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AN OVERVIEW OF INSULATION AND AIRTIGHTNESS IN WOOD FRAME CONSTRUCTION

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INTRODUCTION

Wood frame construction is common in many parts of the world in single family dwellings and small buildings. In Canada and the United States it is generally the system of choice for new small buildings. In addition, apartment buildings up to four storeys in height are constructed using wood frame construction.

The original wood houses were constructed with log walls. In the 1800's the system developed to balloon frame construction for two storey houses, and later evolved into the platform frame construction which is now the system of choice in North America.

The most common wall framing technique, up until approximately 1975 in most parts of North America, was the use of 2 inch x 4 inch (38 mm x 89 mm) wooden studs at 16 inches (400 mm) on centre; typically, approximately 8 feet (2.4 m) in length. In the stud cavity an amount of batt insulation with an insulating value of approximately 0.5 m^2°C/watt (R12) was used. However, since 1975 a number of different wall systems have evolved incorporating improved insulation levels and improved air tightness. In this paper, a discussion is presented of different wall systems to accommodate greater amounts of insulation. In addition, the airtightness details that have evolved will also be discussed.

COMMONLY USED WALL FRAMING TECHNIQUES FOR ABOVE GRADE CONSTRUCTION

Figure 1 shows the use of 2 x 6 (38 mm x 140 mm) wall stud construction. Typical framing practice in Canada is to have the studs set 16 inches (400 mm) on center, but it is now becoming more popular to use 24 inch spacing (600 mm). When 600 mm spacing is used, thicker gypsum board (16 mm) is used to reduce deflection of the gypsum.

Another approach which is sometimes used is optimum value engineering to minimize the excess use of lumber in walls. Shown in Figure 2 is a variation on the 2 x 6 wall framing technique which incorporates less solid wood. A major benefit of this approach, in addition to reducing the use of wood, is the fact that it allows greater use of insulation of the wall cavity.

Variations on the 2 x 6 wall include the use of exterior insulating sheathing boards (Figure 3). Expanded polystyrene, extruded polystyrene, phenolic, polyurethane foam and medium density glass fibre have all been used to provide an extra insulating layer on the wall, usually

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on the outside of the wall. With these techniques, the use of wood panel material for sheathing is sometimes omitted and instead triangular braces are placed in the wall to provide the racking strength.

A second variation on the 2 x 6 wall construction is the use of horizontal 2 x 3 (38 x 64 mm) strapping on the inside of the wall with a vapour barrier sandwiched between the 2 x 6 and 2 x 3 (see Figure 4). If insulation levels beyond that used in the single stud walls are desired, a number of different wall techniques have been used. In Figure 5, a double stud wall construction is shown. With this technique two parallel walls are constructed and greater amounts of insulation can be accommodated. Walls with U values as low as 0.1 W/m^{2}°C (R60) have been constructed in parts of Canada using this technique.

A variation on the double stud wall technique was developed in Western Canada. It uses the placement of a vapour barrier part way through the wall. The design allows the running of the electrical and telephone wiring on the warm side of the vapour barrier thus reducing the potential for air leakage. One of the tightest houses ever constructed in Canada, which had a pressure test value of 0.12 ac/h at 50 Pa, had used this particular technique.

The double frame wall construction results in a relatively large amount of wood being used. In Sweden, several manufactured wall sections has been developed using specially fabricated studs. Two of these wall studs are shown in Figure 6. The advantage of these wall studs is that the thermal bridges through the webs of the manufactured wall section are considerably less than when solid wood is used. In addition, lower quality wood materials can be used.

In Sweden, as of 1984, all electrically heated houses had to meet a maximum U value of 0.17 (≥R33). The use of these manufactured wall studs is now common in Sweden.

In most parts of North America, standard construction usually features about 140 mm (5½ inches) of glass fibre insulation in the walls and as a consequence there has not yet developed a market demand for these innovative wall studs as has developed in Sweden. However, as energy prices and lumber prices increase, it is likely that the developments pioneered by the Swedes will become more widespread in wood frame construction.

BELOW GRADE CONSTRUCTION

In most parts of North America where houses have basements, cast in place concrete basement walls are the most popular. As concrete is a poor insulator, there has been use of either exterior, or more commonly, interior insulation on the walls of the basement. A common detail recommended in Canada for insulation on the inside of walls is shown in Figure 7. The dampproofing is placed on the outside of the concrete wall. In addition, a moisture barrier is placed up to grade level on the inside of the wall and is carried down underneath the bottom plate on the studding. The moisture barrier is then sealed to the air-vapour barrier at the face of the wall. At first glance, there appears that there is a double vapour barrier in the wall; however, in practice the cold upper part of the concrete wall above grade in winter time acts as a conduit for any moisture accumulated in the wall section. It is very important that the wall be well sealed to limit air exfiltration.

Wooden basement walls and to a lesser extent, wooden basement floors have become popular in certain areas of North America. The preserved wood uses either ammoniacal copper arsenate (ACA) or copper chromated arsenate (CCA). Generally, the wood basements perform well (Brown, 1990).

AIRTIGHTNESS DETAILS IN WOOD FRAME CONSTRUCTION

A number of studies have been done over the years detailing the airtightness levels of housing. A study of some Canadian houses (Dumont, 1981) spanning the years from 1920 up to 1980 showed that even without a conscious effort houses had become more airtight. Changes in the use of building materials with greater use of panelized construction tended to increase airtightness of homes over the years. Since 1975 there also has been improvement in airtightness through better detailing procedures and better workmanship. It is quite common for energy efficient homes in the Canadian R2000 program to have airtightness levels below 1.0 ac/h at 50 Pa. Houses with values as low as 0.12 ac/h at 50 Pa have been achieved. It should be noted that these air change values quoted are at a 50 Pa pressure difference. More commonly the pressures acting on low rise houses are the order of 4 Pa. The rough rule of thumb is that one can use the ac/h at 50 Pa and divide by approximately 20 to get the approximate winter time air change rate in the house.

Since 1977, new detached houses in Sweden have had a maximum allowable air leakage of 3.0 ac/h at 50 Pa. In Canada, a federal government sponsored voluntary program (the R2000 program) for energy efficient new houses, has a maximum allowable rate of 1.5 ac/h at 50 Pa. For program control purposes, each individual house in the Canadian R2000 program is checked for compliance to the air leakage standard by having a pressure test done. As illustrated by these test results, it is possible to reduce the residential air leakage values to < 3 ac/h at 50 Pa on a widespread basis as is the case in Sweden. Under a program of training and quality control, it is possible to further reduce the air leakage values to < 1.5 ac/h at 50 Pa. Over 6000 homes have been constructed under the R2000 program in Canada and all the homes have been able to meet the 1.5 ac/h target. Average values in the program were < 1 ac/h.

It should be noted that in both the Swedish houses and Canadian R2000 program houses controlled mechanical ventilation is also mandated. A house with an n_{50} value of 1.5 would typically have a natural air change rate ≤ 0.1 ac/h. This is about 1/3 to 1/5 of the recommended ventilation rate for dwellings. As a consequence, mechanical ventilation is used in these more well sealed homes. In the absence of mechanical ventilation, tight houses would be seriously under ventilated. For well sealed homes that use a balanced mechanical ventilation with a heat recovery ventilator, it would seem prudent for energy conservation reasons to limit the amount of uncontrolled air flow through the envelope. If the envelope is tightened to a n_{50} value of 1.0, the approximate value of the uncontrolled infiltration will be about 0.05 ac/h or approximately 1/10 of total ventilation rate supplied (usually about 0.5 ac/h).

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An unbalanced heat recovery ventilation system using an exhaust air heat pump also requires that the building envelope be tightly sealed. The slot vents used on the windows rely on a relatively uniform negative pressure throughout the house. If the house is leaky, inadequate ventilation of some rooms can occur if the house is not tightly sealed when ventilated using the negative pressure approach.

KEY AIR LEAKAGE SPOTS IN WOOD FRAME RESIDENTIAL CONSTRUCTION

In Figure 8, a cross section through a house with a basement is shown and in it typical air leakage locations are found. Up until about 1975, it was thought that most of the air leakage in homes occurred around windows and doors. Efforts to control air leakage concentrated on these two elements. However, detailed measurements in homes since that time has found that it is leakage between the intersection and the interface of building components (such as the wall - floor intersection) that tend to be much greater sources of air leakage. A number of methods of controlling air leakage have been developed. (Eyre, Jennings, 1981), (Anon, 1982).

There are two major approaches used in North American wood frame construction to provide airtightness. One method makes use of a polyethylene vapour barrier as both the vapour retarder and air barrier in the system. The second approach makes use of solid components such as the gypsum board and solid materials as the air barrier; this is often called the airtight drywall approach (ADA). In both systems the intent is to provide as continuous an air and vapor retarder as possible.

More recent designs that combine the best features of the polyethylene approach and the ADA approach are now being used.

INSULATION MATERIALS FOR WOOD FRAME CONSTRUCTION

The following materials have been used in wood frame construction in recent years.

1. Glass fibre insulation.
2. Mineral fibre insulation.
2. Cellulose fibre insulation.
3. Board insulation materials of plastic: a) extruded polystyrene b) expanded polystyrene c) isocyanurate d) polyurethane e) phenolic foam

Generally, the rigid plastic insulations have had an insulating cost of approximately 3 to 5 times that of the loose fill insulation materials and as consequence have been less popular. A number of more exotic insulations such as powder evacuated panels, vacuum insulated panels, and multi-layer aluminumized fabric panels may over the long run challenge the use of fibrous materials in walls. It is not certain that these exotic insulations can be produced at a price that is competitive and can be handled satisfactorily under the harsh conditions under which most houses are built.

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SUMMARY

Wood frame construction has evolved considerably from the first years of log construction through balloon framing to platform framing. Since 1973 there has been a large number of innovations taken place in terms of systems that incorporate greater amounts of insulation.

Improved air sealing techniques have also been developed which can be used on a routine basis to reduce air leakage to less than 1 air change per hour at a 50 pascal pressure difference.

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REFERENCES

Anon, "Energy Efficient Housing: A Prairie Approach", 1982, Department of Energy and Mines, Government of Saskatchewan, Regina, SK, Canada.

Brown, T.N. "An evaluation of preserved wood foundations in Alberta", Alberta Municipal Affairs, 9925-107th St. Edmonton, AB, Canada T5K 2H9

Eyre, D. and Jennings, D. "Air-Vapour Barriers" Saskatchewan Research Council Publication No. E-825-2-E-81, Saskatoon, SK, Canada, S7N 2X8, 1981.

CMHC, 1982 "Energy Efficient Housing Construction", Canada Mortgage and Housing Corporation, Ottawa, ON, Cat. No. NH 17-16/1982E.

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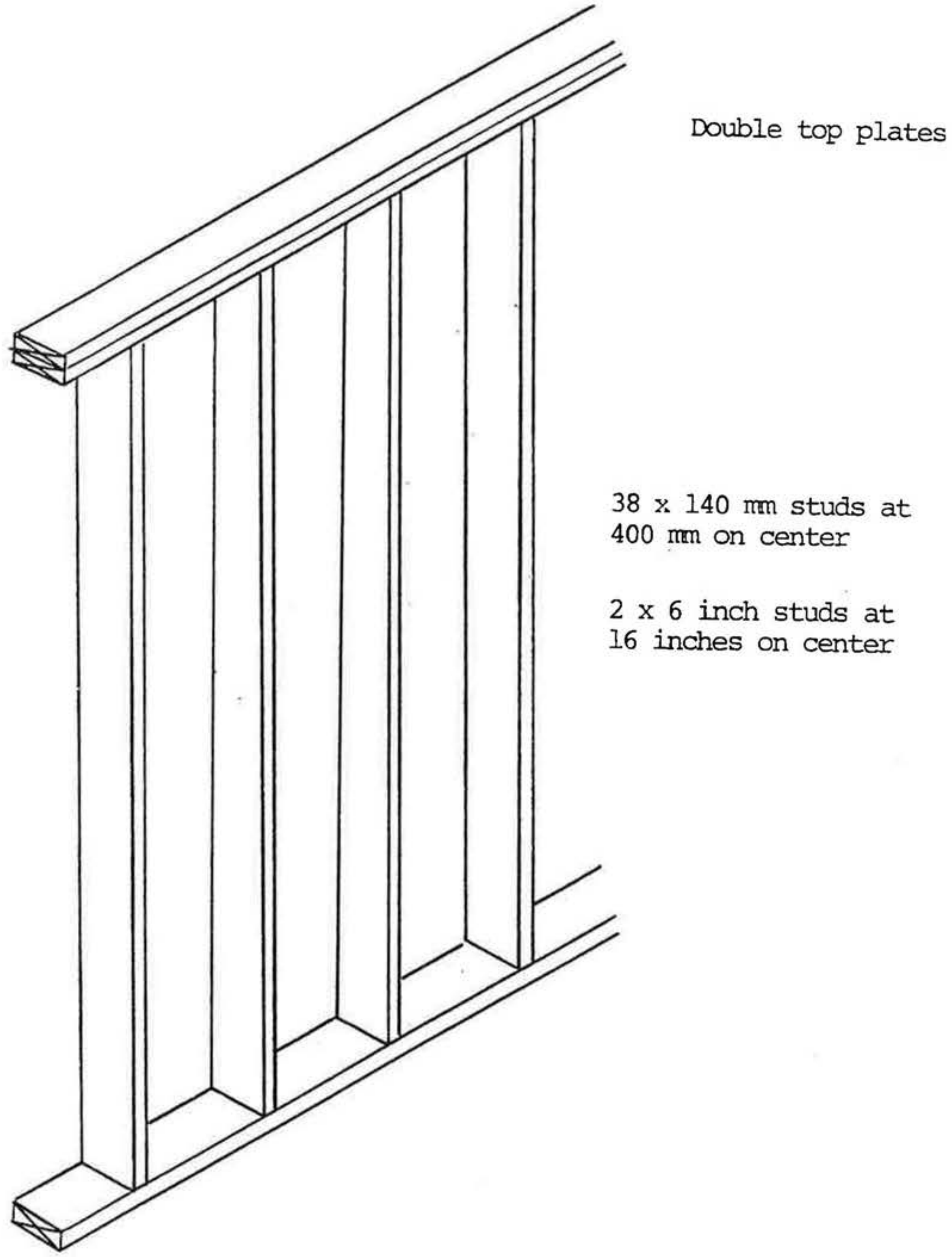

Figure 1. 2 x 6 Wall stud Construction (38 x 140mm)

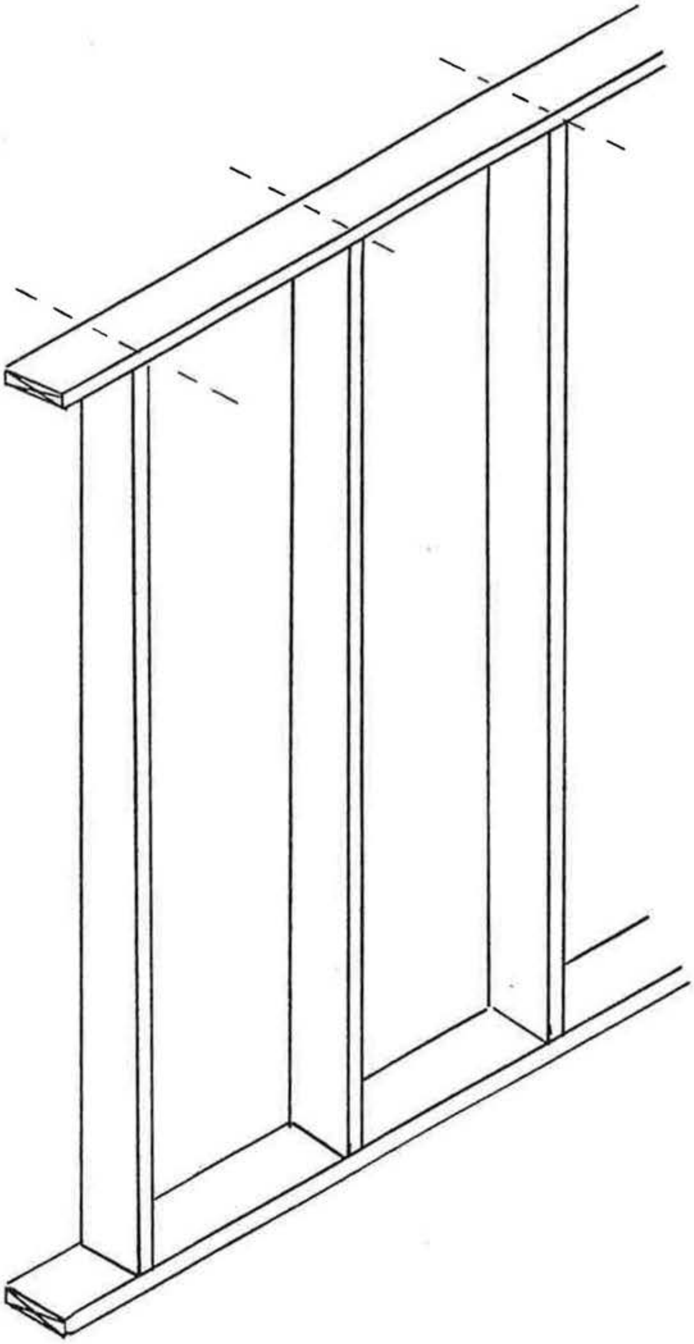

Figure 2. Optimum Value Engineering Wall Incorporating Fewer Wood Members (Less wood in wall facilitates greater use of insulation)

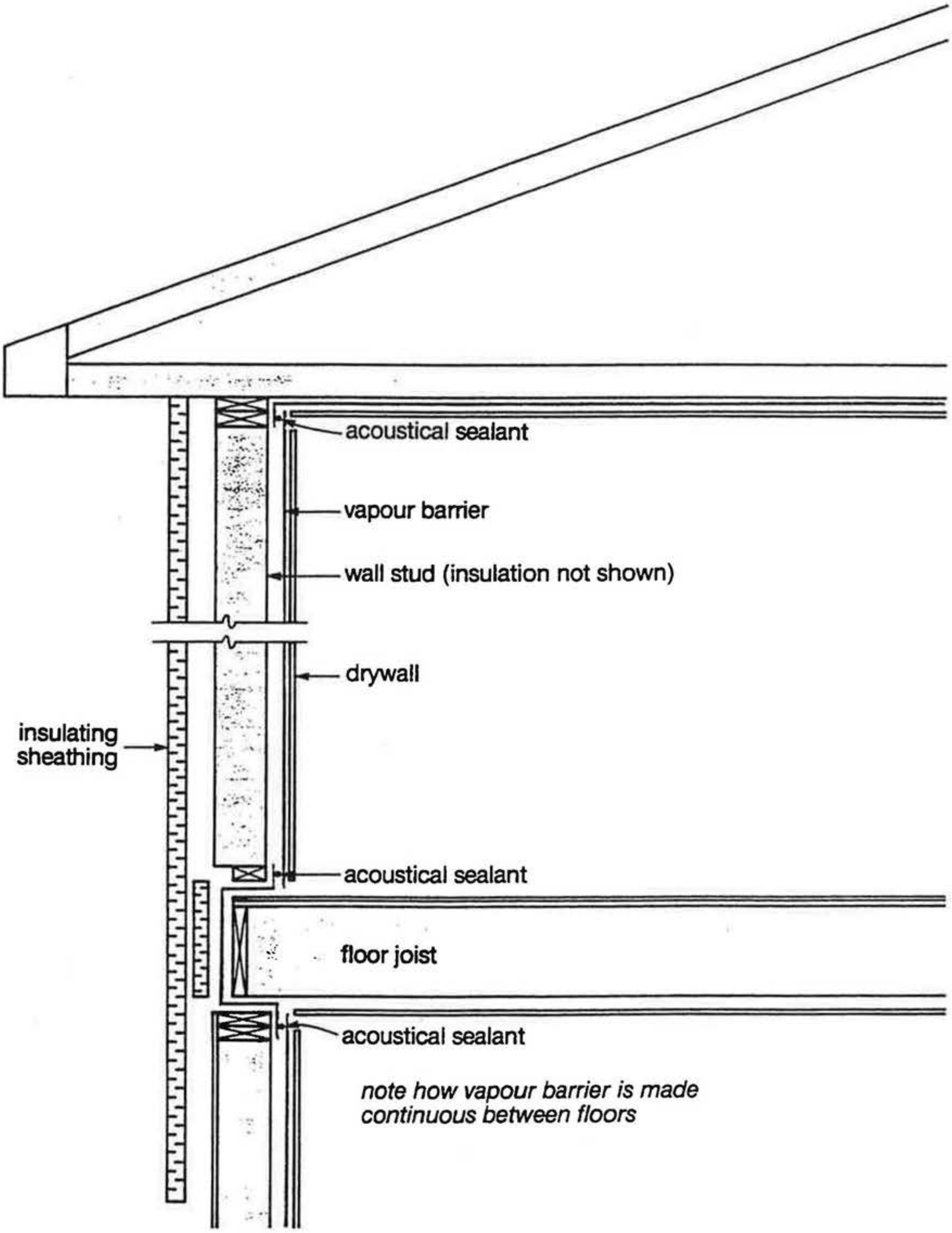

Figure 3. 2 x 6 Wall construction incorporating exterior insulation

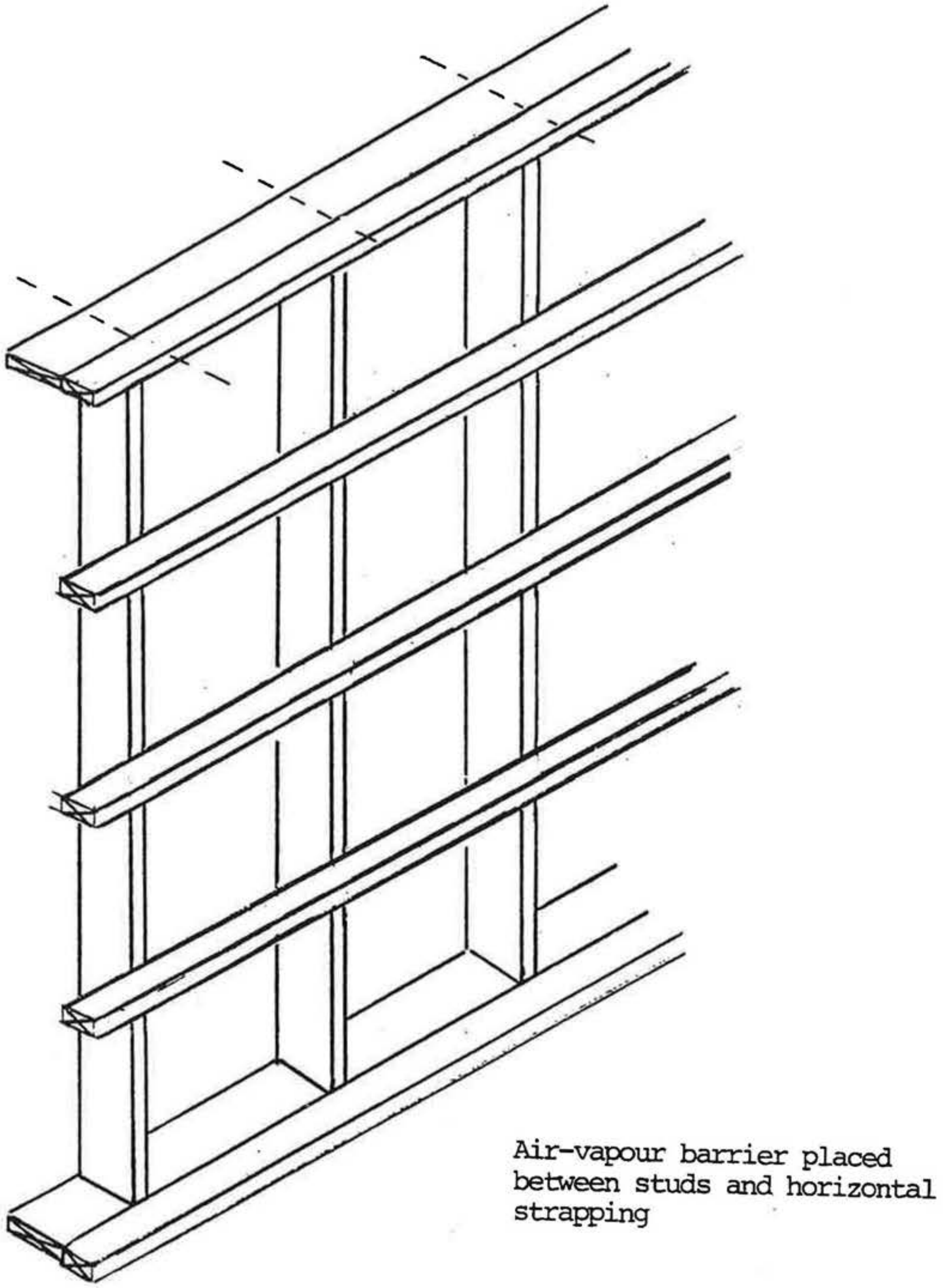

Figure 4. 2 x 6 and 2 x 3 strapping

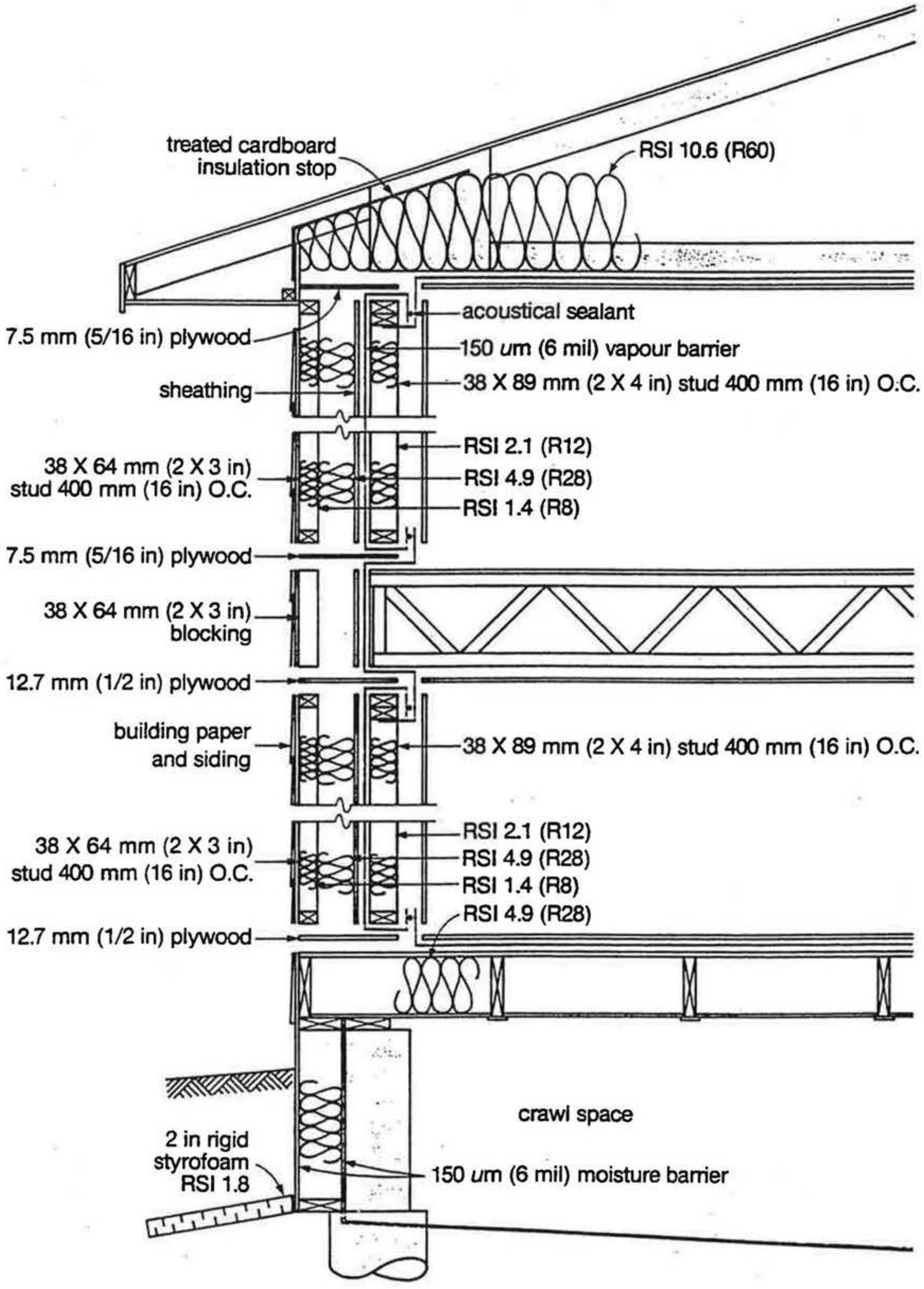

Figure 5. Double stud wall construction

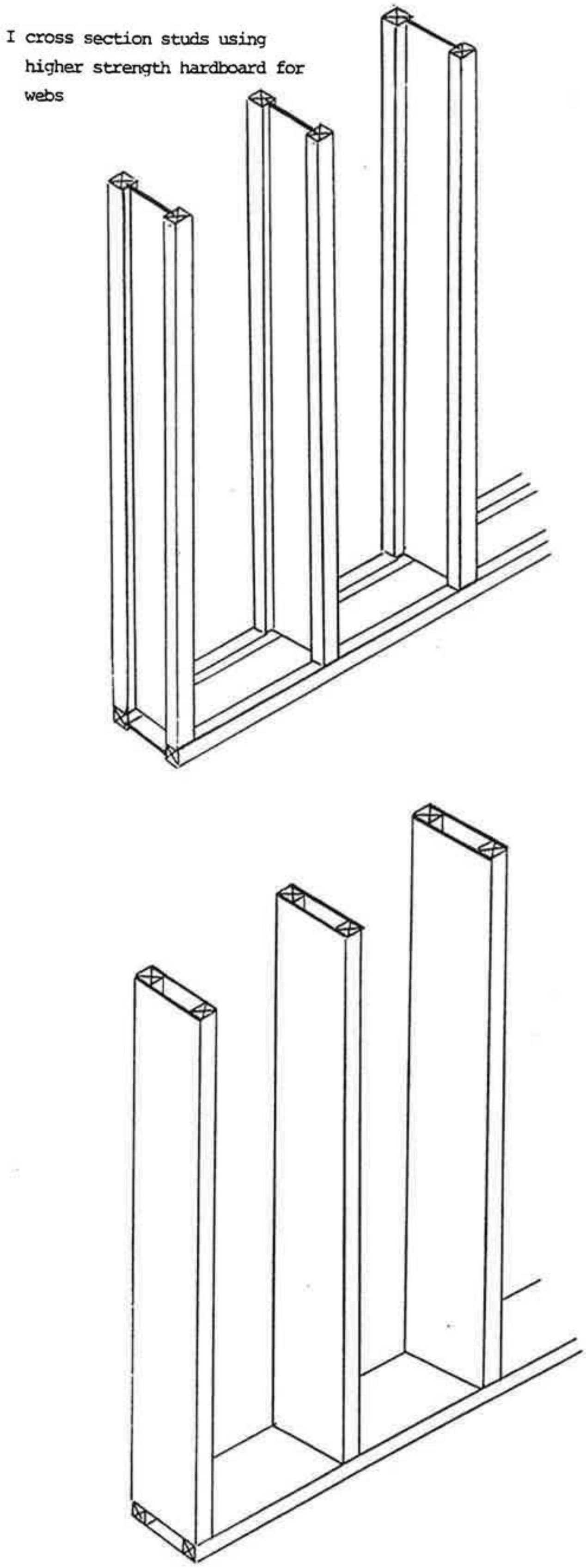

Figure 6. Wall studs able to accommodate large wall insulation

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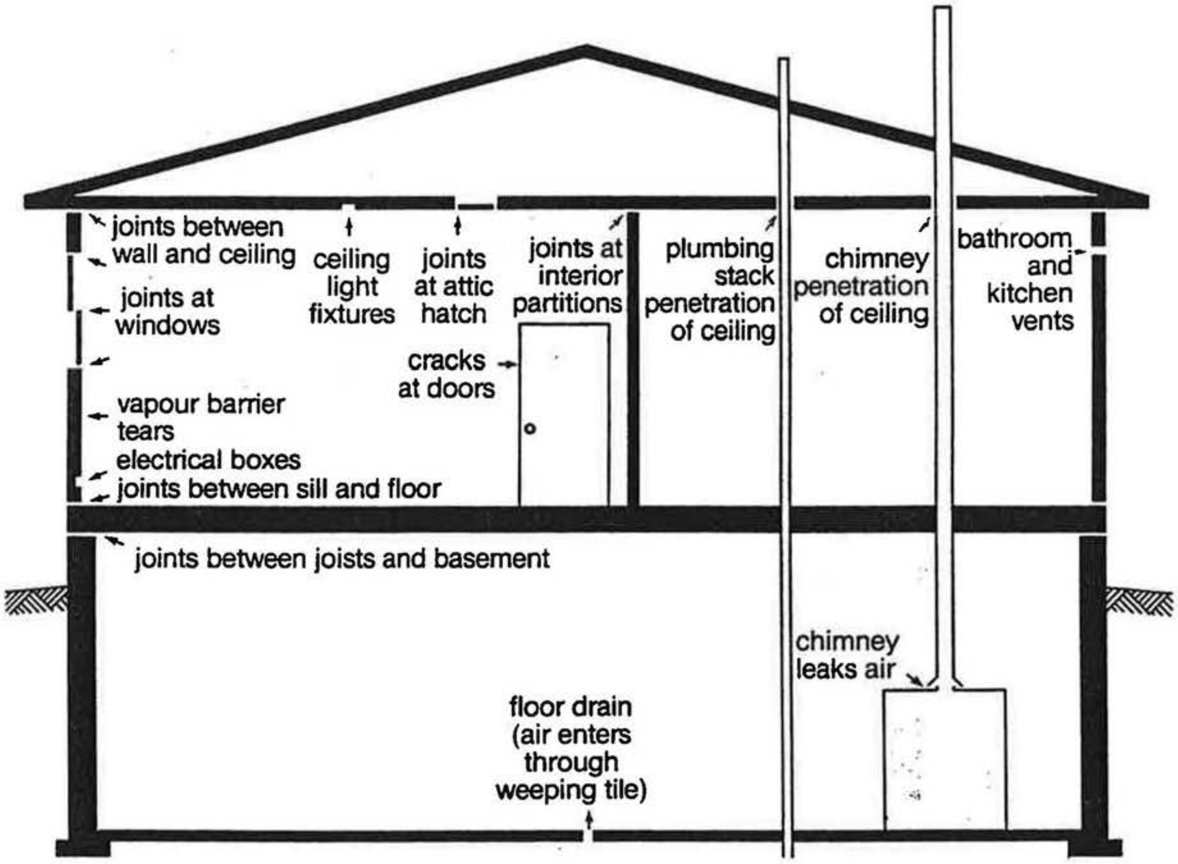

Figure 8. Typical air leakage spots in housing