Buildings for the North

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SUBJECT

BUILDINGS FOR THE NORTH

Recent increase in construction in the North of Canada has resulted in several building systems being proposed for northern housing. Not all of those used have been satisfactory.

This note has been prepared in the belief that a number of the performance difficulties that have arisen with these buildings could have been prevented, or at least reduced, by careful analysis at the design stage with due regard to climatic conditions of the North. It is hoped that this note, by drawing attention to some of the factors which have been shown to be important in the performance of northern buildings, will assist in establishing a useful basis for assessing the suitability of building systems for northern use.

In designing buildings for the North it is important to note that the technical problems that arise, other than those imposed by permafrost, differ mainly in degree rather than in kind from those encountered in other areas of Canada. Climatic conditions in the North are severe but not much more so than the conditions experienced in the Prairie Provinces. Although some revisions are necessary to foundation design owing to the existence of permafrost, special above grade constructions are not required for northern areas. Experience has already shown that standard wood-frame construction can give satisfactory service for even severe northern exposures providing the building details conform with the best practice for other cold areas in Canada. On the other hand there is no evidence to show that the use of less conventional methods of building in the North will provide performance equivalent to good wood-frame construction.

It is significant that wood has received such wide acceptance in Canada as a building material that satisfies the performance requirements of houses for cold weather. It first became a traditional material for domestic buildings in Canada because of its availability. It has since proven itself in practice and has remained the most important single material in house construction because it combines a number of desirable properties and a few that are essential to the successful performance of structures exposed to cold weather. Among the most important of these are its strength - weight ratio, rigidity, ease of cutting and fastening, and its thermal properties.

In the light of present knowledge it is recommended that the basic wood-frame wall consisting of 2- by 4-inch studs at 16- or 24-inch centres, sheathing, building paper, some form of exterior finish, insulation between the studs, and a vapour barrier and interior finish be accepted as the standard of construction for northern housing. Before materials or systems of construction other than conventional wood frame are used in the North, they should be carefully assessed to establish as clearly as possible that they will satisfy the primary requirements of a building enclosure and that in over-all performance they will be at least as acceptable as standard wood-frame construction.

The primary requirements of a wall construction for a heated building exposed to Canadian climatic conditions may be stated as follows:

1. Strength and rigidity;
2. Resistance to heat flow;
3. Resistance to water vapour flow;
4. Resistance to air flow and liquid water movement;
5. Resistance to fire.

It will be useful to examine the way in which these primary requirements are met in conventional wood-frame construction and to relate these where possible to problems encountered in alternative types of construction.

1. Strength and Rigidity

Strength and rigidity are provided in wood-frame construction by the 2- by 4-inch studs in combination with 1-inch wood sheathing, or alternatively with ½-inch or 5/8-inch rigid sheet-type sheathing boards. One advantage of standard wood-frame construction is that under stress, it can deform sufficiently, and without damage, to take up some of the movement that may be produced in the structure by the action of permafrost on the foundations. Lack of this degree of flexibility is one of the disadvantages of prefabricated panel constructions which tend to concentrate movements in the building at the panel joints and often results in an opening of the joint and a corresponding reduction in weathertightness. This is particularly true of the stressed skin plywood panels which, although more economical through the use of smaller framing members and thinner coverings, are more rigid than normal frame construction and therefore tend to complicate the joint problem.

2. Resistance to Heat Flow

Resistance to heat flow in wood-frame construction can be obtained conveniently by adding insulation to the space between the studs without increasing the over-all thickness of the wall. In addition the wood studs are sufficiently good insulators that they do not introduce serious thermal discontinuity in the structure, nor do they cause any large reduction in the over-all insulating value of the wall. This is an important feature of wood-frame construction and a vital factor in its ability to perform well thermally in severe climates. The thermal conductivity of wood is about 1.0, that of mineral wool is 0.27; thus 4 inches of wood are nearly equivalent in insulating value to 1 inch of mineral wool. In contrast the thermal conductivity of concrete is 10 to 12, that of steel 310 and of aluminum 1475.

The high conductivities of metals cause much of the difficulty experienced with metal structures in cold climates. The amount of heat that is conducted by metals in a structure is sufficiently great to cause severe condensation within the building. This condensation can only be overcome by covering the metal with a maximum of material having good thermal properties. Often this means building the equivalent of a wood-frame wall on the interior of a metal building thus considerably increasing the total cost.

In selecting thermal insulating materials for northern buildings, bulk-type thermal insulations are preferable to arrangements which rely on air spaces for resistance to heat flow. In addition, because of the more severe climatic conditions and the generally high cost of fuel, substantial thicknesses of insulation can be justified. Complete filling of the spaces in the walls and at least the equivalent amount of insulation in ceilings and floors is recommended. This can be achieved by using bulk insulations in either the batt or blanket form or in the loose fill form.

One insulating material which appears particularly well suited for the North is shredded redwood bark which is marketed as a proprietary product mainly on the west coast of this continent. This is a loose fill-type insulating material which can be compacted for shipping and yet can be easily returned to a light density prior to placing in the stud space. The natural fibres cling readily to one another and the material can therefore be placed by hand in vertical stud spaces prior to the application of the interior finish. This provides opportunity for examination to ensure that the insulation completely fills all of the stud space, particularly those parts otherwise relatively inaccessible such as areas beneath windows. When other fill-type insulations are used they must be applied after the interior and exterior coverings are in place. Shredded redwood bark is combustible but burns slowly and can be obtained with a flame-proofing treatment which adds resistance to ignition and burning.

Reflective materials have the obvious advantage of being light and compact in packaged form and therefore easy to ship. Unfortunately experience has shown that reflective insulations are susceptible to poor performance in very cold areas due to convective action in the air spaces. These air spaces must be present in order for the reflective material to be effective as insulation. In addition a number of reflective surfaces with adjacent air spaces are required to provide the necessary insulating value for northern exposures. These materials are particularly inefficient in ceilings in the wintertime because of their low resistance to upward heat flow. Finally, reflective materials in the form usually available are likely to require much greater care in obtaining a satisfactory installation than is required when installing the bulk-type insulations.

3. Resistance to Water Vapour Flow

Condensation of water vapour on the room side of enclosing surfaces and within wall, floor, and ceiling constructions is probably the greatest single source of difficulty with buildings in the North. Problems resulting from such condensation are water stains on wall and ceiling finishes, wetting of the insulation and rotting of the structure. compaction and displacement of the insulation, and peeling of paint on exterior wood surfaces.

Surface condensation tends to occur on windows first because the surface temperatures of windows are usually lower than the surface temperatures of the remaining parts of the building. Condensation on windows can be controlled by using double or triple glazing. Condensation can also occur on the surfaces of the structure itself, over those areas where the structure is poorly insulated or where there are paths of high heat flow through the wall such as over nail heads and other materials having high conductivity. Prefabricated panel constructions are particularly vulnerable at the panel connections and insofar as possible all joints and fastenings should be made so that any metal used is covered with a maximum of material having good thermal properties. Occasionally condensation will occur in closets, especially those having one or more exterior walls, or behind large pieces of furniture, due to poor heat distribution in the building. This latter condition is very likely to arise in northern buildings where heat is often supplied by a space heater.

Concealed condensation which occurs within the framework of the structure is more damaging than surface condensation partly because it is not visible and can therefore continue to occur for some considerable time unknown to the occupant. This problem is controlled in wood-frame construction by installing a vapour barrier across the inside face of the studs directly behind the interior finish on the warm side of the insulation. This reduces the flow of water vapour from the interior of the building into the wall. Papers containing unbroken films of asphalt or wax, metal foils, and recently some plastic films, have been used for this purpose. To be effective they must be continuous across all insulated surfaces. Again this introduces problems in the design of prefabricated panel systems because of the difficulty of maintaining reasonable continuity of vapour control across the panel joint.

Maintaining a tight vapour seal and uniformly good thermal conditions is also made difficult when electrical or other services are installed in outside walls. It is therefore recommended that mechanical and electrical services be kept away from exterior walls and ceilings. If they must occupy these locations they should be kept out of the wall or ceiling spaces and mounted instead on the surface.

Exterior coverings with high resistance to water vapour flow such as metal siding tend to further complicate the moisture problem by trapping water vapour in the wall. When such materials are used it may be necessary to provide for the escape of the vapour by ventilation of the space behind the material. It is preferable, however, to avoid constructions requiring such openings since the direct entry of cold air into a wall construction may seriously disturb the thermal conditions.

Condensation in attic or roof spaces is controlled in frame construction by providing a vapour barrier in the ceiling and a means of ventilating the roof space to the outside. Sloping roofs are preferred to flat roofs because ventilation can be obtained more readily. In some areas of the North which are subject to high winds, these ventilation openings need to be carefully located and baffled to prevent the entry of fine wind-blown snow.

Metal window sash and metal window frames are becoming increasingly popular but must be used with great care in northern buildings. Because of the high conductivity of metal, their use in severe climates may lead to excessive condensation. Double-glazed units consisting of two individual single metal sash in a wood frame will not create difficulties but when the frame itself is metal then a path of high heat flow is provided through the wall which may result in condensation on the inner surface.

4. Resistance to Air Flow and Liquid Water Movement

A basic problem in wall design for northern buildings is to achieve good wind-tightness while avoiding outside coverings which stop vapour flow. In frame construction, protection against liquid water movement is provided by the external covering and air infiltration is controlled largely by means of a building paper placed between the sheathing and exterior finish. Increased resistance to air movement can be obtained by using the large sheet-type sheathing materials instead of narrow sheathing boards with consequent reduction in the number of joints. Further reduction in air leakage can be achieved by limiting the total window area and by keeping the amount of openable window area to a minimum since sealed windows significantly reduce the leakage of cold air under wind action.

One result of more tightly built construction is that it tends to increase the relative humidity in the building which may in turn introduce problems of condensation. To maintain the humidity at a reasonable level it may be necessary to provide alternative means of ventilation such as by louvred openings protected by insulated doors or by a forced system of ventilation.

5. Resistance to Fire

The main weakness of wood construction is in relation to fire safety. Building assemblies having more than a 1-hour fire rating cannot be easily devised using wood construction and fire protection from outside sources is therefore more readily obtained by space separation of adjacent buildings.

Further protection in frame construction can be obtained by careful selection of exterior finish. On the outside of the building, particularly the roof, only materials having fire retardent qualities should be used, that is, materials which have the ability to give protection against flame and burning brands and which do not ignite easily. Materials such as wood shingles should be avoided.

To reduce the fire hazard within the building, materials used as interior finish should have low flame-spread characteristics, that is, a low rate at which flame can travel across their surface. Materials such as fibreboard can contribute greatly to the rapid spread of fire within a building and whenever possible less combustible materials should be used. Some improvement in the flame-spread characteristics of interior finishes may be effected by the use of fire-retardant paints but such paint cannot be expected to make a naturally poor material good.

Heating

Closely allied to this subject of fire is that of heating. The tendency to be less restrictive in the standards of equipment and installation in buildings in the North because of difficulties encountered can lead to fire hazards of far greater seriousness than arise in the more heavily populated regions in the South. Faulty electric wiring, insufficient clearance around heating appliances, and inadequate chimneys are examples of such hazards.

Achieving adequate heating in northern buildings is complicated when a space, through which cold air can circulate, must be left between the underside of the building and the ground to maintain the soil in its frozen state. This requirement leads to a high heat loss through the floor construction which in turn requires substantial amounts of insulation in the floor assembly to conserve fuel and to raise the temperature of the floor to a comfortable level. To maintain comfortable floor temperatures, even when considerable insulation is used, the heat must be introduced either at or very close to the floor level.

In many northern buildings the only heat source is a space heater. The heat distribution obtained with such equipment is largely by convective action and is characterized by the natural tendency of the air at floor level to be colder than the air at ceiling level. This often leads to temperature differences of 50°F. between floor and ceiling. A most effective method of reducing this temperature gradient is by mounting a fan directly over the space heater near ceiling level and arranging for it to blow downward toward the floor. This forces rising warm air back across the floor surface and provides a more even distribution of heat throughout the room. Studies show that the vertical temperature gradient can be reduced to 10°F. by this means.

Prefabrication

In the North of Canada the extremely short building season and the shortage of on-site labour, particularly skilled labour, have tended to emphasize the importance of quick assembly at the site. Under these conditions prefabrication has assumed greater significance than in the more southerly regions. Experience with the prefabricated panel systems of construction developed to date suggests that they offer advantages over conventional construction only in reducing on-site labour requirements. They have not been shown to be more economical than conventional construction and in some cases have posed many serious problems in the field. The most important problem with the panel systems of construction is that of making a satisfactory connection between panels. The objective of joint design is to maintain reasonable continuity of the basic wall characteristics in respect to strength and rigidity, heat and moisture flow, and air tightness. In practice this has been difficult to achieve. This weakness in joint design has assumed greater proportions in the North because of the tendency for movement in the structure due to permafrost conditions.

As stated earlier in this note, the basic requirements of resistance to heat and moisture flow become particularly difficult to meet in structures in which metal is the prime element. Several types of such structures in prefabricated form have been proposed for northern use. A number of these which appear to have a favourable cost differential over frame construction will be seen on analysis to consist mainly of a structural frame and so require considerable on-site construction to make the building satisfactory for northern exposure. In the semi-circular type of structure similar to the Quonset hut, there is the difficult problem of sealing the interior surfaces of the building against air leakage into the wall space. If such leakage occurs it will result in considerable air movement by "chimney" action from the building interior into the roof space, carrying with it large quantities of water vapour and producing severe condensation problems in the roof.

In view of these problems a precut system of construction has often been suggested as an alternative to panel construction. This involves the precutting of all members to their correct size and shipping of these in carefully marked bundles to the site.

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