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ABSTRACT

Methods for improving the thermal characteristics and airtightness of the house envelope and basement are outlined, with some examples of features that will affect actual performance. The factors that influence ventilation rates are discussed including the effect of fans and chimneys on the air pressure differences and direction of air leakage through the house walls and ceilings. An understanding, by all concerned, of the interactions between the house enclosure, the equipment and services installed and the occupancy pattern is suggested as the best route toward energy conservation.

RÉSUMÉ

Des méthodes pour améliorer les caractéristiques thermiques et l'étanchéité à l'air de l'enveloppe et du sous-sol des maisons sont présentées, avec des exemples de particularités qui pourront modifier la performance réelle. Les facteurs qui influencent le débit de renouvellement d'air sont discutés, y compris l'effet des ventilateurs et des cheminées sur les différences de pression d'air et la direction d'écoulement d'air au travers les murs et les plafonds des maisons. Une bonne compréhension de l'interaction entre l'enceinte de la maison, l'équipement et les services qui y sont installés et les habitudes des occupants est considérée comme essentielle pour la conservation de l'énergie.

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INTRODUCTION

The amount of energy required to maintain an acceptable environment in houses is determined by three different but interactive components of the system:

1. The characteristics of the building enclosure and the internal partitions floors and compartments that make up the building;

2. The characteristics of the energy producing, transfer, distribution and control elements that make up the equipment and services of the building;

3. The characteristics of the occupancy and method of use and operation of the building and its equipment.

The tendency has been to address each of these components separately and to develop guidelines or norms that oversimplify the actual situation.

Construction is a tradition based industry, i.e., the inclination is to do things the way they were done in the past, because they worked. If we do not understand why things work, or how they interrelate, it is difficult to predict what will happen if we change some part of the system. Every effort should thus be made to utilize the experiences of the past if only to sort out what is known and what is not.

THE BUILDING ENVELOPE

The design and construction of the walls, floors, roofs and windows that make up a house envelope offer one basic means to control the energy required to maintain a satisfactory environment within the house. Heat transmission through the opaque elements is primarily controlled by insulation: the thicker the insulation the lower the rate of heat loss or gain.

Thicker insulation can be achieved either by creating a structurally supported space for non-structural insulation, or by incorporating self-supporting rigid insulation boards on the basic structure.

In Canada, wood-frame is the primary construction method used for low-rise residential buildings; it has the inherent advantage of providing a space that can be filled with inexpensive thermal insulation.

In wood-frame roofs incorporating an attic space, no practical restriction on insulation thickness is encountered. Flat wood-frame roof construction and some cathedral-type roofs, however, impose a practical limit on insulation thickness.

One accepted method of providing additional insulation for wood-frame walls has been the use of insulated sheathing boards of foamed plastic, mineral fibre or wood fibre. An incremental insulation increase might also be achieved by using similar rigid insulating materials as backer boards for metal or plastic outside cladding. It is difficult to secure these materials to the structural frame without significantly affecting the overall thermal resistance if high thermal conductivity fasteners, like nails, are used. A reduction in the number of nails or failure to anchor them suitably can cause difficulties. Other problems can arise from the unintentional imbedment of the projections of self-furring stucco reinforcement in soft sheathing materials resulting in inadequate keying of the stucco base coat.

In some regions of Canada, nominal 38 x 140 mm framing members are used to allow an increased thickness of thermal insulation in walls. The framing members, which extend directly through the insulation, may, however, constitute a significant thermal bridge. In addition, the increased thickness of low density insulation may promote convection within the material and a decrease in its overall thermal resistance, particularly if it does not completely fill the space.

Double stud wall construction, staggered stud wall construction, trussed studs or cross-framing with furring strips are other methods that have been employed to increase the thickness of the space for thermal insulation.

There are some difficulties in accurately estimating the true thermal resistance of these new constructions but experimental work is underway to determine applicable values and to improve understanding of the transfer mechanisms and relationships involved.

INSULATING BASEMENT WALLS

The emphasis on improving the thermal resistance of the frame superstructure has often meant that the question of insulating basement walls is ignored. Clearly, the portion above grade should have a thermal resistance at least equivalent to that of the superstructure. Where the basement is to extend some distance above grade, preserved wood foundations seem to be advantageous as they provide the space for both insulation and structural continuity for lateral loads between the basement floor and first floor levels. Concrete or masonry foundation walls are best insulated on the exterior to avoid undesirable lateral conduction vertically and convective effects in hollow masonry.

It may be difficult to predict subsurface heat losses accurately because of the variable influences of groundwater, soil type and moisture content, snow cover and the location of adjacent buildings. These determine the outside environment of the basement in a rather unpredictable way. At present, it seems reasonable to suggest that below-grade masonry walls should be insulated down their full height, preferably on the outside. This could be achieved by using either a closed cell foam plastic insulation that is water resistant or a draining type, such as mineral fibre. Investigations of the performance of these materials are underway in several locations across Canada.

A two-stage approach to insulating basements has been suggested whereby some insulation is incorporated on the exterior of basement walls during construction when it is easier to install. The owner or occupant can subsequently upgrade the insulation on the inside in accordance with his needs.

It may also be pertinent to consider additional insulation extending outward from the foundation wall at or near the ground surface to prevent frost action on the foundation while reducing further the heat loss from the basement.

The use of light metal framing instead of wood in basement locations may also have advantages. Metal framing may also be appropriate in above-grade construction, particularly in non-loadbearing applications such as furring on exterior walls and for the framing of non-loadbearing interior partitions.

SOLAR RADIATION

The exterior colour of the opaque portions of the enclosure can influence the radiant heat exchange with the outside environment. Solar radiation absorbed by the cladding will raise its temperature and change the rate of heat transfer through the element. At night, radiation of the exterior surface to the clear sky will lower the surface temperature and increase the rate of heat transfer through the element. These effects, however, will become less and less significant as the total thermal resistance of the element is increased.

Solar radiation is of greatest importance in heat transfer through transparent elements (windows and skylights). The characteristics of the surfaces in multiple-glazing units can also affect both solar gain and heat loss through the element.

Windows offer the main source of solar heat; they are an advantage in winter and a disadvantage in summer. Simple shading devices on south-facing windows can maximize the heat gain in winter and minimize it in summer.

For houses in most parts of Canada, double-glazed or triple-glazed windows facing south offer a net heat gain in winter when considered on a seasonal basis. The use of insulated covers can increase this benefit by providing added insulation to windows at night. Automatic or manually controlled insulating or shading devices may thus be desirable or even required to avoid unnecessary overheating in mild weather for houses with a low transmission heat loss.

It should be recognized that such devices are operational features and the energy savings that result will depend not only on their thermal characteristics but on the way they are controlled by the occupant. A similar relationship exists between the air leakage of the building envelope and the method of operation of the house and its equipment.

AIRTIGHTNESS OF THE BUILDING ENVELOPE

Both the double wall arrangements, such as those used in Saskatchewan, and the furring method of the HUDAC Mark XI project, attempt to improve the airtightness of the envelope by placing a polyethylene barrier at a location where it is not likely to be penetrated by electrical services. Double wall constructions used in Saskatchewan also provide continuity of an air barrier on the warm side of the insulation at floor intersections. In the HUDAC Mark Xl, air barrier continuity was similarly maintained but the membrane barrier is outward of the bulk of the insulation at floor joist intersections.

A number of studies have undertaken to determine where unintentional leakage openings occur. Many are found where services, such as electrical components, wiring, plumbing and duct work, penetrate the exterior enclosure elements. Another major leakage opening occurs at cracks that develop because of the shrinkage of wood framing members where floors and interior partitions intersect with walls and ceilings. The floors and interior partitions in a house are essentially flues which can connect the interior to the cold exterior spaces in walls and attics.

In an effort to cover these shrinkage cracks, Canada Mortgage and Housing Corporation has required that polyethylene barriers be carried over the tops of partitions in upper storeys and around the intersections with exterior walls.

Airtightness of upper ceilings and exterior walls might also be more easily achieved with trussed roof construction if the interior gypsum board or air barrier were applied before the interior partitions are erected. Unfortunately, such techniques, or others that involve changes in established construction methods or sequences, are often rejected without due consideration of their technical and economic advantages.

Most current approaches to improved airtightness attempt to use polyethylene film as a combined air and vapour barrier without always recognizing some inherent disadvantages in the combination, both in application and performance.

The idea of using the interior finish as the air barrier was tried in the HUDAC Mark VII Project in Vancouver in 1970. A method that follows the same principle and attempts to provide continuity through floor and wall intersections using exterior grade plywood is now being considered as an alternative.

There is also some justification for reassessing the practices of installing electrical wiring in houses, particularly the utilization of electric fixtures in the ceiling and wiring through the attic space. The desire for concealed wiring in these exterior enclosure elements can result in many openings in the air barrier. If surface mounted fixtures could be used and surface wiring accepted, a marked improvement in the airtightness of the envelope might well be achieved.

AIRTIGHTNESS AND VENTILATION

One of the most common oversimplifications to date has been the direct linking of enclosure airtightness with air exchange rate, ventilation and air quality. Statements that houses have become much tighter in recent years owing to the increased use or thickness of insulation are not technologically sound nor are they borne out by measurements that have been made. Published values suggest that enclosure tightness, on the average, has remained about the same since 1946 and differences are related more to the type of house or location. The average total leakage area for the enclosure based on pressurization or evacuation tests has been in the order of 0.08 to 0.1 square metres.

The rate and direction of air leakage through these cracks and holes can depend on their location and more particularly on the direction and magnitude of the air pressure differences across them created by natural forces such as stack effect and wind and by the action of chimneys, fans and blowers. The most significant and perhaps least recognized is the effect of the chimney and the draft control systems employed with conventional fuel-fired furnaces.

An operating chimney acts as an exhaust fan. The hot gases in the chimney are light and less dense than the gases in the house or outside and tend to rise creating a negative pressure or draft. This draft draws in air through the burner and also through a barometric damper in oil-fired systems or a draft diverter in gas-fired systems, each of which serves to control the level of draft over the fire.

An operating chimney will exhaust air at a rate of perhaps 40 litres per second or more. This can draw in outside air through all openings in an enclosure, including the ceiling, and may even counteract the effect of outward movement of air through walls on the leeward side of the house.

In a house with no operating chimney, e.g., an electrically heated house, the pressure differences across the envelope are quite different and only some of the leakage openings will be involved as air inlets. As has been observed, the actual air exchange rate in electrically heated houses is lower than in fuel-fired houses not because they are any tighter, but because they have no operating chimney.

The excess volume of air exhausted up the chimney for draft control purposes in conventional furnaces and boilers is reduced or eliminated in high-efficiency or condensing-type fuel-burning appliances. Both of these systems will normally use induced draft fans and much less air will be exhausted through them than in traditional systems. The operational characteristics of the house will therefore be closer to those of an electrically heated house, not just because they have improved combustion efficiencies, but because they are not exhausting an added amount of air that has already been heated to the indoor temperature.

It should be appreciated that conventional fuel-fired systems have provided a form of ventilation system whereby fresh air leaks inward through openings in the building enclosure and is exhausted with the products of combustion up the chimney. It has not been thought of this way, but rather lumped into the so-called "seasonal efficiency" of the heating unit.

Since 1950, in many houses on the Prairies and in the Atlantic Provinces, outside air has been provided through an insulated, dampered outside air duct to the return air system to control the rate of outside air supply to the house and allow for the heating and uniform distribution of the fresh air to the various rooms.

AIRTIGHTNESS, VENTILATION AND AIR QUALITY

Measurements made using tracer gas techniques or inferred from humidity levels in houses indicate that on average a ventilation rate of about one half an air change per hour was provided by this simple system. The outside air intake adjustment was used effectively as a means to allow the occupant to adjust the ventilation rate to control humidity levels in the house.

This rate of ventilation is about equal to that now being recommended for residential occupancies in the ASHRAE standard 62-1981, "Ventilation for Acceptable Indoor Air Quality". If this represents a current objective, a substitute system is required for houses that have no operating chimney, a system that incorporates a means for heat recovery that was not possible in the simple systems of the past.

One system being developed uses an exhaust fan and recovers heat from the exhaust air utilizing a small heat pump. A simple air inlet can augment any leakage openings in the exterior envelope to provide the fresh air inlets as long as the air flowing in does not affect the comfort conditions in the space or pick up any contaminants that might be in the exterior enclosure or in the outside air.

Air-to-air heat exchangers, however, require that the house enclosure be tight in order for the air coming into the house and the air being exhausted to be brought together so that heat can be exchanged between them. The implications of this should be recognized before promoting the use of an air-to-air heat exchanger in a house that cannot be made tight or where a conventional fuel-fired furnace is in operation.

There are means other than ventilation that can be used to control the levels of contaminants, including moisture. These often involve absorption or dehumidification devices that can provide means for heat recovery.

It is also necessary to consider the source of contaminants in a building and to recognize that capture and exhaust at source may be most effective. Pressurization of a building to control the flow of contaminants that exist in the exterior enclosure may be effective, but may also be inconsistent with other requirements.

In the final analysis, it is the occupant who determines how the house is operated and what ventilation rate, solar gain, internal energy input and equipment operating schedule are followed. About all the designer, developer, builder and regulatory official can do is to ensure that the house can be operated to meet some energy use requirement under a specified operational schedule.

If our objective is to conserve energy, all of the participants must understand the subject thoroughly so they can make thoughtful judgments as to the technical and economic implications of their ideas.

A Webster definition of technology is "the application of knowledge". We all not only need to know more, we also have to apply our knowledge, to understand existing systems, to develop new systems and methods and perhaps most important of all, to fairly assess, evaluate and communicate information on the performance of systems in the real world.

Each house is different and is characterized by a specific occupancy pattern. It would be preferable to concentrate on determining the reasons for the variation in field performance rather than trying to bring a complex, interrelated set of systems to some common denominator for the sake of simplicity and uniformity.

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