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THE NEED FOR IMPROVED AIRTIGHTNESS IN BUILDINGS

by

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Infiltration and exfiltration of air through the building envelope has come to be accepted as an intrinsic feature of a building; in residential construction some regard it as necessary for the proper ventilation and operation of the house. In contrast to these attitudes, it is suggested that air leakage wastes heat and is detrimental to the performance of a building.

Air leaking into a building cannot be treated or conditioned nor can its rate of supply or distribution to the occupied space be controlled. Attempts to do so by intentional pressurization of the building results in greater waste of energy and promotes increased condensation and thus deterioration of the building fabric. Air leakage through a building envelope, and between building compartments, can also disrupt the intended operation of heating, ventilating and air-conditioning systems and places limitations on the control of noise, fire and smoke.

Air Leakage in Buildings

Air leakage occurs as a result of air pressure differences created by fans, wind, and stack effect across unintentional openings in the building envelope (1). Little can be done to change the pressure differences resulting from natural climatic factors and pressure

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differences created by mechanical systems are required for air distribution within the building. The most direct approach is to reduce the number of openings through any structural barriers by the development and application of appropriate building details and construction practices. The objective should be to provide as airtight an enclosure as is possible and to provide the fresh air and exhaust requirements of the occupancy by a separate ventilation system or systems capable of adjustment, control, or adaptation to meet the specific needs of the occupants. Such an arrangement is also necessary for heat recovery and it may be advisable to arrange inlet and exhaust systems in close proximity to each other in order to simplify heat exchange.

The direct energy costs for heating, cooling, humidifying, or dehumidifying the air leaking into a building have long been recognized. Many of the methods for estimating the air leakage rate are related to design calculations. These estimates, however, are based on extreme conditions for purposes of ensuring an adequate maximum capacity of the room heating or cooling unit. To obtain a more accurate prediction, the methods for estimating the seasonal air leakage energy load must take into account the influence of location, size and distribution of the air leakage openings, the variations in wind-induced pressures in space and time and the simultaneous pressure differences created by stack effect and air handling systems.

Laboratory tests on prefabricated structural elements can be made and field measurements employed to determine the actual leakage characteristics of buildings and structural elements in place. The necessarily complex calculations can be made by using computer models. The fact remains, however, that the only way this energy component can be lessened is by reducing the size or number of leakage openings. It is important, therefore, to identify where these openings occur and what changes in details, materials and construction practices can be employed to achieve a more airtight barrier.

Air Leakage Paths and Openings

There has been a general tendency to assume that leakage through the building enclosure occurs primarily at doors and windows where visible joints occur. The ASHRAE Handbook of Fundamentals provides information on air leakage through frame and masonry walls and takes into account cracks such as those between the frame of a window or door and the wall construction in which it is installed.

Studies undertaken on 6 houses in Ottawa, Canada, demonstrated that the leakage openings contributed by windows and doors constituted only about one-fifth of the total; leakage through the ceiling and outside walls ranged up to 70% of the total (2). Studies on larger buildings have shown the actual overall leakage rates to be far above that specified by an industry standard for curtain walls (3).

The investigation of air leakage paths in actual buildings has been of special concern in Canada ever since air leakage was recognized as the most serious contributor to difficulties in buildings caused by cold weather condensation. The provision of an air barrier or an air and vapour barrier combined has been stressed both from a standpoint of condensation prevention and as a feature of the design of building walls to control rain penetration. The role of stack effect has also been emphasized since, in contrast to wind, it provides a continuous force during the cold weather to move moist air outward through the upper portions of a building.

In wood-frame residential buildings condensation in roof spaces is the most common problem as the main paths for air leakage are through partition walls into the attic space(4). These partitions effectively constitute flues for upward air movement under the action of stack effect in winter. Construction practices have resulted in many openings between the interior of such partitions and the attic space. Shrinkage cracks between upper plate and wallboard and holes drilled through plates to carry electrical wiring into the attic space form the major leakage paths. Gaps around plumbing stacks can be identified more readily and can be closed or sealed off.

Measures to Reduce Air Leakage

Measures to reduce air leakage through ceilings in wood-frame houses have been introduced by authorities in Canada (5). Central Mortgage and Housing Corporation now requires that vapour barrier strips be placed over partitions and subsequently attached to the main vapour barrier to provide a continuous membrane. Holes around electrical wiring, plumbing and chimneys must be adequately sealed. Electrical wiring in roof spaces is being discouraged and, as an alternative, furred spaces inward of the vapour barrier for wiring in both walls and ceilings are being promoted.

Air leakage through hollow concrete masonry walls is often much greater than normally assumed. Upward leakage in the cavity is not always adequately blocked and parallel, random air flow passages occur between gypsum wallboard finishes and the block face (4). Because of this, sheet finish material cannot be regarded as an equivalent air seal to site-applied plaster or heavy textured paints and mastics.

In commercial buildings the application of rigid insulation and built-up roofing above the roof deck results in fewer openings from the interior of the space into the roof/insulation system. A critical location for leakage and condensation in such buildings is associated with the junction of wall and roof. This may be further aggravated when dropped ceilings are provided for service spaces and the exterior wall above the ceiling is left unplastered or is inadequately treated with respect to airtightness. In some instances vertical service shafts provide passages for unrestricted air flow to this critical location, or into exterior walls (6).

Air leakage through exterior walls can also occur where the structural system or services penetrate the air barrier, or where joints between dissimilar materials or components occur. There often is a great difference between the construction details as developed on a designer's drawing board and the result that occurs in the field. Masonry cannot be installed tightly to structural steel columns and beams.

In principle, it is preferable to have the structural frame of a building inward and separate from the exterior wall system. The wall can then incorporate a more continuous structural air barrier and be protected from the fluctuating conditions of the weather by insulation applied to the outside. Exterior cladding is best applied following the open rain screen principle to control rain penetration (7). Consideration should also be given to allowing access to the interior wythe and air barrier for maintenance of the air seal at joints.

The deterioration of exterior structural elements of a building and damage to the interior through air leakage and condensation have an important bearing on the operating and maintenance costs and hence on the long-term energy economics. It is hoped that consideration of these matters might change current "first cost" attitudes to the more realistic life cycle cost approach.

There is also some merit in considering the improvement in airtightness of the internal floor systems, particularly in high-rise buildings. This will tend to redistribute the total pressure difference due to stack effect so that the pressure difference acting across the exterior wall on each floor is reduced. Such an approach also has merit in improving control of ventilation and air handling and reducing the air circulation between occupancies on different floors. It should also make it much easier to control smoke movement in buildings in the case of a fire situation and enable a more equitable apportioning of energy charges for space heating between individual units in apartment buildings.

Conclusions

Improving the airtightness of walls, windows, floors and roofs is an essential step toward energy conservation in buildings. Air leakage should never be relied upon for ventilation or air supply and exhaust but should be recognized as an impediment to the proper operation and control of ventilation systems. Specific ventilation systems should be required in all buildings to provide an adjustable or controllable rate of fresh air supply and exhaust with consideration given to the inclusion of energy recovery methods.

Efforts should be made to develop construction details, arrangements of materials and construction methods that will result in walls, windows, floors and roofs being more airtight with provision made for intentional and controllable ventilation openings through the components where necessary. If this is achieved, not only will optimum operation of the building be more readily attained, but it will be easier to evaluate the actual air leakage characteristics of the completed building, easier to monitor the energy associated with ventilation, and easier to predict performance more accurately under anticipated climatic conditions.

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