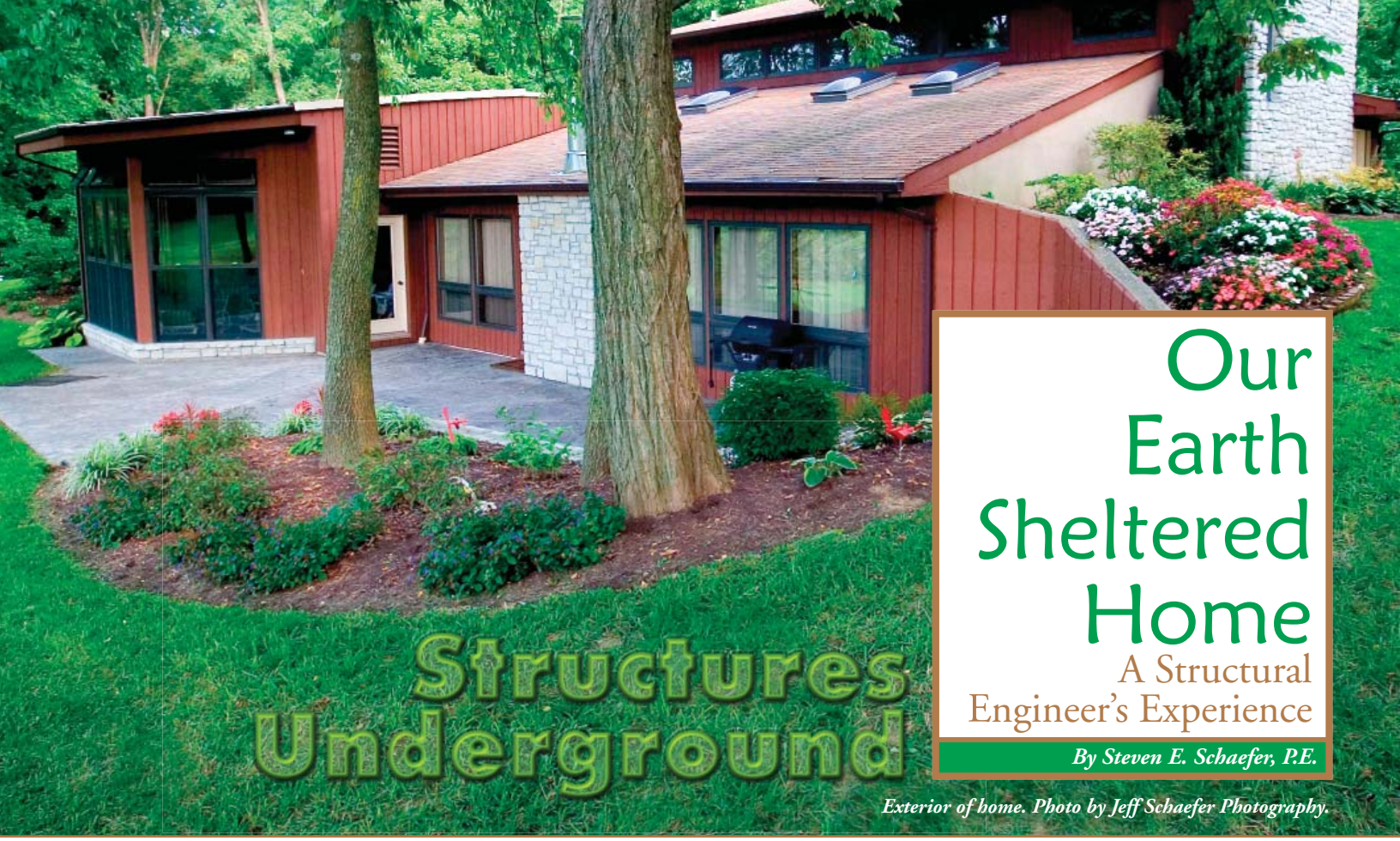


Structures Underground

Our Earth Sheltered Home

A Structural Engineer's Experience

By Steven E. Schaefer, P.E.

Exterior of home. Photo by Jeff Schaefer Photography.

After the severe winters in the Midwest during the late 1970's and the energy crunch that followed, I built an earth sheltered home in 1981 and 1982.

Underground Bedroom Wing

The 1159 square foot (s.f.) bedroom wing of the home is completely underground with 6-inches of foam insulation, 6-inches of pea gravel and 12-inches of earth on top of the 7- to 9-inch thick slab concrete roof. Grass grows readily on the roof. The fill on the roof slopes down to the original grade on the north side which provides access for a garden tractor onto the roof.

There are three spans across 12-foot wide bedrooms which have 8-inch thick concrete bearing walls between them. The ceiling is 8-feet-8-inches high with a "popcorn" spackled finish applied directly to the underside of the concrete roof slab. All of the concrete walls had the rough form edges ground down, the finish etched with muriatic acid and topped with one coat of cement plaster made with white Portland cement and white silica sand.

There are 3 bedrooms on the south half of each span that have a 6-foot wide sliding patio door into a south facing sunroom. The master bedroom is in the northwest corner of this wing, and has a 6-foot wide window on the west wall. There are concrete retaining walls on each side of this window to hold the earth back. On the north half of the center and east span are bathrooms and a laundry, all without windows. All of the infill framing used metal studs and drywall. There is a 2-foot square skylight in the roof to furnish daylight to the corridor that serves the bedrooms.

Main Living Area

The main living area consists of a 34- by 17-foot great room with a sloped cathedral ceiling. The room has two 12- by 6-foot high windows on the south wall plus four 2- by 4-foot skylights near the top of the 13-foot high sloped ceiling. Immediately north of the great room, and open to it, is a dining room and kitchen with an 8-foot high ceiling. To the north of the kitchen and dining room is a utility room.

Above the kitchen, dining room and utility areas, 23-foot long, 9½-inch wood TJI's extend from a steel beam at the south end of the kitchen and dining room to the north foundation wall. These serve as the floor of the recreation room above. Mono-pitched wood roof trusses span the 23-foot north-south direction over the recreation room. By placing the recreation room on the top floor, a 23- by 30-foot room is achieved, which makes it easy to place a pool and ping-pong table in this 9-foot high space without having columns interfere.

East of the dining room there is a 4½-foot high stairway that leads up to a landing at the entrance level and continues up to the recreation room. On the outside of the entrance there are concrete stairs extending up another 1 ½-feet to the exterior grade.

Sun Room

A 10- by 38-foot long sun room was constructed along the south face of the three bedrooms, two feet lower than the main floor. The south wall of this space was originally constructed with a 14- by 38-foot long window wall. Pre-finished dark brown corrugated metal panels were custom fabricated and placed on the south side of the bedroom, and brown brick pavers were placed on the sunroom floor. This space is not heated but on sunny winter 20 degree (F) days, the temperature in the sun room would be close to 90 degrees.

Appearance

The street and access to the home are on the east side. Since the home sits low, the architect created a more contemporary massing of the home by sloping the roof of the garage, which is on the north side, from 8-foot high in the back (west) to over 16-feet at the front. This also allowed constructing a storage loft over the front half of the garage. Using the mono-pitched roof trusses over the recreation room also increased the height seen from the street. The east wall of the stairway area and lower portion of the front wall of the garage are stone masonry. The remainder of the

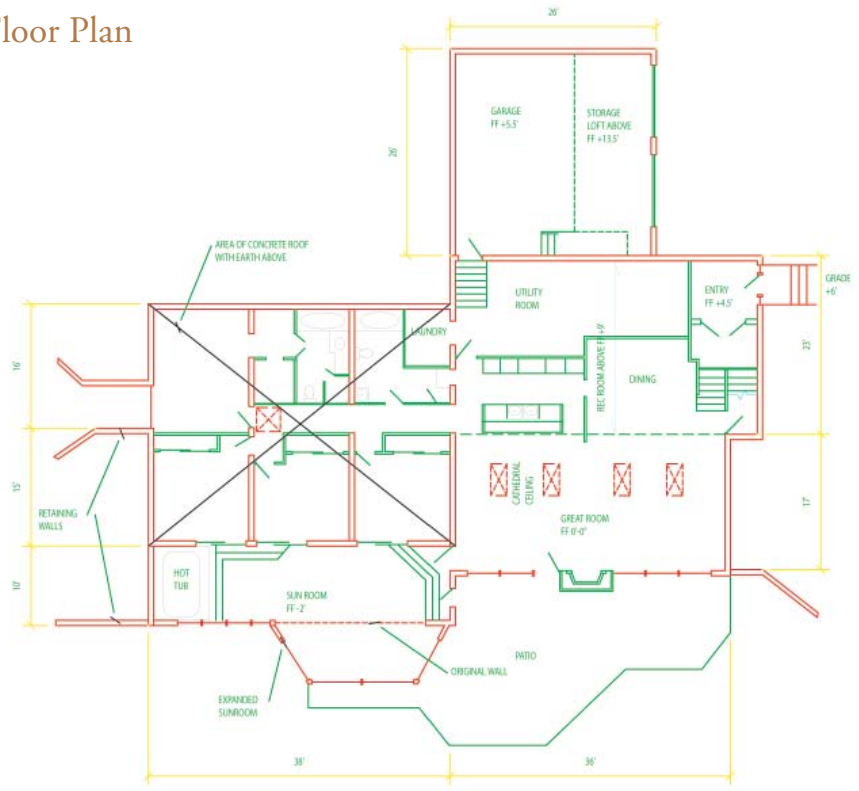
wood framing is covered with vertical cedar siding. Any concrete that is exposed is faced with EIFS.

Waterproofing and Insulation

All below grade walls used Volclay bentonite panels nailed to the outside of the concrete for waterproofing. These are corrugated cardboard panels, with the corrugations filled with bentonite powder and the edges of the panels sealed. Bentonite is a type of clay that, when it gets wet, expands to many times its original volume and seals out water. (I describe it as a jello consistency.) On the concrete roof of the bedroom wing, we used ⅜-inches of loose bentonite powder which was purchased in bags and applied with a lawn spreader.

Two inch thick expanded polystyrene insulation was used at the lower section of all walls, while at the top four feet the thickness was increased to 6-inches. Six inches of extruded polystyrene was used to insulate the top of the concrete roof slab. Although it was considerably more expensive, extruded was used where the insulation was placed flat on the roof because it didn't absorb water like the expanded polystyrene.

Floor Plan



Mechanical Systems and Energy Efficiency

The home was built only partly into the ground on the gently sloping site, and the excavated soil was used as backfill on the north and west sides and on top of the underground portion. Almost all of the windows face south to pick up solar gain in the winter, but are shaded in the summer by trees.

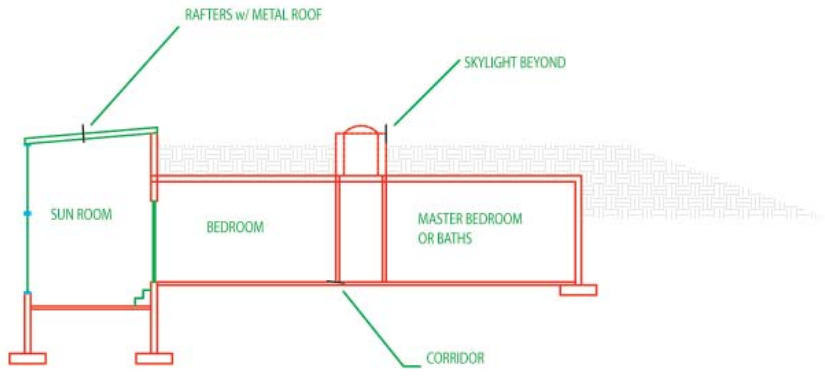
When the home was built, natural gas was not available, so an electric heat pump system was installed that provides both heat and air conditioning. The heat pump blows downward to ducts just below the slab that distribute the air to the first floor. The return air ducts are at the ceiling level and the furnace blower is set to run constantly. Originally, there was a very efficient wood burning stove in the great room. The hot air from the stove would rise and be drawn into return air ducts near the top of the cathedral ceiling and re-distributed to the rest of the home. The locust trees that were thinned from the heavily wooded two acre lot produced enough firewood to last about 17 years. We would heat the entire house with the wood stove for most of the winter each year, until we got tired of bringing in fire wood and putting up with the mess that carrying the wood into the great room created.

Natural gas is now available in the area and a few years ago we decided to take out the wood stove and had a stone veneer faced ventless gas fireplace installed. We keep this on most of the winter. I don't know how energy efficient it is, but it adds a nice atmosphere to the great room.

When the temperature in the sun room reached 80 degrees in the winter, a thermostat would automatically open ducts so that the warm air was circulated throughout the rest of the home. The insulated glass in the sun room was not low-E type, and let the energy from the sun penetrate this room. Since the sun room was only 10-feet wide, it was very efficient for energy but not a practical size for using the room. A few years ago, we enlarged half of the room and used new large double hung operable windows that our contractor had available. These windows had low-E glass and with the larger volume of space in the room, we found that the sun would only warm the room in the winter to about 78 degrees. We do not circulate this air through the rest of the home anymore.

It is difficult to determine how much we really save with the earth sheltered construction. I compared our total gas and electric bills for the past year to three other homes, all built since ours was constructed. For our 2,600 s.f. home, currently occupied by two, the bills totaled $2,100 for the year. A 2,400 s.f. ranch with four occupants had bills of $2,200 and a 3,000 s.f. two story home with six occupants had bills of $2,400. Another

Section through bedrooms



Great Room. Photo by Jeff Schaefer Photography.

recently built 2,600 s.f. ranch home using composite polystyrene and plywood panels with two occupants had an annual energy cost of only $1,530. Although our home uses an electric heat pump which we keep set at 71 degrees during the winter, and the others use more economical gas heat, our maximum winter monthly bill compared to the two conventionally built homes was $110 and $150 less per month.

The other homes spent about $100 less per month during the hottest part of the summer. We keep the air conditioner set at 73 degrees all summer and also run a dehumidifier. Before we started using the air conditioner all summer, we found that we could use the large whole house fan when the temperature was below 70 degrees to pull in cool air. If we then closed the windows, the mass of the home kept the temperature below 76 degrees for two or three days, although the humidity would increase. Despite this energy efficiency, we have found it easier to keep the humidity and temperature constant by running the air conditioner. If we are away from the home for a week or more during the summer, we close all of the windows and turn off the air conditioner. When we return, the temperature is never more than about 78 degrees.

To complicate the energy efficiency comparison further, we also have a large hot tub that we keep heated all year.

A Great Place to Live

In addition to being a very comfortable home that is great for entertaining, the home has a few additional advantages. Although it is less than 200-feet from a heavily used expressway, we cannot hear the highway noise inside the home. Also, the Greater Cincinnati area is hit by a tornado every few years. Although the risk of any specific home being hit is remote, it is very reassuring knowing that we are completely safe in the underground bedrooms.▪

Steve Schaefer is president of Steven Schaefer Associates, Inc., a 40 person structural engineering firm in Cincinnati, Ohio. He is a member of the STRUCTURE Magazine editorial board, active in CASE and the SEAoOhio. He can be contacted at **ses@ssastructural.com**.

ERRATA

In the June 2005 issue of STRUCTURE magazine, the Great Achievements article inadvertently referenced *Steven H. Long*. The correct title should have been ***Stephen H. Long***.