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BUILDING PRACTICE NOTE

THERMAL ENVELOPE HOUSES

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INTRODUCTION

The thermal envelope house is the product of an innovative approach to energy efficient design. The concept was developed in the 70's in the U.S.A. Known also as envelope, double envelope, or double shell houses, these buildings are intended to provide architecturally pleasing spaces and a high degree of comfort while minimizing heating costs. The purpose of this Note is to describe the construction and operation of this type of home and the advantages and limitations of the approach.

CONSTRUCTION

From the outside, a thermal envelope house may look like any other. The form of the building is determined primarily by personal preference and local architectural trends. The Figures in this Note show a variety of possible forms.

In cross-section, a thermal envelope house looks much like a house within a house (Figure 1).

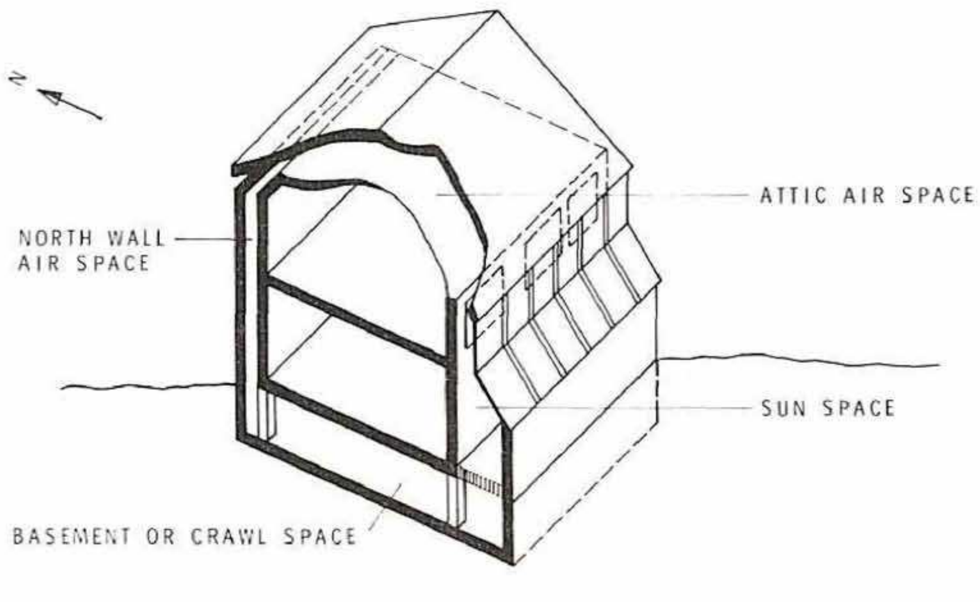

Figure 1: Isometric of a Thermal Envelope House

The east and west walls are single walls similar to those in standard construction but with more insulation.

The north wall consists of two separate parallel walls. They are positioned about a foot apart creating an air space in between. Each wall is insulated and contains a continuous air/vapour barrier to prevent the flow of air and moisture between the living space and the air space, and between the air space and the outside.

The wall on the south side is also made up of two walls. Here, however, they are further apart creating a usable living area referred to as the sun space. The outer wall is mostly glass and may be vertical or sloped depending on the owner's preference and how the space is to be used.

Both the ceiling and the roof are insulated and incorporate continuous air/vapour barriers. The attic space between is open to the north wall air space and to the sun space.

Like the attic, the basement or crawl space under the house is open to the air spaces in the north and south walls. The foundation walls and the floor between the living space and the basement are sealed and insulated. The basement floor may be finished but is not insulated.

THEORY OF OPERATION

The design of the thermal envelope house is based on the concept that the heating or cooling of the air in the sun space will initiate convective air flow between the inner and outer envelopes (1). Proponents of the design claim that the flow of warm air reduces heat loss from the house and provides the capability to store heat on sunny days and recover it on cloudy days or at night. Air flow between the inner and outer envelopes is also intended to provide cooling during the summer.

Heating and Heat Storage

On sunny winter days, radiation from the sun warms the air in the sun space. Since warmer air rises, the air in the sun space tends to rise into the attic. As the air in the north wall loses heat through the inner and outer envelopes, it falls toward the crawl space or basement. In this manner the air circulates around the house through the air spaces (Figure 2). Where temperatures in the air spaces exceed those in the living spaces, heat is transferred into the living spaces. As the earth or floor in the crawl space or basement will be cooler than the cycling air, it will collect heat from the air and store it.

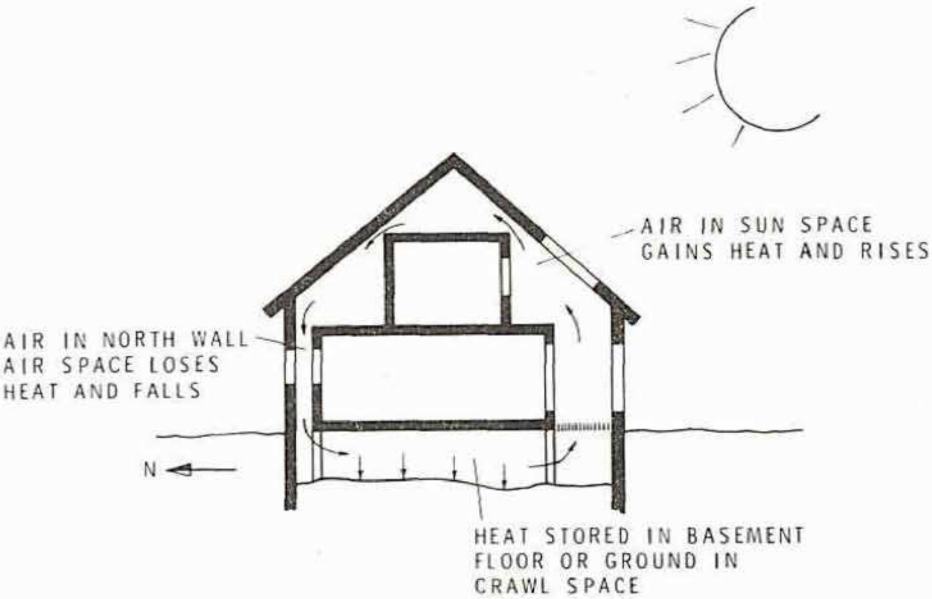

Figure 2. Winter Heating and Storage

Heat Recovery

At night or on cloudy days in winter, the large areas of glazing in the sun space allow rapid heat loss. The cooled air settles into the basement or crawl space setting up convective air flow in the direction opposite to that which occurs during heat gain. The heat stored in the ground is released to the air to maintain a relatively warm blanket of air around the inner walls, ceiling and floor (Figure 3).

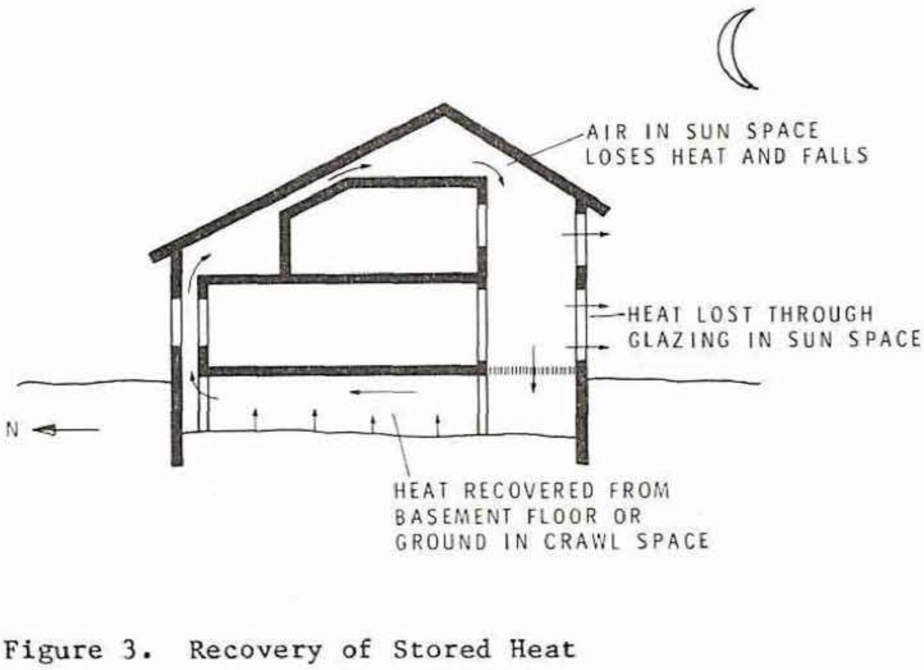

Figure 3. Recovery of Stored Heat

Summer Cooling

In the summer, the air in the wall and attic spaces picks up heat from the house, outside air, and sun. By allowing the warm air to escape through a vent at the top of the attic space and by replacing it with cool air drawn through a duct in the ground, the house is kept cool (Figure 4).

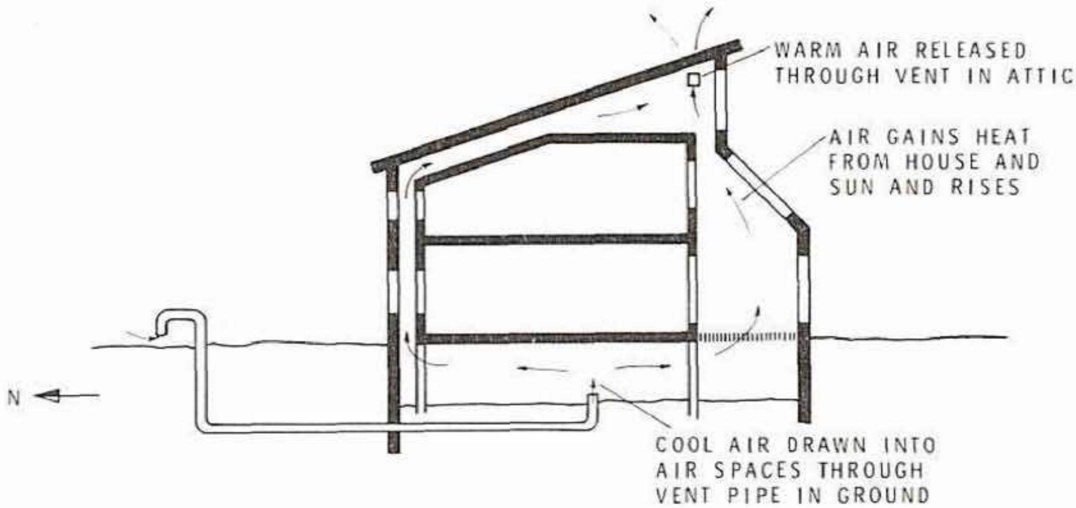

Figure 4. Summer Cooling

CRITICISM OF THE THEORY

A number of questions have been raised regarding the theory of the operation of double envelope houses. The major criticisms are related to heat transfer from the air spaces to the living spaces, the paths of the convection currents and the ability of the soil or basement floor to store and release heat.

The amount of heat transferred to the living spaces or the outside air from the air between the envelopes depends on the temperature differences across and the thermal resistances of the envelopes. Because the temperature difference between the outside air and the air spaces is much greater than that between the air spaces and the living spaces, substantially more heat will be lost to the outside than will be transferred to the interior (2). The efficiency of the double envelope design as a means of heating the living spaces is questionable.

In a number of buildings which have been examined, the temperature difference between the north and south air spaces is not sufficient to set up a complete convective air flow loop (3); any convection currents tend to be localized (Figure 5). Some advocates of the double shell system have recognized this problem and recommend the use of fans to move the air (4).

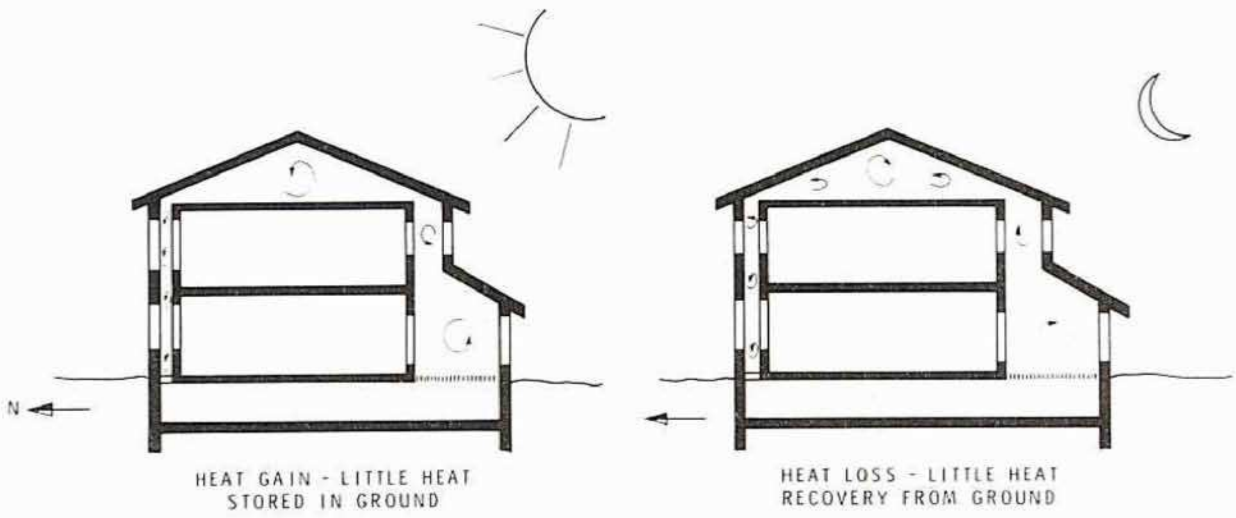

Figure 5. Localized Convection Currents.

Assuming that the air warmed in the sun space does cycle around the inner shell and enter the basement, the warmest air will pass through this space very close to the floor above. The cooler air already in the basement will tend to stay close to the basement floor or ground. Therefore the amount of heat which is stored in the ground is small (5).

PERFORMANCE CLAIMS

Proponents of thermal envelope houses claim a variety of benefits from this design.

Heating - As the house is heated by the sun in the winter and cooled by the earth in summer, little or no auxiliary heating or cooling is required.

Comfort - Because the house is wrapped in a blanket of warm air, the walls, ceiling and floor are warmer than if standard construction was used. With warmer walls the radiative heat loss from the occupants is reduced and comfort is increased.

Air Leakage - The double envelope system provides a double line of defence against air leakage. The reduction of draughts leads to a further increase in comfort.

Sun Space - The sun space is an architectural focal point providing additional space for family activities or a productive greenhouse.

Although thermal envelope homes have proved to be energy efficient, few of the benefits can be attributed solely to the thermal envelope design; the concept also presents some problems of its own.

Heating

Because both the inner and outer envelopes are insulated, the combined thermal resistance of the two envelopes is higher than it would be in standard single shell construction. Optimistic reports on energy use have tended to be based on comparisons with houses of standard construction which have half to one third of the insulation. Table 1 shows the differences in insulation levels in four different house types: standard to 1978; CMHC recommended for 5000 °C degree days (6), double envelope and single envelope low energy.

Table 1. Comparative Insulation Level

Building Component	Typical Standard Construction RSI (R)	CMHC Recommended Construction (for 5000 Cdd) RSI (R)	Typical Double Shell Construction RSI (R)	Average Low Energy Construction RSI (R)
Roof -				
Exterior shell	---	---	5.6 (32)	---
Interior shell	---	---	2.1 (12)	---
Total	5.0 (28)	5.6 (32)	7.8 (44)	9 (50)
North Wall -				
Exterior shell	---	---	4.9 (28)	---
Interior shell	---	---	2.1 (12)	---
Total	2.2 (12.5)	3 (17)	7.1 (40)	6 (34)
South Wall -				
Exterior shell	---	---	2.8 (16)	---
Interior shell	---	---	2.1 (12)	---
Total	2.2 (12.5)	3 (17)	4.9 (28)	6 (34)
East & Walls -				
Total	2.2 (12.5)	3 (17)	4.9 (28)	6 (34)
Basement Walls -				
Above grade	1.6 (9)	1.6 (9)	4.2 (24)	5 (28)
Below grade	1.6 (9)	1.6 (9)	3.5 (20)	1 (6)
Basement Floor	0.0 (0)	0.0 (0)	0.0 (0)	1 (6)

With thermal envelope houses, particular attention is paid to the orientation of the glazing. The number and size of north-facing windows is reduced to a minimum and a large percentage of the south wall is glass. The solar heat gain is therefore considerably higher than in standard construction so the net heat losses are correspondingly lower. This technique for reducing energy requirements, however, is not restricted to double shell houses. The same advantages can be achieved in any type of house through proper planning and orientation.

A comparison of double envelope housing with similar single envelope housing rather than standard construction would provide more valuable information. A computer simulation developed for this type of analysis indicates that a super insulated house with a fan-forced rock heat storage would require significantly less auxiliary energy than the equivalent double envelope house (7).

Comfort

Thermal gradient calculations (2,9) indicate that two wall systems with the same thermal resistance, one with an air space and one without, will provide the same degree of comfort. If the double system did provide a significantly higher level of comfort, it stands to reason that the approach would be used in the east and west walls as well as in the north and south.

Air Leakage

The comparison of double shell houses to standard construction with respect to draughtiness and heat loss by air leakage is also misleading. Most double envelope houses have been custom projects. The quality control in these houses tends to be better than in standard homes so air leakage will tend to be lower. Air sealing in low energy housing has been significantly improved over standard construction. The need for two walls and an intercepting blanket of air has not been demonstrated.

Sunspace

The usefulness of the sunspace as a living space or as a greenhouse is limited by the temperature swings to which it is subjected. Except in more moderate climates or where fans are used to circulate the air, the double envelope design would not keep the sun space from overheating on sunny days and over cooling on winter nights. In most regions of Canada, additional heating, cooling and insulating systems would be required to keep a greenhouse productive year round.

The location of the sunspace with respect to the rest of the house and the yard can also present complications. Because the sun space extends across the full width of the south wall, any direct traffic between the living spaces and the yard to the south must pass through the sunspace. In many designs the sunspace becomes primarily a traffic corridor with little room for other activities.

The sun space has been identified as an architectural highlight of thermal envelope design. This feature, however, is not peculiar to these houses and can easily be incorporated into single shell designs.

Other Considerations

The crawl space, because it is often left open to the earth, may be a source of insect or animal infestation or may allow excessive amounts of moisture into the building. Because most of the air circulation space is inaccessible to adults, it may be impossible to remove any insects or small animals which get between the north walls or into the attic.

The lack of fire stops in the north wall may lead to rapid flame spread in the case of fire. It may be necessary to line both sides of the air space with gypsum board and install automatic dampers to reduce the risk.

Because of the extra floor area required for the air spaces, the additional foundation wall height for the crawl space, and the extra windows and wall finishes, the cost of a double shell house will be greater than that of the equivalent single shell house. Unless the sunspace can be used year round it becomes an expensive luxury. These costs should be considered in conjunction with the auxiliary heating requirements and the functional aspects of the design.

CONCLUSIONS

As there are very few independent analyses of double shell houses, there are still many unanswered questions. Double shell houses would appear to use less energy for space heating than houses of standard construction. The cost effectiveness of double shell construction compared to other low energy approaches has not been demonstrated.

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