# Earth sheltering

From Wikipedia, the free encyclopedia

**Earth sheltering** is the architectural practice of using earth against building walls for external thermal mass, to reduce heat loss, and to easily maintain a steady indoor air temperature. Earth sheltering has become relatively more popular in modern times, especially among environmentalists and advocates of passive solar and sustainable architecture. However, the practice has been around for nearly as long as humans have been constructing their own shelters.

Turf houses in Keldur, Iceland.

Turf house in Sænautasel, Iceland.

Turf house in Sænautasel, Iceland. Inside view showing the turf layers on the walls.

## Contents



## Definition

The expression earth-sheltering is a generic term, with the general meaning: *building design in which soil plays an integral part*.

A building can be described as earth-sheltered if its external envelope is in contact with a thermally significant volume of soil or substrate (where “thermally significant” means making a functional contribution to the thermal effectiveness of the building in question.)

Earth-sheltered buildings consist of one or more of three types: earth-covered, earth-bunded, and subterranean. An earth-covered building is one where the thermally effective element is placed solely on the roof, but is more usually a continuation of the earth-bunding at the unexposed elevations of the building. An earth-bunded building is one where the thermally significant element insulates one or more of the sheltered elevations of the building. The bunding can be partial or total. A subterranean building is one where the thermally significant element insulates all elevations of the building, leaving only the roof exposed; or, if the building is built into an incline, it may be that the roof is covered and only one elevation is left exposed.[1]

# Background

Living within earth shelters has been a large part of human history. The connection to earth shelter dwellings began with the utilization of caves, and over time evolving technologies led to the construction of customized earth dwellings. Today, earth shelter construction is a rare practice, especially in the U.S.A. During the energy crisis and the 1973 Oil Crisis,[2] along with the back-to-the-land movement, there was a surge of interest in earth shelter/underground home construction in an effort toward self-sufficient living. However, progress has been slow, and earth shelter construction is often viewed by architects, engineers, and the public alike as an unconventional method of building. Techniques of earth sheltering have not yet become common knowledge, and much of society still remains unaware of the process or benefits of this type of building construction.

# Types of construction

Example of an abandoned Icelandic turf house in the region of Búðahraun via earth berming

- **Earth berming:** Earth is piled up against exterior walls and packed, sloping down away from the house. The roof may or may not be fully earth covered, and windows/openings may occur on one or more sides of the shelter. Due to the building being above ground, fewer moisture problems are associated with earth berming in comparison to underground/fully recessed construction.
- **In-hill construction:** The house is set into a slope or hillside. The most practical application is using a hill facing towards the equator (south in the Northern Hemisphere and north in the Southern Hemisphere). There is only one exposed wall in this type of earth sheltering, the wall facing out of the hill, all other walls are embedded within the earth/hill.
- **Underground/fully recessed construction:** The ground is excavated, and the house is set in below grade. It can also be referred to as an Atrium style due to the common atrium/courtyard constructed in the middle of the shelter to provide adequate light and ventilation.

# Benefits

The benefits of earth sheltering are numerous. They include: taking advantage of the earth as a thermal mass, offering extra protection from the natural elements, energy savings, providing substantial privacy, efficient use of land in urban settings, shelters have low maintenance requirements, and earth sheltering commonly takes advantage of passive solar building design.

The Earth's mass absorbs and retains heat. Over time, this heat is released to surrounding areas, such as an earth shelter. Because of the high density of the earth, change in the earth's temperature occurs slowly. This is known as 'thermal lag.' Because of this principle, the earth provides a fairly constant temperature for the underground shelters, even when the outdoor temperature undergoes great fluctuation. In most of the United States, the average temperature of the earth once below the frost line is between 55 and 57 degrees Fahrenheit (13 to 14 degrees Celsius). Frost line depths vary from region to region. In the USA frost lines can range from just under the surface to more than 40 inches. Thus, at the base of a deep earth berm, the house is heated against an exterior temperature gradient of perhaps ten to fifteen degrees, instead of against a steeper temperature grade where air is on the outside of the wall instead of earth. During the summer, the temperature gradient helps to cool the house.

The reduction of air infiltration within an earth shelter can be highly profitable. Because three walls of the structure are mainly surrounded by earth, very little surface area is exposed to the outside air. This alleviates the problem of warm air escaping the house through gaps around windows and door. Furthermore, the earth walls protect against cold winter winds which might otherwise penetrate these gaps. However, this can also become a potential indoor air quality problem. Healthy air circulation is key.

As a result of the increased thermal mass of the structure, the thermal lag of the earth, the protection against unwanted air infiltration and the combined use of passive solar techniques, the need for extra heating and cooling is minimal. Therefore, there is a drastic reduction in energy consumption required for the home compared to homes of typical construction.

Earth shelters also provide privacy from neighbours, as well as soundproofing. The ground provides acoustic protection against outside noise. This can be a major benefit in urban areas or near highways. In urban areas, another benefit of underground sheltering is the efficient use of land. Many houses can sit below grade without spoiling the habitat above ground. Each site can contain both a house and a lawn/garden.

# Potential problems

Problems of water seepage, internal condensation, bad acoustics, and poor indoor air quality can occur if an earth shelter has not been properly designed.

Issues also include the sustainability of building materials. Earth sheltering often requires heavier construction than conventional building techniques, and many construction companies have limited or no experience with earth sheltered construction, potentially compromising the physical construction of even the best designs.

The threat of water seepage occurs around areas where the waterproofing layers have been penetrated. Vents and ducts emerging from the roof can cause specific problems due to the possibility of movement. Precast concrete slabs can have a deflection of 1/2 inch or more when the earth/soil is layered on top of them. If the vents or ducts are held rigidly in place during this deflection, the result is usually the failure of the waterproofing layer. To avoid this difficulty, vents can be placed on other sides of the building (besides the roof), or separate segments of pipes can be installed. A narrower pipe in the roof that fits snugly into a larger segment within the building can also be used. The threat of water seepage, condensation, and poor indoor air quality can all be overcome with proper waterproofing and ventilation.

The building materials for earth sheltered construction tend to be of non-biodegradable substances. Because the materials must keep water out, they are often made of plastics. Concrete is another material that is used in great quantity. More sustainable products are being tested to replace the cement within concrete (such as fly ash), as well as alternatives to reinforced concrete (see more under Materials: Structural). The excavation of a site is also drastically time- and labor-consuming. Overall, the construction is comparable to conventional construction, because the building requires minimal finishing and significantly less maintenance.

Condensation and poor quality indoor air problems can be solved by using earthtubes, or what is known as a geothermal heat pump—a concept different from earth sheltering. With modification, the idea of earthtubes can be used for underground buildings: instead of looping the earthtubes, leave one end open downslope to draw in fresh air using the chimney effect by having exhaust vents placed high in the underground building.

# Landscape and site planning

The site planning for an earth sheltered building is an integral part of the overall design; investigating the landscape of a potential building site is crucial. There are many factors to assess when surveying a site for underground construction. The topography, regional climate, vegetation, water table and soil type of varying landscapes all play dynamic roles in the design and application of earth shelters.

## Topography

On land that is relatively flat, a fully recessed house with an open courtyard is the most appropriate design. On a sloping site, the house is set right into the hill. The slope will determine the location of the window wall; a south-facing exposed wall is the most practical in the Northern hemisphere (and north-facing in the Southern hemisphere) due to solar benefits. The most practical house design in the tropics (and with equal advantage in both hemispheres) is that the two shorter walls on the ends be exposed, one facing east and the other facing west.

## Regional climate

Depending on the region and site selected for earth sheltered construction, the benefits and objectives of the earth shelter construction vary. For cool and temperate climates, objectives consist of retaining winter heat, avoiding infiltration, receiving winter sun, using thermal mass, shading and ventilating during the summer, and avoiding winter winds and cold pockets. For hot, arid climates objectives include maximizing humidity, providing summer shade, maximizing summer air movement, and retaining winter heat. For hot, humid climates objectives include avoiding summer humidity, providing summer ventilation, and retaining winter heat.

Regions with extreme daily and seasonal temperatures emphasize the value of earth as a thermal mass. In this way, earth sheltering is most effective in regions with high cooling and heating needs, and high temperature differentials. In regions such as the south eastern United States, earth sheltering may need additional care in maintenance and construction due to condensation problems in regard to the high humidity. The ground temperature of the region may be too high to permit earth cooling if temperatures fluctuate only slightly from day to night. Preferably, there should be adequate winter solar radiation, and sufficient means for natural ventilation. Wind is a critical aspect to evaluate during site planning, for reasons regarding wind chill and heat loss, as well as ventilation of the shelter. In the Northern Hemisphere, south facing slopes tend to avoid cold winter winds typically blown in from the north. Fully recessed shelters also offer adequate protection against these harsh winds. However, atria within the structure have the ability to cause minor turbulence depending on the size. In the summer, it is helpful to take advantage of the prevailing winds. Because of the limited window arrangement in most earth shelters, and the resistance to air infiltration, the air within a structure can become stagnant if proper ventilation is not provided. By making use of the wind, natural ventilation can occur without the use of fans or other active systems. Knowing the direction, and intensity, of seasonal winds is vital in promoting cross ventilation. Vents are commonly placed in the roof of bermed or fully recessed shelters to achieve this effect.

## Vegetation

The plant cover of the landscape is another important factor. Adding plants can be both positive and negative. Nearby trees may be valuable in wet climates because their roots remove water. However a prospective builder should know what types of trees are in the area and how large and rapidly they tend to grow, due to possible solar-potential compromise with their growth. Vegetation can provide a windbreak for houses exposed to winter winds. The growth of small vegetation, especially those with deep roots, also helps in the prevention of erosion, on the house and in the surrounding site.

## Soil and drainage

The soil type is one of the most essential factors during site planning. The soil needs to provide adequate bearing capacity and drainage, and help to retain heat. With respects to drainage, the most suitable type of soil for earth sheltering is a mixture of sand and gravel. Well graded gravels have a large bearing capacity (about 8,000 pounds per square foot), excellent drainage and a low frost heave potential. Sand and clay can be susceptible to erosion. Clay soils, while least susceptible to erosion, often do not allow for proper drainage, and have a higher potential for frost heaves. Clay soils are more susceptible to thermal shrinking and expanding. Being aware of the moisture content of the soil and the fluctuation of that content throughout the year will help prevent potential heating problems. Frost heaves can also be problematic in some soil. Fine grain soils retain moisture the best and are most susceptible to heaving. A few ways to protect against capillary action responsible for frost heaves are placing foundations below the freezing zone or insulating ground surface around shallow footings, replacement of frost sensitive soils with granular material, and interrupting capillary draw of moisture by putting a drainage layer of coarser material in the existing soil.

Water can cause potential damage to earth shelters if it ponds around the shelter. Avoiding sites with a high water table is crucial. Drainage, both surface and subsurface, must be properly dealt with. Waterproofing applied to the building is essential.

Atrium designs have an increased risk of flooding, so the surrounding land should slope away from the structure on all sides. A drain pipe at the perimeter of the roof edge can help collect and remove additional water. For bermed homes, an interceptor drain at the crest of the berm along the edge of the roof top is recommended. An interceptor drainage swale in the middle of the berm is also helpful or the back of the berm can be terraced with retaining walls. On sloping sites runoff may cause problems. A drainage swale or gully can be built to divert water around the house, or a gravel filled trench with a drain tile can be installed along with footing drains.

Soil stability should also be considered, especially when evaluating a sloping site. These slopes may be inherently stable when left alone, but cutting into them can greatly compromise their structural stability. Retaining walls and backfills may have to be constructed to hold up the slope prior to shelter construction.

# Construction methods

## Current methods

In earth sheltered construction there is often extensive excavation done on the building site. An excavation several feet larger than the walls' planned perimeter is made to allow for access to the outside of the wall for waterproofing and insulation. Once the site is prepared and the utility lines installed, a foundation of reinforced concrete is poured. The walls are then installed. Usually they are either poured in place or formed either on or off site and then moved into place. Reinforced concrete is the most common choice. The process is repeated for the roof structure. If the walls, floor and roof are all to be poured in place, it is possible to make them with a single pour. This can reduce the likelihood of there being cracks or leaks at the joints where the concrete has cured at different times.

On the outside of the concrete a waterproofing system is applied. The most frequently used waterproofing system includes a layer of liquid asphalt onto which a heavy grade waterproof membrane is affixed, followed by a final liquid water sealant which may be sprayed on. It is very important to make sure that all of the seams are carefully sealed. It is very difficult to locate and repair leaks in the waterproofing system after the building is completed.

One or more layers of insulation board or foam are added on the outside of the waterproofing. If the insulation chosen is porous, a top layer of waterproofing is added. After everything is complete, earth is backfilled into the remaining space at the exterior of the wall and sometimes over the roof to accommodate a green roof. Any exposed walls and the interior are finished according to the owners' preferences.

## Materials

### Structural

Reinforced concrete is the most commonly used structural material in earth shelter construction. It is strong and readily available. Untreated wood rots within five years of use in earth shelter construction. Steel can be used, but needs to be encased by concrete to keep it from direct contact with the soil which corrodes the metal. Bricks and CMUs (concrete masonry units) are also possible options in earth shelter construction but must be reinforced to keep them from shifting under vertical pressure unless the building is constructed with arches and vaults.

Unfortunately, reinforced concrete is not the most environmentally sustainable material. The concrete industry is working to develop products that are more earth-friendly in response to consumer demands. Products like Grancrete and Hycrete are becoming more readily available. They claim to be environmentally friendly and either reduce or eliminate the need for additional waterproofing. However, these are new products and have not been extensively used in earth shelter construction yet.

Some unconventional approaches are also proposed. One such method is a PSP method proposed by Mike Oehler. The PSP method uses wooden posts, plastic sheeting and non-conventional ideas that allow more windows and ventilation. This design also reduces some runoff problems associated with conventional designs. The method uses wood posts, a frame that acts like a rib to distribute settling forces, specific construction methods which rely on fewer pieces of heavy equipment, plastic sheeting, and earth floors with plastic and carpeting.

### Waterproofing

Several layers are used for waterproofing in earth shelter construction. The first layer is meant to seal any cracks or pores in the structural materials, also working as an adhesive for the waterproof membrane. The membrane layer is often a thick flexible polyethylene sheeting called EPDM. EPDM is the material usually used in water garden, pond and swimming pool construction. This material also prevents roots from burrowing through the waterproofing. EPDM is very heavy to work with, and can be chewed through by some common insects like fire ants. It is also made from petrochemicals, making it less than perfect environmentally.

There are various cementitious coatings that can be used as waterproofing. The product is sprayed directly onto the unprotected surface. It dries and acts like a huge ceramic layer between the wall and earth. The challenge with this method is, if the wall or foundation shifts in any way, it cracks and water is able to penetrate through it easily.

Bituthene (Registered name) is very similar to the three coat layering process only in one step. It comes already layered in sheets and has a self-adhesive backing. The challenge with this is the same as with the manual layering method, in addition it is sun sensitive and must be covered very soon after application.

Eco-Flex is an environmentally friendly waterproofing membrane that seems to work very well on foundations, but not much is known about its effectiveness in earth sheltering. It is among a group of liquid paint-on waterproofing products. The main challenges with these are they must be carefully applied, making sure that every area is covered to the right thickness, and that every crack or gap is tightly sealed.

Bentonite clay is the alternative that is closest to optimum on the environmental scale. It is naturally occurring and self-healing. The drawback to this system is that it is very heavy and difficult for the owner/builder to install and subject to termite damage.

Bi-membranes have been used extensively throughout Australia where 2 membranes are paired together —typically 2 coats of water based epoxy as a 'sealer' and stop the internal vapor pressure of the moist concrete exploding bubbles of vapor up underneath the membrane when exposed to hot sun. The bond strength of epoxy to concrete is stronger than the internal bond strength of concrete so the membranes won't 'blow' off the wall in the sun. Epoxies are very brittle so they are paired up with an overcoat of high-build flexible water based acrylic membrane in multiple coats of different colors to ensure film coverage—this is reinforced with non-woven polyproplene textile in corners and changes in direction.

### Insulation

Unlike conventional building, earth shelters require the insulation on the exterior of the building rather than inside the wall. One reason for this is that it provides protection for the waterproof membrane against freeze damage, another is that the earth shelter is able to better retain its desired temperature. There are two types of insulation used in earth shelter construction. The first is close-celled extruded polystyrene sheets. Two to three inches glued to the outside of the waterproofing is generally sufficient. The second type of insulation is a spray on foam. This works very well where the shape of the structure is unconventional, rounded or difficult to get to. Foam insulation requires an additional protective top coat such as foil to help it resist water penetration.

In some low budget earth shelters, insulation may not be applied to the walls. These methods rely on the U factor or thermal heat storage capacity of the earth itself below the frost layer. These designs are the exception however and risk frost heave damage in colder climates. The theory behind no insulation designs relies on using the thermal mass of the earth to store heat, rather than relying on a heavy masonry or cement inner structures that exist in a typical passive solar house. This is the exception to the rule and cold temperatures may extend down into the earth above the frost line making insulation necessary for higher efficiencies.

## Design for energy conservation

Earth sheltered homes are often constructed with energy conservation and savings in mind. Specific designs of earth shelters allow for maximum savings. For bermed or in-hill construction, a common plan is to place all the living spaces on the side of the house facing the equator. This provides maximum solar radiation to bedrooms, living rooms, and kitchen spaces. Rooms that do not require natural daylight and extensive heating such as the bathroom, storage and utility room are typically located on the opposite (or in hill) side of the shelter. This type of layout can also be transposed to a double level house design with both levels completely underground. This plan has the highest energy efficiency of earth sheltered homes because of the compact configuration as well as the structure being submerged deeper in the earth. This provides it with a greater ratio of earth cover to exposed wall than a one story shelter would.

With an atrium earth shelter the living spaces are concentrated around the atrium. The atrium arrangement provides a much less compact plan than that of the one or two story bermed/inhill design; therefore it is commonly less energy efficient, in terms of heating needs. This is one of the reasons why atrium designs are classically applied to warmer climates. However, the atrium does tend to trap air within it which is then heated by the sun and helps reduce heat loss.

# Earth sheltering with solar heating

Earth sheltering is often combined with solar heating systems. Most commonly, the utilization of passive solar design techniques is used in earth shelters. In the Northern Hemisphere, a south facing structure with the north, east, and west sides covered with earth, is the most effective application for passive solar systems. A large double glazed window, triple glazed or Zomeworks beadwall (vacuum/blower pumps that filled your double pane solar windows with styrofoam balls at night for extra insulation and vacuumed the beads out in the morning, patent now expired. This changes a window from an R3 thermal resistance to an R16 to R32(depending on thickness of styrofoam bead wall)), spanning most of the length of the south wall is critical for solar heat gain. It is helpful to accompany the window with insulated drapes to protect against heat loss at night. Also, during the summer months, providing an overhang, or some sort of shading device, is useful to block out excess solar gain. Combining solar heating with earth sheltering is referred to as "annualized geo solar design", "Passive annual heat storage", or sometimes as an "Umbrella house." (See Nick Pine's posting on usenet alt.homepower and alt.solar.thermal groups about this type of house.) In the umbrella house, Polystyrene insulation extends around 23 feet (7.0 m) radius from underground walls. A plastic film covers the insulation (for waterproofing), and soil is layer on top. The materials slope downward, like an umbrella. It sheds excess water while keeping the soil temperature warm and dry.

Passive cooling which pulls air with a fan or convection from a near constant temperature air into buried Earth cooling tubes and then into the house living space. This also provides fresh air to occupants and the air exchange required by ASHRAE.

# Earth shelter construction: history and examples

## Berming

Historically, earth berming was a common building practice that combined heavy timber framing and rough stone work with stacking thick layers of sod or peat against the walls and on the roof. This served as excellent protection from the elements. In a relatively short period of time the earth layers grow together leaving the structure with an appearance of a hill with a door.

In these early structures, the heavy timber framing acted as structural support and added comfort and warmth to the interior. Rough stone was often stacked along the outer walls with a simple lime mortar for structural support and often serves as an exterior facing wall and foundation. There is a greater use of stone work in earth shelter structures in areas where timber is scarce. These are the most sustainable of the earth shelters as far as materials go because they are able to decompose and return to earth. This is why there are few remaining example like Hvalsey Church in Greenland where only the stacked stones remain. One of the oldest examples of berming, dating back some 5,000 years, can be found at Skara Brae in the Orkney Islands off northern Scotland.

Earth Sheltered rest area along Interstate 77 in Ohio, USA

Today's bermed earth structures are built quite differently from those of the past. Common construction employs large amounts of steel reinforced concrete acting as structural support and building shell. Bulldozers or bobcats are used to pile earth around the building and on the roof instead of stacking earth in place. One modern example of bermed earth structures is the Hockerton Housing Project, a community of 5 homes in Nottinghamshire, England.

## In-hill

One historical example of in-hill earth shelters would be Mesa Verde, in the southwest United States. These building are constructed directly onto the ledges and caves on the face of the cliffs. The front wall is built up with local stone and earth to enclose the structure. Similarly today, in-hill earth shelter construction utilizes the natural formation of a hillside for two to three of the exterior walls and sometimes the roof of a structure. Alternative builders craft a type of in-hill structure known as an Earthship. In Earthship construction, tires rammed with earth are used as structural materials for three of the walls and generally have a front façade of windows to capture passive solar energy.

A well-known example of an earth-sheltered home is the residence of Bill Gates, who had it built over a period of several years on a heavily wooded site on the shore of Lake Washington, USA. It is an excellent example of the lack of obtrusiveness of this kind of home, since it appears much smaller than it actually is, when seen from the lake.

## Underground

Though underground construction is relatively uncommon in the US (except for basements where only 1 floor is underground), successful examples can be found in Australia where the ground is so hard that there is little to no need for structural supports and a pick ax and shovel are the tools of the builder/remodeler. See Coober Pedy and Lightning Ridge. The Forestiere Underground Gardens in Fresno, California is a North American example.

In the early 1970s, China undertook the construction of Dixia Cheng, a city underneath Beijing. It was primarily a complex of bomb shelters that could house 40% of the population at that time. It was a response to the fear of Soviet attack. Parts of it are now used in more commercial ventures.

# Gallery

Loir-et-Cher (France)

Kandovan, East Azarbaijan (Iran)

Hôtel Sididriss in Matmata (Tunisia)

Interior of a cave in Matmata (Tunisia)

Cave house in Louresse-Rochemenier (France)

Granada (Spain)

Sassi di Matera (Italy)

Earth house estate in Dietikon made by Peter Vetsch

# See also

**Topics:**

- Earth house
- Earth structure
- Green building
- Underground home
- Underground living

**Types:**

- Burdei
- Dugout
- Earth lodge
- Earthship
- Grubenhaus
- Kiva
- Pit-house
- Quiggly hole
- Rock cut
- Sod house
- Yaodong
- Zemlyanka

**Applications:**

- Daylight basement
- Earth cooling tubes
- Energy-efficient landscaping
- Energy conservation

- Green roof
- Hurricane-proof building
- Passive house
- Passive solar
- Radiation shielding

**Proponents:**

- Bill Gates's house, a very large earth-sheltered home
- Coober Pedy, an Australian opal mining town famous for its underground buildings
- Cosanti—site of "Earth House" designed by architect Paolo Soleri
- Earl Young (architect)—works commonly referred to as gnome homes, mushroom houses, or Hobbit houses
- Malcolm Wells, proponent of earth-sheltered building
- David Baggs, proponent of earth-sheltered building, author and architect of over 40 earth covered buildings in Australia

# Notes

1. Harrall. J. 2007. Demonstrating the Viability and Growing Acceptability of Earth-Sheltered Buildings in the UK
2. "Earth-sheltered Homes". *Mother Earth News*.

# References


- Baggs, Sydney A., Baggs, Joan C. & Baggs, David W., *Australian Earth-Covered Building* New South Wales University Press, NSW Aus, 1991 ISBN 0-86840-060-2
- Baggs, Sydney A., Baggs, Joan C. & Baggs, David W., *Australian Earth-Covered Building* IP Publishers, QLD, Aus, 2005 ISBN 978-0-9756807-1-1 can be accessed online at [1] (http://www.ipoz.biz)
- Berge, Bjorn. *The Ecology of Building Materials.* Architectural Press, 2000. This book includes detailed information about building materials.
- Campbell, Stu. *The Underground House Book.* Vermont: Garden Way, Inc., 1980.
- De Mars, John. *Hydrophobic Concrete Sheds Waterproofing Membrane'* Concrete Products, January 2006. Concrete industry magazine it can be accessed online at [2] (http://www.concreteproducts.com).
- Debord, David Douglas, and Thomas R. Dunbar. *Earth Sheltered Landscapes.* New York: Wan Nostrand Reinhold Company, 1985.
- Edelhart, Mike. *The Handbook of Earth Shelter Design.* Dolphin Books, 1982. This has in depth information about earth shelter construction with many illustrations.
- Miller, David E. *Toward a New Regionalism.* University of Washington Press, 2005. It includes examples and information of sustainable building including earth shelters.
- Reid, Esmond. *Understanding Buildings.* The MIT Press, 1984. This book includes detailed construction and building information.
- Roy, Robert. *Earth Sheltered Houses.* New Society Publishers, 2006. This book is an up-to-date guide of the owner builder. It features much of the information that is in his earlier book.
- Roy, Robert. *Underground Houses: How to Build a Low-Cost Home.* New York: Sterling Publishing Co. Inc., 1979.
- Terman, Max R. *Earth Sheltered Housing: Principles in Practice.* New York: Van Norstrand Reinhold Company, 1985.
- The Underground Space Center University of Minnesota. *Earth Sheltered Housing Design.* Van Nostrand

Reinhold Company, ed. 1978 and ed. 1979. This is an academic look at how to construct an earth shelter building.
- Wade, Herb, Jeffrey Cook, Ken Labs, and Steve Selkowitz. *Passive Solar: Subdivisions, windows, underground.* Kansas City: American Solar Energy Society, 1983.
- Oehler, Mike. *The $50 & up underground house book.* Mole publishing Co, 1978.

# External links

- Hockerton Housing Project (http://www.hockertonhousingproject.org.uk) - Community of 5 earth sheltered homes near Nottingham, UK
- StocktonUnderground : An Owner-Builder Approach (http://www.freewebs.com/stocktonunderground)
- Earth-Sheltered Houses (http://www.uaf.edu/files/ces/publications-db/catalog/eeh/EEM-01359.pdf)
- An Earth Sheltered Directory (http://theundergroundhomedirectory.com/)

Wikimedia Commons has media related to ***Earth sheltering***.