounding an earth home also acts as thermal mass, helping to maintain constant temperature. When evaluating insulation, there are many factors to consider. The final decision must include economics, weather, building orientation, and site conditions. (p. 145)

The roof of an earth sheltered home, like a roof in a conventional home, is where most heat is lost. The primary concern is the depth of the soil, not the depth of the insulation. The thermal mass of the soil has a direct relation to effectiveness of the insulation. Studies have shown the comparison of varying soil and insulation depths in roof sections. These tests showed that there was a small increase in energy savings as the depth of soil over the roof was increased. It must be noted that the increase in soil depth will increase the efficiency of an earth home, due to surface temperature fluctuations. However, once the soil depth goes over 18 to 20 inches on top of 4 inches of insulation, the cost of extra construction to hold the roof may not be economical. (p. 56)

When considering the walls, there have been two approaches used, the first one is covering the entire wall. At first this seemed the most likely thing to do: however, this takes away the thermal mass effect of the soil surrounding the earth home. As the building is heated, the surrounding soil picks up the heat until the temperature evens out between the building and the ground. Once the ground has reached a steady temperature, there will be less heat loss. After the earth-home is constructed, it may take up to three years for the soil temperature to become stable. (p. 60)

The other approach that is used is to only cover the upper half of the wall. Unless the earth home is more than ten feet below the surface, the upper portion of the wall will, like the roof, have temperature changes due to the ground surface conditions. Because the bottom portion of the wall is lower in the ground, it is more suitable for use of thermal mass which helps maintain the earth homes' temperature. Figure 3 is an example of insulating earth sheltered homes:

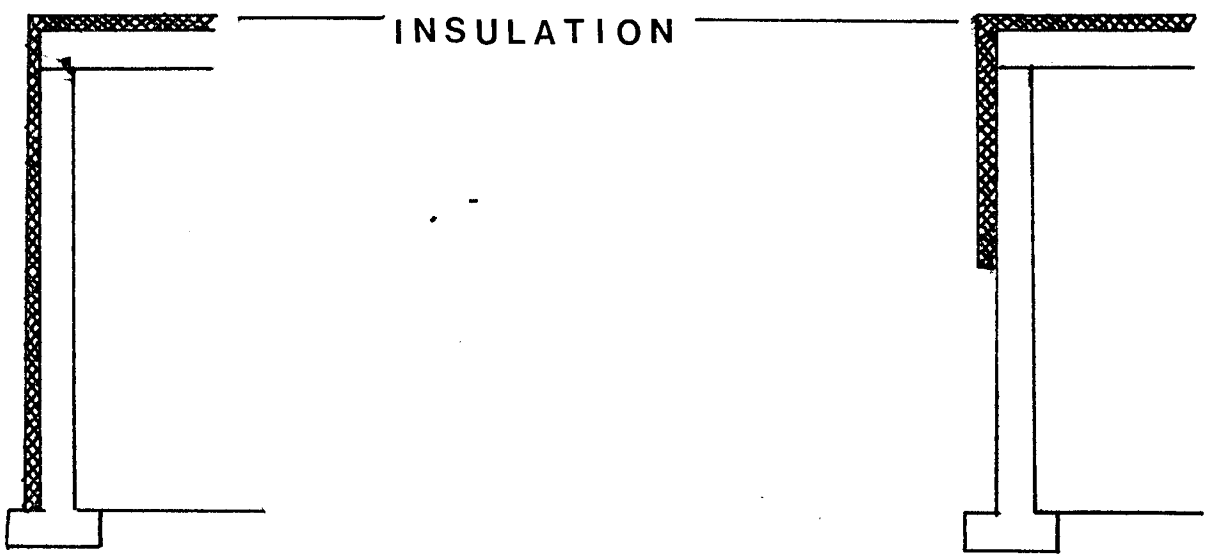

Figure 3.

Wall Insulation
(Wall One)
(Underground Space
Center, 1978, p. 64).

Wall Insulation
(Wall Two)
(Underground Space
Center, 1978, p. 64).

Another possible alternative in insulating the walls, is to extend the roof insulation before dropping a vertical section of insulation. The benefit of this method would be that the soil would be next to the wall, enclosed in an insulated shell which will increase the thermal mass of the building. The tests done by the University of Minnesota have shown energy savings by this method. (p. 145) The drawback to this method is that the insulation must stay sealed for the life of the building. If the insulation does not, there is the possibility of greater losses of heat than with the insulation against the building. This problem could result from the setling of the soil. Figure 4 is an example of wall insulation.

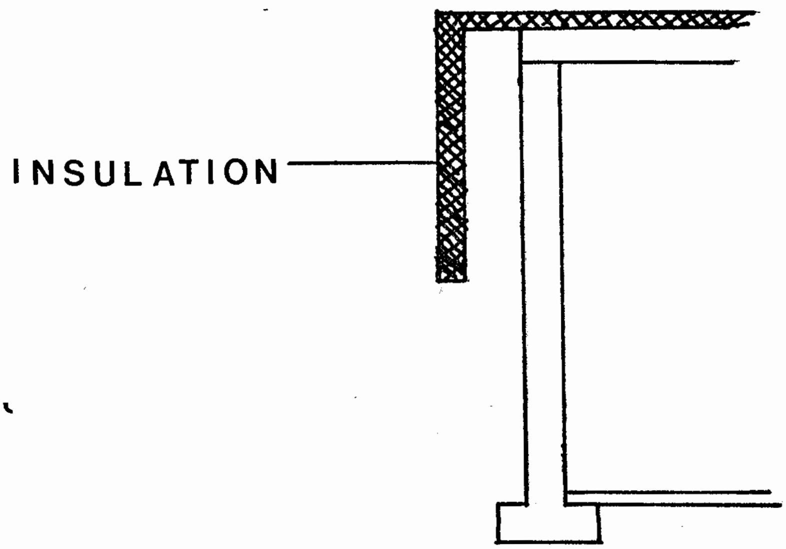

Figure 4. Wall Insulation (Wall Three) (Underground Space Center, 1978, p. 65).

The final alternatives for insulating the walls would be to extend the roof insulation horizontally several feet beyond the wall. Not only would there be an increase in the thermal mass, but the insulation would prevent water from accumulating around the walls. This could also lessen waterproofing requirements by channeling the water away from the building. Figure 5 is an example of wall insulation.

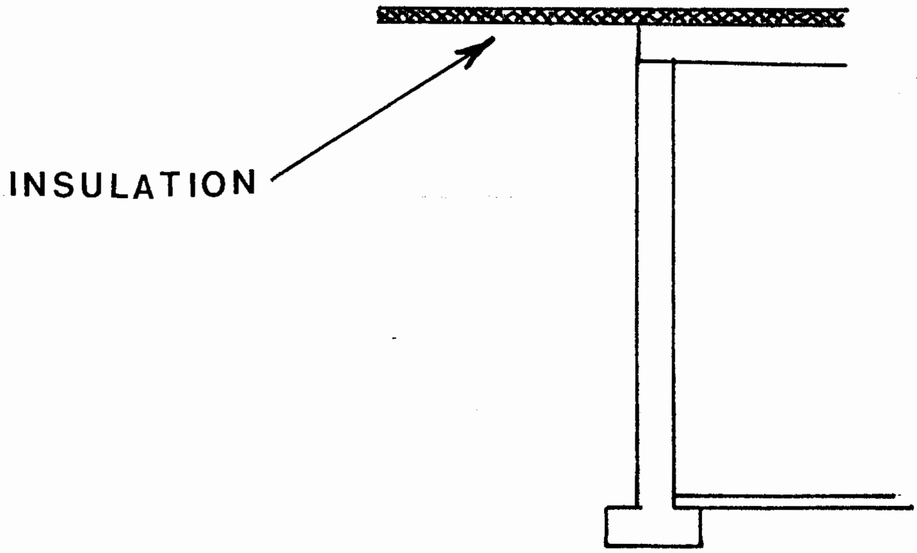

Figure 5. Wall Insulation (Wall Four) (Underground Space Center, 1978, p. 65).

There is no question that there is a need for insulation. The placement is, however, important along with the cost, availability, and longevity of the insulation. These considerations will need to be looked at with each individual development. The following data was made available to the University of Minnesota by the Dow Chemical Company:

	initial[1] R-value per inch	final[2] R-value per inch	cost[3] per foot	R-value[4] per $
extruded polystyrene	5.0	4.54	.16	28.38
beadboard	4.0	2.85	.11	25.91
polyurethane	6.89	2.985	.19	15.68
fiberglass	3.5 (for comparison)			

(Underground Space Center, 1978, p. 146).

Insulation, when working with an earth home, is usually placed on the outside; this allows the mass to be enclosed in the insulation which helps with unwanted, rapid temperature changes. To go along with this, insulation placed on the inside of the wall will cause the wall to become cooler. This cooling causes water vapor permeating outward to condense on the cold side of the insulation. The water vapor will drop the effectiveness of the R-value of the material used. The following is a list of characteristics needed for underground insulation:

1. High compression strength to resist the lateral earth loads imposed by the backfill.
2. High resistance to water and very low water absorption so that the R-value of the insulation is not reduced.
3. High resistance to the various chemical properties of soil; therefore, long lived.
4. Good dimensional and R-value stability over a large period of time.
5. Tongue and groove configuration to reduce cold spots and water movement between the insulation sheets.
6. Low cost, presently available and easily handled (p. 145).

Materials

In above ground construction, the materials used have become fairly standard. The live load (wind and snow) and dead load (stationary structural material) applied to a conventional above ground house are not crucial in the design of an earth sheltered home. Basements in conventional homes usually are less than six feet deep and can be constructed with concrete block or wood foundations. They will be able to withstand the pressure of the soil.

In contrast, an earth home will have a significant load increase due to the constant pressure of the soil. For example, a conventional roof may be designed for a dead load of 10 lbs./sq. ft. and a live load of 40 lbs./sq. ft. An earth home roof must be designed for 300 to 400 lbs./sq. ft. Because of these greater loads, care must be taken in the design of the roof. There is a good deal of flexibility in the design of an earth home, but good planning is needed so there is no unnecessary construction cost. (p. 105)

In earth sheltered buildings, the most commonly used materials are reinforced concrete. Concrete adds to the thermal mass of a building. Some builders of earth homes have used concrete block, but block is not as strong and still needs reinforcement bar for strength. There are many reasons why other materials are not used. Depending on the span of the roof, wood timbers can be cost competitive and are aesthetically, acoustically, and thermally superior to concrete; however, there may be problems with the shrinkage and life span of wood timbers. Interior walls of 2 x 6 frame walls can be used, but they lack the ability of thermal storage. There have been some foundations made from wood, but there is little evidence of their life cycle. Steel also has been used in the construction of earth homes, but the cost is very high. (p. 110)

Climate Control

One reason for building earth homes is the conservation of energy, but no one has said that the people living in an earth home should live uncomfortably. Going underground has its advantages, the main one being the thermal mass of the soil. As stated earlier, soil is not a good insulator, but it does have the ability to release heat slowly in comparison to air. Between the soil and the concrete in an earth home, there is a large volume of thermal mass. However, this thermal mass is no good unless there is a way to heat and cool it to the temperature that is suitable to the occupants of the earth home. The units of energy that can be stored in the thermal mass is called British Thermal Unit (Btu). Btu is the amount of energy required to raise or lower one pound of water one degree Fahrenheit. (Campbell, 1980, p. 109)

In controlling the climate of any home in the northern United States, the primary concern is for heating during the winter. With economics a big factor in today's life style, a passive solar system may be the primary heat source for a house. With a well-planned orientation of the windows to the south, as much as 60 to 70% of the home's heat may come from the sun's radiation. Some heat gain is possible from east and west facing windows, but maximum gain will be from the south. With a passive solar heat system, there will be heat gain when the sun is out but loss on cloudy days and nights. To retain the heat gain, drapes and shutters will be needed in the design. (p. 111)

Because the sun also cannot be relied upon, there is a need for a back-up system. These systems can include oil, natural gas, electricity, coal, and wood. Statistics on heating and cooling earth homes are somewhat inconsistent due to the fact that earth homes are a new type of construction.

However, with the data available, experts agree that no matter what back-up system is used, the system will be more efficient underground. (p. 112)

When considering the size of the back-up system, there are certain factors that need to be discussed. The earth sheltered home is much more air tight than a conventional home, which stops air infiltration. With less air infiltration, the life style of the occupants can change the size of the needed back-up system. This means appliances may be adding heat gain to the home and reduce the need for a large heating unit. When analyzing the energy needs of a home, it should be noted that a large heating unit shutting on and off may use more energy than a smaller unit running all the time. (p. 112)

With the constant increase in the cost of fossilfuels, wood is becoming a popular back-up system in earth homes. Increased efficiency and design of wood furnaces and fire places has made it convenient to place them in earth homes. Wood may be inconvenient in heating large homes as the primary heat source, but with low heating requirements of earth homes, the use of wood is very feasible.

Chapter Five

Summary

The purpose of this study was to determine if earth sheltered housing may be the trend for the future in residential construction. Because natural fossil fuels are becoming scarce, it seems that earth homes will become a promising alternative to residential housing. If earth homes are going to become a good alternative to conventional housing people will need to be exposed to this new technology and convinced of its effectiveness.

People's attitudes, energy use, the initial cost of building, geographic location, building codes, insurance changes, and maintenance of earth sheltered homes are areas of general concern. Necessary technical information for building earth sheltered homes include acoustics, waterproofing, insulation, building materials, and climate control.

Now, through advances in technology, people are seeing the advantages that this earth has to offer in the construction industry. Because earth shelter homes are designed to be energy efficient, there will be less waste of our natural resources.

Conclusions

The success of earth homes will depend on many variables within the construction industry. Each year more earth homes are built; but because so few have been tested, there are little data available to convince the general public that underground homes can be enjoyable living spaces. Builders of earth homes generally agree that underground living can cut back energy consumption 50 to 60% compared to the conventional above ground home. It is the belief of this writer that earth shelter homes have great potential for energy saving and represent a great future in residential construction.

Recommendations

The public needs to be informed to see how earth sheltered construction compares to conventional construction. If people are going to use natural resources carefully, they need to be exposed to the different alternatives in construction. It is the belief of this writer that public schools need to expose students somewhere in their course work to the needs of more energy efficient residential homes.

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