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STRATEGIES FOR THE USE OF THE BUILDING ENVELOPE AS A DYNAMIC ELEMENT IN THERMAL PERFORMANCE.

ABSTRACT

Strategies for improving thermal performance of buildings begin with conservation through increased insulation and weather seals. Designers must now concern themselves with toxins indoors. The building envelope has become a barrier to human interaction with the outdoors.

This paper will examine alternative strategies in the design of the building envelope, grouped as follows: (1) designing the envelope as a dynamic used to adjust thermal performance; (2) using the envelope as a buffer between interior and unconditioned exterior space -- using the perimeter of the building as an occupiable but only partially conditioned space. Benefits include: (1) improved thermal performance without sacrificing environmental quality to toxins; (2) the economy of occupying unconditioned space; (3) improved environmental quality.

These strategies are empirical; they do not lend themselves to a priori scientific evaluation of performance. Their effectiveness is, nevertheless, intuitive and well founded in building practice.

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INTRODUCTION

The end of the era of cheap energy has not brought an end to the practice of sealing buildings off from the outdoors, but has instead increased and spread it from artificially conditioned curtain-walled offices to residential construction. Almost every strategy for improving the thermal performance of buildings begins with energy conservation implemented through increased insulation and weather seals. Designers must now concern themselves with the removal of toxins from the indoor environment. This is usually accomplished by mechanical ventilation. The building envelope has become a barrier to any human interaction with the outdoors.

This paper will examine alternative strategies in the design of the building envelope. These strategies can be grouped as follows: (1) designing the envelope not as a static element, but as a dynamic system that can be used to adjust thermal performance; (2) using the envelope, not as a barrier between indoors and out, but as a buffer between the conditioned space of the interior and unconditioned space outside -- using the perimeter of the building as an occupiable but only partially conditioned space. The benefits of these strategies include: (1) improved thermal performance of the building as a whole over the long run, without sacrificing environmental quality to toxins and the means of their removal; (2) the ability to reduce construction costs, by allowing the economy of unconditioned occupied space, not *inside* the building envelope, but as part of the envelope; (3) improved environmental quality.

These strategies are empirical; for a number of reasons, they do not lend themselves to a priori scientific evaluation of performance. Nevertheless I will show that evidence of their effectiveness is not only intuitive but well founded in building practice.

This paper will evaluate uses of the following types of spaces in modifying the performance potential of the building envelope: (1) Tempering spaces are deliberately included in the design to effect changes in the conditioning of the building's interior; (1) Transitional spaces that are normal buffers between outside and in; (3) Spaces used for marginal activities, that are normally included inside the conditioned space of the building, but don't need to be; (4) Unconditioned or partially conditioned spaces into which the building's activities can be expanded on a seasonal basis.

HISTORICAL PERSPECTIVE

Dynamic modification of the building envelope to affect thermal performance is nothing new. We do it all the time without thinking. If it is too hot, we can open a window. If it is too cold we can close the door. In some climates storm windows go up in the fall and are replaced with screens in the spring. In others screens stay up year round. What are window screens that if not a design element that allows us to modify the building envelope for comfort? If a window is too cold and drafty we close the drapes. When we want the warmth of the sun we can open them. If the sun becomes too hot we can draw the blinds. It is only recently in the history of building, since the invention of mechanical heating and cooling, that it has become possible to modulate indoor temperatures without dynamic modifications of the building envelope.

The Building Envelope

The first evidence of artificially constructed human shelter at Terra Amata, France dates back a remarkable four hundred thousand years. The frames of these huts could be sealed against drafts with animal skins, and the presence of a hearth indicates that these buildings were artificially heated (Kostof 1985). Early architecture developed along two lines: ritual or sacred architecture and shelter. From the earliest times in Western civilization the technology of shelter changed little until the 18th century. Buildings were constructed either of masonry (stone, brick or earth), or timber, or some combination of the two. Although solar architecture dates from antiquity (Butti and Perlin 1980) and the Romans developed window glass (Hornbostel 1978), buildings could not be considered sealed against the elements, let alone enclosing a heated environment (cooling was neither possible nor necessary). Artificial heat was available only as a direct product of the combustion of wood, charcoal or coal on an open hearth or firebox. The indoor environment was either smoky, drafty or both. The tempering envelope was not typically of the building but of the person in the form of voluminous clothing. It was not until the 18th century when glass windows became common and Count Rumford improved the fireplace, that any kind of true indoor comfort became possible on a wide scale (Rybczynski 1986). The development of coal, gas and electricity as fuels for heating and the invention of air conditioning finally brought about the possibility of total separation of indoors and out.

Traditional Dynamics of Building Use

Before the development of artificial heat and the building envelope rooms did not have specialized functions. Only the main room of a house was heated by a fireplace or wood stove. The other rooms had no heating at all. The main room would serve as workshop, kitchen, dining room and bedroom. Furniture was movable, hence the origin of the words for it in Latin languages (Rybczynski). Use of the heated room was dynamic, changing easily from one activity to another. As winter changed to spring and then summer, more and more of the house could be used.

In warm climates vernacular architectures developed around the dynamics of keeping cool. That idyllic scene of Americana, the front porch on a summer evening, represents the traditional dynamics of the building envelope as much as it does social values. From the Bengali word ‘bungala’ comes our bungalow, a single story house surrounded by a verandah, an occupiable part of the envelope (Slesin and Cliff 1990). The bungalow has proved such a useful building prototype that its use has become universal and the word is often used to describe houses differing greatly from the original type. In the Mediterranean region terraces and roof gardens can be occupied on a warm winter’s day or a cool summer’s evening. Back yard cook outs, barbecues and parties take place in spaces that may not be inside, but are used seasonally as rooms. In India and other warm climate cultures sleeping on the roof in summer is common.

THE HUMAN FACTOR

People take the building envelope and interior space conditioning for granted. It is easier to turn up the heat than put on a sweater, but we are told to turn down the thermostat to save energy. For most people an indoor work environment without air conditioning would be unimaginable. No matter what the temperature outside we expect the indoor temperature to remain constant. Many people will turn the thermostat past a desired temperature setting thinking that this will make it heat or cool faster. We are expected to understand that a ten dollar compact fluorescent light bulb will save money over a 25 cent incandescent bulb, when changing all the bulbs in a house could easily cost 1000 dollars and the electric bill may be only 50. Technology is expected to take care of the conservation problem and we are expected to become consumers of conservation technology.

But true conservation is a matter of conscience. Building codes can mandate energy conservation measures but not conservation. There is no measure of building efficiency like miles per gallon for vehicles. Therefore we can prescribe more insulation, more weather stripping, or more efficient appliances, but not necessarily less energy use. In order for any measures to reduce energy consumption people must use them properly. Building efficiency must depend on the cooperation of users. All the insulation and weather stripping in the world will not save energy if the windows are left open. In many commercial buildings the windows are not openable and thermostats have locks.

Many of the measures that I will propose are user dependent for effectiveness. The cost of energy is still relatively cheap and any attempt to artificially raise it through taxes, or the like, may be sound economic policy but is political disaster. Until market forces drive energy costs up conservation measures in building design will always remain user dependent.

Why We Should Be Allowed to Live in Tents

Building codes require a heating system capable of maintaining a comfortable minimum temperature. Then they require a minimum building envelope to conserve that heat. Then they require ventilation to penetrate that envelope. All of these raise costs. What if we didn't have to heat a building to 70 degrees? Couldn't we build for a fraction of the cost? Shouldn't people be able to choose to have only minimal shelter?

Shouldn't the homeless be able to have at least minimal shelter? In this country you can live in a car, but not in a tent or a shack.

The direct cost of heating and insulating a house is between five and six percent of the over all cost (Kiley 1997) But the indirect costs of producing a climate controlled environment inside a building envelope are considerably more. The cost of building a residential garage, which is better shelter than most people in the world and many in this country have, is less than half that of the residence. We have come to expect, and indeed require, a sealed indoor environment, much more than basic shelter and probably more than basic need.

Why We Can't Live in Tents

In many climates heating is not just a matter of comfort but of survival. And comfort is not always a matter of pleasure but often one of tolerability. Permitting the construction of unheated buildings does not assure that those buildings will remain unheated. Someone living in a tent with an electrical outlet will have an electric heater as soon as the weather gets cold. All housing is certainly not occupied by the owner. Minimal standards of comfort and safety must protect renters.

Cooling, on the other hand, is never a matter of survival. Intense climatic heat can kill, but protection from this need not include air conditioning. That is a matter of comfort. But some minimum degree of comfort is necessary for most activities. It would be nearly impossible to toil in the sun of a summer day in Phoenix, but not many people would live there anyway if it weren't for air conditioning. You could manage inside a Las Vegas casino without cooling, but would you?

As soon as we acknowledge the need for space conditioning we are also acknowledging the need for the integrity of the building envelope. But this does not mean that the entire building has equal requirements for conditioning. Conditioning of space needs to be a function of the activities that take place in that space.

CONVENTIONAL ENERGY REDUCTION

The reduction of energy requirements has become since the 1960s a major factor in the construction of buildings. Strategies to accomplish this end take two forms: those that conserve the purchased energy used to heat or cool a building and those that use energy from some other source.

Conservation Strategies

Conservation of energy in a building can take two forms. The first of these is the reduction of energy use by improved efficiency of systems. Heat pumps, water heaters, refrigeration, lighting and so on can be designed to use less energy. Although the building designer can choose the products the building will use, their design is usually in the hands of the manufacturer and is therefore a technological solution.

The second form of conservation is the reduction of energy lost to waste. This typically involves reduction of conduction loss by use of more insulation, reduction of convection loss by using tighter weather seals, and reduction of radiation loss by installation of various barriers. These have effectively tightened the building envelope to create a hermetically sealed indoor environment with resultant problems of indoor air quality: (1) accumulation of moisture from human aspiration, respiration and activities such as cooking; (2) entrapment of natural toxins such as radon; (3) off-gassing of artificial toxins from increasing use of synthetic materials. In commercial uses these problems can be even greater due to the lack of openable windows and 100 percent dependence on mechanical conditioning. We can now even speak of “the sick building syndrome”. Prescriptive solutions often involve the introduction of outside air through heat recovery or direct ventilation. The first is expensive; latter would seem to be counter productive.

Another way to reduce energy waste is through zone conditioning. The idea being to condition only the spaces being used. Zone heating systems often employ inefficient uses of energy, such as electric resistance heating, under the presumption that by isolating use to active zones only the over all efficiency will be greater than heating the entire space. Zone conditioning is inherently dependent on educated user participation to be effective.

Solar Strategies

Tempering spaces using the sun’s heat is an ancient idea, which has borne today’s passive strategies, many of which have become prescriptive requirements of local codes. The idea of using the sun as the source of heat in an active system, that can be switched on and off at will, is appealing and has produced some interesting technologies, such as solar hydronic heat, but has not proved cost effective enough to become wide spread.

The idea behind passive solar is simple. The sun shines on the south side of the building, usually through glass increasing heat through the greenhouse effect. This heats some form of mass for thermal storage. This in turn releases the heat as temperatures fall. The idea is simple, but refinements are numerous.

Some provision for shading must be made to prevent over heating during those months when the sun is hottest and requirements for heating are the least. This is often accomplished through eaves extended to provide ‘optimal overhang’. In reality there is no such thing. The altitude of the sun varies during the course of any day from zero degrees to a maximum that depends on time of year and latitude. Ideally the south side of the building would be fully exposed for the whole day when heating was desired and fully shaded when heating was not needed. The trouble arises because the lowest noontime altitude of the sun is on the winter solstice; the demand for maximum heat often occurs later in the winter on a day when the altitude of the sun would correspond to a fall day when heating was not needed. An overhang that blocked afternoon and morning sun during the warm months would block needed sun during the cold months.

DYNAMIC STRATEGIES

With this background in mind I would like to propose a program for a building with a dynamic envelope. The program will consist of a number of strategies that can be used together or individually to modify the thermal performance of the building by: (1) actually affecting the indoor environment, and; (2) producing usable space at a greatly reduced cost by allowing construction of a less expensive envelope. These strategies will be based on my own experience, on proven technologies, on building tradition and vernacular architectures. They are grounded in the principles of user participation, the thermal effects of any human activity, and the principle that although certain activities need shelter from the elements they do not need artificial space conditioning. I will consider strategies for the two most common climates in this country: heating only; and mixed winter heating and summer cooling. I will try to be consistent in my terminology; I will use ‘inside’ to refer to the conditioned space surrounded by the building envelope and ‘within’ to refer to the unconditioned spaces created by the dynamic use of the envelope.

A Central Core

The use of a flexible envelope in the design of a building allows space conditioning to be confined to its basic core -- the minimum facilities needed to support the activities that must occur regardless of weather. In the case of a residence these are cooking, eating, sleeping, socializing and recreation, work, and bathing and personal hygiene. These uses do not all occur simultaneously and space inside the core can support multiple uses. Like the houses of the middle ages with only the central room heated, activities in our contemporary house can retreat with the weather into a concentrated central space. The actual design of the core will of course be dictated by the user’s own demands, which must take into account the dynamic spaces that surround the core.

Tempering Spaces

Spaces designed to deliberately affect the thermal environment of the building can be classified into two basic types: south facing glazed spaces to promote solar gain, and; chimneys or other spaces used to stimulate cooling through natural ventilation.

Solar spaces for tempering the indoor environment are typically included in the building envelope, the south facing sun room for example, or are outside the envelope, such as the attached greenhouse. They use direct gain, indirect gain or isolated gain of solar radiation (Mazria 1979). Distribution of heat from these spaces is often problematic and prevention of overheating necessary. There are wide varieties of conventional approaches to the details of passive solar applications in the storage and distribution of heat.

When the approach to the building envelope shifts from static to dynamic, many of the problems resolve themselves. I have used south facing sunrooms in designs in both heating climates (Washington state) and mixed climates (Southern California). These designs shift the exterior envelope of the building to include the sunroom or sunrooms when solar gain is present and desired, and to exclude them when it is not. In both climates this means that the wall between the sunroom and conditioned space is not fixed but made of glazed doors that can open to combine the two spaces. These must be designed as part of the prescriptive building envelope. Since the sunroom is not included in conditioned space, it may be designed by use and budgetary requirements.

The south side should have openable or removable glazing and preferably some sort of screening system. There need not be any overhang on this side of the sunroom. In mixed climates or where ever there is a possibility of over heating the roof should be opaque. In some climates overheating will never be a problem so the roof can be transparent. In designs for Washington I have called out polycarbonate roofing material. In the months when solar gain is desired the south sunroom wall glazing should be closed. As long as the sunroom temperature remains above the desired temperature for the building interior the wall between the building and the sunroom should remain open. I have designed forced air systems that use sunrooms as an alternative source of supply or make up air, so that heat distribution can occur through conventional mechanical systems. When the temperature in the sunroom drops below the desired indoor temperature, it can be closed off from the interior effectively tightening the building envelope. (See Figure 1.)

When solar gain is not desired the south glazing of the sunroom can be opened. In climates where the roof is opaque this effectively provides a south overhang the depth of the sunroom. If the doors between the interior and the sunroom are closed during the day they will be totally shaded, by this overhang. (See Figure 2.) Screening the south side of the sunroom allows its use during the cool hours of the evening and cool air from this space can be drawn into the interior with the forced air system. In heating only climates the sunroom can be left open to the interior during all the months when heating is not required.

The separation between the interior and the sunroom should be designed in accordance with the requirements of the building envelope. The effectiveness of the sunroom itself will vary according to the design of its envelope. It can be anything from a simple fiberglass greenhouse all the way up to or exceeding the requirements of the building envelope, but will invariably use more glazing area than is permitted by normal prescriptive requirements for interior space. No matter what the design of the sunroom envelope it will always provide some thermal benefit in addition to increasing the usable interior space on a seasonal basis.

Cooling Spaces are designed to take advantage of the cooling effects of shading, natural convection currents or winds. The *malquaf* is a wind catching device invented to satisfy the need for ventilation in the hot climates of the middle east and north Africa (Fathy 1986). The exterior verandahs of the bungalow provide shading and protection from the sun's heat. Interior courtyards provide protection from heat and provide natural ventilation. Most California houses dating from the 1920s through the 40s have a pantry cupboard ventilated from the crawl space to the roof to draw cool air from under the house by convection. Clerestories promote natural ventilation by drawing air upwards.

In order to take advantage of the chimney effect to promote convection a cooling space needs to run the full height of the building, from grade or below to the roof. It needs to be vented at the top to allow hot air to escape and to have some provision for drawing cool air into the house to replace this exhausted hot air. Because it can be glazed on the south to heat the air causing it to rise through convection and thermal mass is desirable for cooling, its use can change seasonally from cooling to heat gain. Because its environment is buffered from the extremes of the exterior, it will support a multitude of activities on a seasonal or temporal basis.

Transitional Spaces

These are spaces that separate the interior from the outdoor environment. They affect the thermal performance of the building, not by directly acting on the temperature of the interior, but by serving as a buffer between the two environments. It is very seldom the case that we enter a building directly from the outside. There is almost always some sort of transition. This might be only a covered spot where we can stand out of the rain to open the door or we may pass through the building into an atrium before entering the spaces of the building itself. Porches, foyers and lobbies are transitional spaces of this type. It is only typical of modern architecture that the building facade presents itself to the exterior without transitional devices.

Thermal resistance is never zero. Air surfaces provide some resistance to heat flow (Fathy). If this were not the case, interior temperatures would equalize with exterior whenever we opened a door. But heat flow is dependent on temperature differential, so in extreme climates heat loss can be rapid. Some transitional space functioning as an air lock is a necessity. This can be as simple as a revolving door or it can be a occupiable space as part of the building envelope. Often this is a “mud room” giving a person entering a building a place to shed outer clothing before going into the heated interior. Even when these spaces are not heated they serve to contain heat that would normally be lost to the exterior. In cooling situations temperature differential is never so extreme as to make a transition of this type essential, but it will, nevertheless, improve overall thermal performance.

Just as thermal resistance is never zero, neither is thermal transmittance (Fathy). No matter how well insulated and sealed a building is some heat transfer between the inside and outside is inevitable. (See Figure 3.) Since heat transfer is dependent on temperature differential, it follows that if, in a heating situation, waste heat can be somehow contained temporarily on the outside of the building, loss will be slowed. Since heat rises, simply blocking the upward flow on the exterior surface of the envelope will provide some benefit. It follows, too, that this benefit will increase the more effectively this space is sealed against heat loss to the outside. (See Figure 4.) But, the true benefits of any system are dependent on costs. It is unlikely that the construction of this exterior room would be cost effective if its sole purpose were the containment of waste heat. This could be accomplished more economically through the use of more insulation. In order to be cost effective this space must be usable by some activity that would normally occur inside the building envelope.

In a cooling situation these dynamics are not reversed symmetrically. Heat transfer can only occur from hot to cold. The object of any cooling strategy must be to prevent heat gain rather than cold loss. But cold loss can occur in the form of cooled air volumes spilling out of the building. Transitional spaces can contain this air, shade the exterior of the building and provide a buffer that will reduce the temperature differential between the cooled interior and the transitional spaces, thus reducing the cooling load. Since these spaces are the same as the transitional spaces used for heat containment the offer the same use possibilities.

Marginal Activities

In looking at the types of activities that <u>can</u> take place in dynamic spaces within the envelope, I will first examine some that already do, perhaps without recognition. I an referring specifically to the attached garage. This space that is not inside the conditioned envelope but is still 'in' the building. Therefore, it can be said that it is within the envelope. Protected against the extremes of rain, snow and wind it is often not insulated. Its cost is usually less than half that of the equivalent square footage inside the envelope. Its purpose by definition is storage of a vehicle and it often serves as an entry buffer. An automatic opener allows access to the shelter of the building without leaving the shelter of the car. The door can then be closed before the building envelope is breached functioning as an air lock. Vehicle storage and entry functions are often only a fraction of those supported by the garage.

Storage of other items is often a major function. These may include the oft used, such as cleaning supplies and food to the seldom used such as Christmas decorations. A good deal of the space inside the building envelope is devoted to storage and often this is not enough. Yet, there is no reason why this function cannot be moved from inside to within the envelope. In fact, stored items are often better preserved at cooler temperature, if they are protected from moisture, rodents and insects. Garages often have a utility function. Furnaces, water heaters, electrical and other equipment that needs to be accessible as well as protected can be located in the garage. In milder climates it is not unusual for residential laundry facilities to be in the garage rather than inside the house. Many people have workshops in their garages, ranging from simple home maintenance to complete businesses. Garages are ideal spaces for many hobbies. Recreation, too, is a function of the garage. From pool or ping pong tables to complete parties, it is often the largest available ‘room’ in the house.

From the activities that take place in the garage we can begin to see that the potential uses for unconditioned space are great. The potential for marginal use must be considered as part of the economic consideration in the design of space within the building envelope. If we can produce a space that is usable more than half the time for less than half the cost of conventional space, we will approach a bargain if we can reduce the conventional space equivalently. If we can substitute a space within the envelope for one inside the envelope, we not only realize reductions in construction cost, we benefit from the thermal mitigation properties of that space.

The designer together with informed users must consider the program for the building on an element by element basis for potential use of the space within the envelope. Storage is an obvious use. Stairways and corridors are another use that is not so obvious. These can take a considerable area inside the envelope for activities that may occur only infrequently. It should be up to the users to decide if these can be outside the conditioned envelope. Stairways and utility chases are an obvious use for cooling chimneys, because they occupy vertical space and can be constructed thermally massive materials.

Seasonal Activities

Everyone is familiar with the seasonal use of space. Even in the harshest climates, summer is a time to enjoy outdoor living on patios, decks or in gardens. In cooler climates these spaces are comfortable in the warmer months; in hot summer climates they provide welcome relief from summer heat and may be usable for much of the year. For the most part they are used for leisure activities, entertaining, eating or sports. I suspect that very few people move TVs to the patio in summer. Sleeping outdoors is common in certain cultures and climates but in this country is generally limited to camping while away from home. Indoor work is usually kept indoors year round. Some activities, such as gardening and swimming, are limited to the outdoors and warmer temperatures.

Adopting strategies that allow greater use of outdoor spaces we can reduce the demand for indoor space and climate conditioning. First and most obvious of these is the protection of these spaces from precipitation with some sort of roof. South facing spaces are usable for more of the cooler months, but in some climates may be too hot in the summer without shading. In these climates outdoor activities can shift to the north when heat is greatest, thus reducing cooling demand. Protection from wind may also be desirable and can be accomplished by closing the ends, presuming one side of the space is against the building envelope. This should reduce the effect of strong winds without eliminating cooling breezes on summer evenings. Screens allow activities that could normally be made unpleasant by the presence of insects.

The popularity of eating, cooking and entertaining outdoors has generated the prototype of the outdoor kitchen. This evolved from the simple barbecue to complete kitchens with counter tops, stoves, sink and refrigerators. Many restaurants provide for alfresco eating, sometimes occupying public space. In Europe these spaces are often covered with awnings and surrounded with glass until the distinction between indoors and out becomes blurred, and 'seasonal' use becomes almost year round. With a high level of activity heating is unnecessary. They not only provide cheap usable space within the envelope, they buffer the conditioned environment inside.

The popularity of outdoor living has brought with it the introduction of the outdoor fireplace. Unfortunately, like the fireplace indoors, these are often more decorative than functional. If the outdoor fireplace is built in, the logic of construction places it against a wall of the building where the chimney can run to the roof, perhaps shared with a fireplace indoors. This placement is wrong. (See Figure 5.) If it is placed facing the building, heat is trapped making the building envelope usable and reducing heat loss from the inside. (See Figure 6.) The outdoor fireplace need not be built in. There are several free standing portable units on the market.

Roofs

The rooftop has been called the fifth wall of the building and is just as much a usable part of the envelope as the other four (Busch 1991). As an occupiable space roofs have limitations especially in retrofits, but also offer unique opportunities. The extra loads imposed on the structure by use must be accommodated, but a flat platform for this use is often available. A traditional and obvious occupation of the building envelope is the use of attics either for storage or activity. Christopher Alexander offers a number of patterns for roofs including the extensive use of roof gardens directly accessible from some lived-in part of the building (Alexander et al. 1977). The roof garden can be used as an outdoor living space with shade. Plants and soil can affect the thermal performance of the roof. Traditional designs include loggias and roof covers that shade the roof during the day and allow comfortable living and sleeping at night (Fathy).

Techniques

I will offer a brief number of techniques for implementing these strategies through use of materials. No comprehensive list is possible, since it will always be expanded by the imagination of the designer. In practice I have tried to avoid exotic materials or experimental uses, concentrating instead on that which is readily available and easy to use. These are techniques that I have either used, seen used or that I know can be implemented without difficulty. Some of the products that I describe are European, and I have made no attempt to investigate their availability in this country. If they are not available here they should be.

Sliding glass and French doors have useful and distinct functions in the design of the building envelope. Although sliding glass doors have been maligned

(Brand 1994) and current fashion seems to favor French doors, these criticisms seem to be more a matter of personal preference than unbiased criticism. Sliding glass doors have a number of advantages that cannot be matched in any other opening wall system: (1) since they slide and no floor space is necessary for the door swing furniture can be placed in the immediate proximity; (2) screens are easily operated and are unobtrusive; (3) they are an economical way to glaze large areas especially when tempered glass is required; (4) they are easy to install; (5) they come with very positive systems of weather stripping; (6) the are sized for very large openings.

There are two innovations in sliding glass door design that are appropriate to mention here. The first is my own idea; the second a European design. Sliding glass doors are normally purchased as a complete unit, but individual components can be ordered. This would allow configuring one as a pocket door. For example, by using the head and sill, the two sliding panels and screens, and the two interlocking stiles from the fixed panels of a 16 foot OXXO door, a fully opening eight foot biparting pocket sliding glass door could be located in the center of a 16 foot wall. I have not had opportunity to use this system, but there is nothing exotic in its design. There is a European sliding glass door in which neither panel is fixed; it can open either way.

French doors can be installed singly or as multiple units. Most common is a two door swinging configuration. They offer the advantage of being able to open the entire width of the doors. Room for the door swing is required and screening is difficult. Retractable door bottoms allow French doors to be used in multiple-fold arrangements without a threshold. Two spaces can be converted to one by opening the doors, without the physical or psychological separation that a threshold would impose. This is the arrangement I typically use in the envelope at the sunroom separation. I have screened a two unit French door, against insects and sun, by using biparting pocket louvered doors in the wall. I have seen pictures of biparting exterior French doors, but am not sure how they were weather-stripped. The combination of a glass door and a louvered door for screen and shade is ideal for a dynamic envelope.

Rolling doors such as sectional or roll-up garage doors allow opening large sections of walls. These doors are available insulated and can be used as a shading device when combined with large areas of glass. These doors are available with glazed panel or entirely glazed in commercial configurations. Weather-stripping in standard form is not sufficient for the requirements of the main building envelope.

Folding wall systems are available commercially or can be fabricated from readily available components. European systems use aluminum framed glass panels that fold and slide. Their operation is simple and smooth enough for them to be opened and closed daily. I have ganged wood framed glass doors into operating systems using hinges, overhead tracks, rollers, and conventional weather-stripping to make systems that can be opened seasonally. I have seen similar commercially constructed units at ten times the cost of my site built ones. Single glazed sliding glass door panels are light enough to be removed easily.

Thin membranes, that may expose the exterior material to the interior as finish, reduce the cost of the outer building envelope. Glass obviously fits this category, but numerous other materials can be used similarly when insulation is not a consideration. Metal, tile, brick and wood all represent possibilities. Metal roofing is an economical and durable material that can put over skip sheathing to expose the underside as a ceiling treatment. Although it is not an inexpensive material I have used copper roofing in this fashion. Tile, similarly applied, makes an attractive cover for spaces where a 100 percent seal is not needed. Until the advent of building felt and plywood all tile was applied this way. Canvas or cloth roofs make attractive finishes for both outside and in and offer the advantage of being able to be made retractable. Prescriptive insulation requirements make traditional open beam ceilings difficult and expensive to build. But over spaces where there is no requirement they present an economical alternative either under a roof or a waterproofed deck. Modern roofing materials, either liquid applied or membranes, offer many more options for decks and usable 'flat' roofs than did hot tar. Materials with great thermal mass such as brick, block or concrete can be used as both exterior and interior finishes.

Shading devices should be part of any dynamic system. Fixed shading devices such as the brise-soleil are seldom desirable for they can function only part of the time and often block needed winter gain. We are all familiar with dynamic shading devices such as blinds, shades, curtains or drapes. Usually these are placed inside windows comprising the building envelope. In a heating situation this is ideal. Closing the shades traps air between them and the glass creating an insulating effect. In cooling situations, however, this location of the shades allows them to be heated by the greenhouse effect. This heat is then conducted or convected to the interior.

Dynamic use of the envelope should allow seasonal adjustments. The flexible sunroom makes the southern exposure of the envelope self shading in summer. If screens are used they may be made of shade cloth or screen, doubly shading the south. European windows make extensive use of roll-up insulating blinds. Usually on the outside of the window these may be closed to make them opaque to light and wind, partially closed, as slats, that shade but allow air movement, or opened. In Barcelona I encountered one situation where these were used between two sliding glass doors, set about a foot apart. This allowed a choice of multiple configurations of window and shade openings, although I suspect sound insulation was a large factor in this design.

Shutters have long served as external protection of windows from wind and sun. Although today their use is most likely to have become purely symbolic (Dovey 1985), they serve as a useful prototype for dynamic design. I have already suggested the combination of louvered and French doors as a model based on this prototype and common European usage.

Caveats

Building codes are written to protect health and safety. They specify minimum permitted openings in the building envelope for light, ventilation and egress. They prescribe maximum openings for energy conservation. Minimum openings for light, ventilation and especially for egress have severe restrictions on opening into another space. Building officials may be flexible in interpreting the dynamic envelope in terms of light, ventilation and insulation requirements or they may not; there will be no flexibility in exit requirements. Designers should make no assumptions based on their interpretations of codes but should work closely with local officials.

Energy codes often require prescriptive measures, formulaic calculation or computer evaluation. The dynamic envelope does not lend itself to a priori evaluations. The outside envelope will meet neither prescriptive or evaluative requirements; the inside envelope will perform better with dynamic adjustment than alone. Evaluation of both envelopes as a single assembly is not practical due to the complexity of the whole and the dynamics of its use. I have used and lived with many of the measures I suggest, and can attest to their effectiveness. Others are logically or traditionally effective. But even in practice the degree of this effectiveness is difficult to quantify. It is only as predictable as the weather and the informed and conscientious reactions of the users in adjusting the envelope. For those who want to make a difference by taking an active role in adjusting their own environment the dynamic envelope offers real alternatives. Those who want systems that adjust automatically or at the flip of a switch should look elsewhere.

FIGURES

Figure 1 shows the solar exposure of a 12 foot deep sunroom at 40 degrees north latitude on December 21. The glass south side (left) gets 100 per cent of the available sun on that day. Most of the solar energy will be absorbed within the building; very little will be re-radiated out through the south glass.

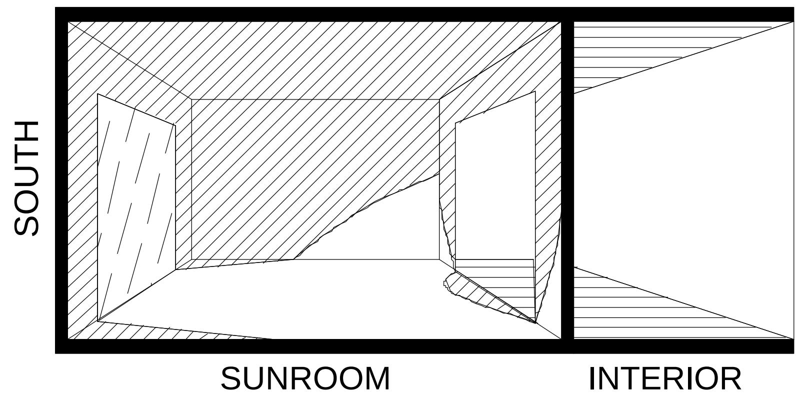


Figure 2 shows the shading of a 12 foot deep sun room at 40 degrees north latitude on June 21. The opening the south side (left) shades the south wall of the inside 100 per cent.

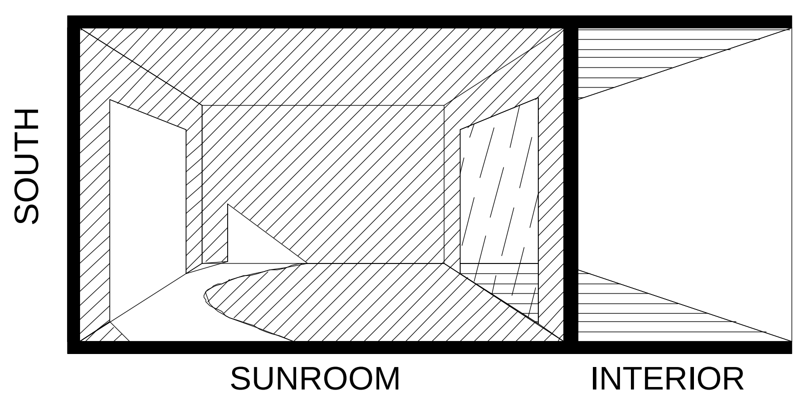


Figure 3 shows the heat loss through the normal building envelope.

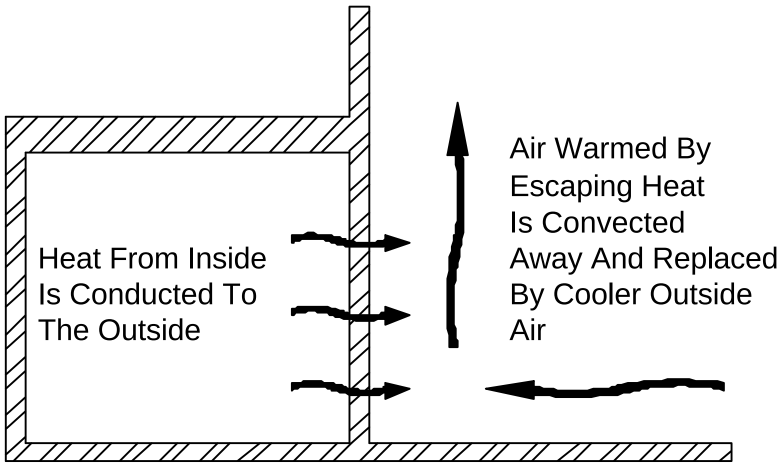


Figure 4 shows how the dynamic building envelope traps escaping heat, partially tempering the space within the envelope, reducing building heat loss.

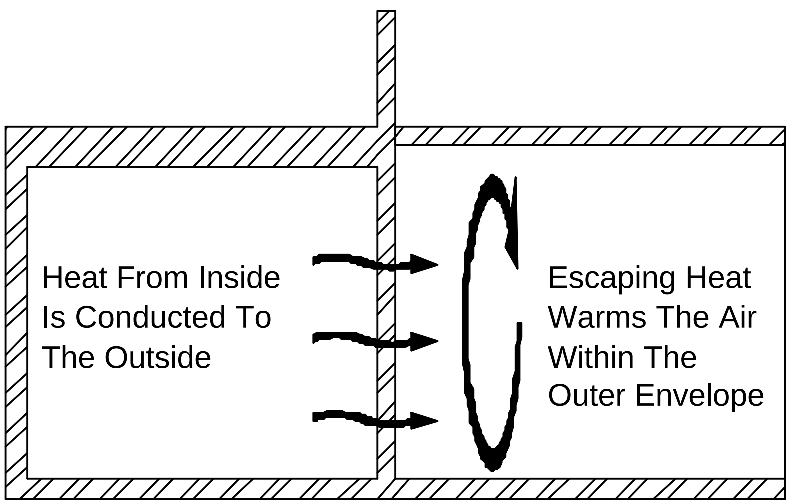


Figure 5. If the outdoor fireplace is placed facing away from the building, heat is radiated away. The person facing the fireplace is warmed only on the side toward it. Heat is lost to the building. The space is usable only in mild weather.

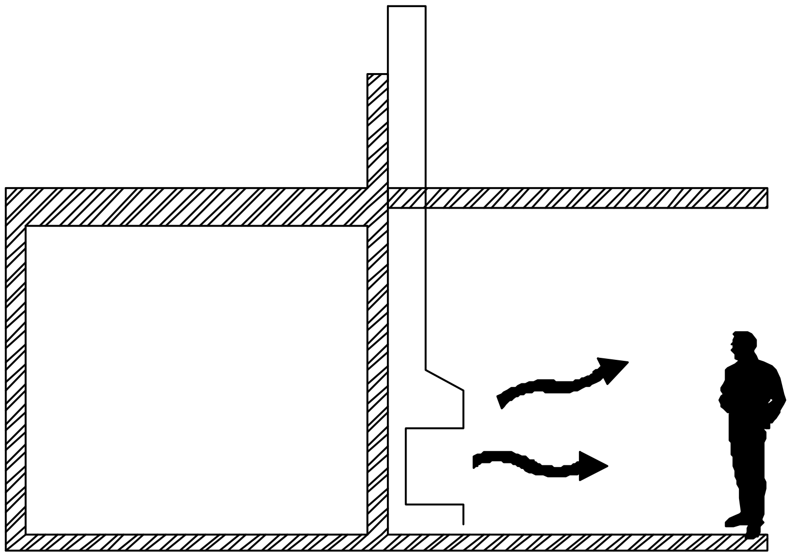


Figure 6. If the outdoor fireplace is placed facing toward the building, heat is radiated in and the whole space is warmed. The person facing the fireplace feels warmth from the fire on the front and the building behind. Temperature differential between the inside and the dynamic envelope is reduced, thus reducing heat loss. The space within the envelope is usable many more days of the year.

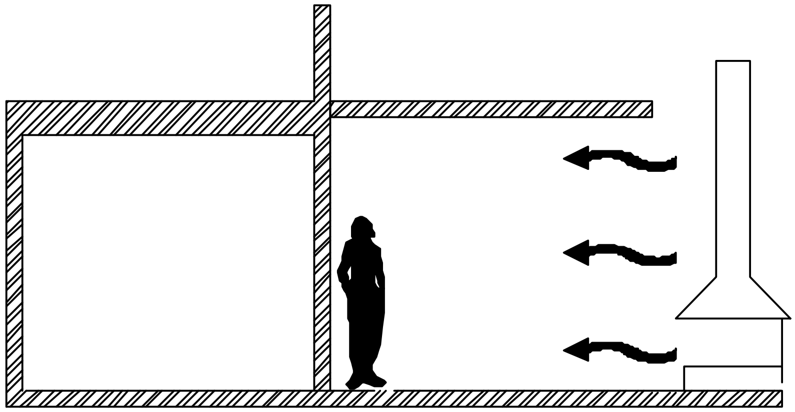
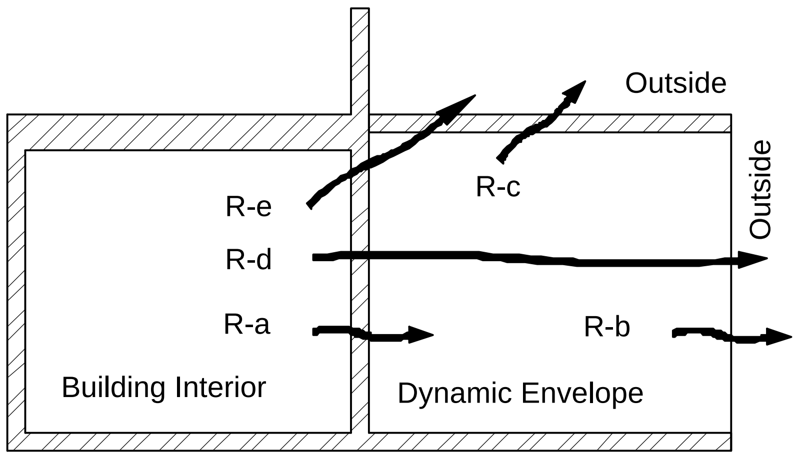


Figure 7 shows the difficulty of predicting thermal performance of the dynamic envelope. R-a is the thermal resistance of the inside building envelope. R-b and R-c are thermal resistances of two different assemblies of the outer envelope. Neither R-d nor R-e can be taken to be the resistance of the entire assembly. Even the area exposed to the outside subjective. Actual thermal performance is dependent on the temperature differential between the dynamic envelope and the outside and on the temperature differential between the dynamic envelope and the inside. The latter is dependent on the heat loss across R-a and the amount of heat contained in within the envelope.



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