SCANDINAVIAN TIMBER FRAME HOUSE CONSTRUCTION TECHNICAL DESIGN AND FUTURE TRENDS

Trond Ø. Ramstad and Åge Hallquist, Civil Engineers, Norwegian Building Research Institute, Oslo, Norway

Summary

The paper reviews the present position of timber frame house construction in Scandinavia. The purpose of the paper is to provide knowledge about the technical design principles and the materials currently in use. Some future trends and developments towards new designs for timber frame construction are also discussed.

Résumé

Cet exposé presente la position acutelle de la construction en charpente de bois en Scandinavie. L'intention de l'exposé est de procurer connaissance sur les principes techniques de la construction et les materiaux actuellement en usage aujourd'hui. Certains tendances futures et developpements vers nouvelles constructions en bois sont aussi discutés.

Introduction

Timber frame house construction as presented in this paper is based primarely on Norwegian design solutions. However, timber frame houses in Sweden and Denmark are technically very similar, and the main design concept is also closely linked with the traditional North American construction practice.

In Norway low-rise houses are now accounting for close to 80 % of all residential buildings (house units), and more than 95 % of these are timber frame construction. Also in Sweden are wooden houses dominating residential building to approximately the same extent.

A majority of these houses are financed through the State Housing Bank, being built to a standard and cost reflecting the government's social policy programme. Privately financed housing, also to luxury standards, is also usually timber frame design.

In 1978 over 60 % of all houses were built by the use of standard drawings (catalogue designs). Apart from residential building is timber frame construction also widely used for building low-rise schools and kindergartens, smaller industrial and service buildings etc., in addition to an important market for secondary homes like cottages at the seaside or in the mountains.

It is the intention with this paper to provide knowledge about Scandinavian timber frame building and give technical background for comparison with similar constructions in other countries. It is also hoped that the paper shows the flexibilities of timber frame design and its possibility of adapting to local environmental conditions, thus providing background for a consideration of utilizing the wooden house concept also in areas without a tradition with this type of houses.

Design principle

Characteristically for timber frame construction is the use of several materials or products in combination. Each product serves only one or a few functions as part of the total system, and being specialized and refined for these functions particularly.

Wall construction starts with a load-bearing frame of timber studs and plates as shown in *figure 1*. This frame is completed with a number of other materials to form the finished wall, using the design principle indicated in *figure 2*.

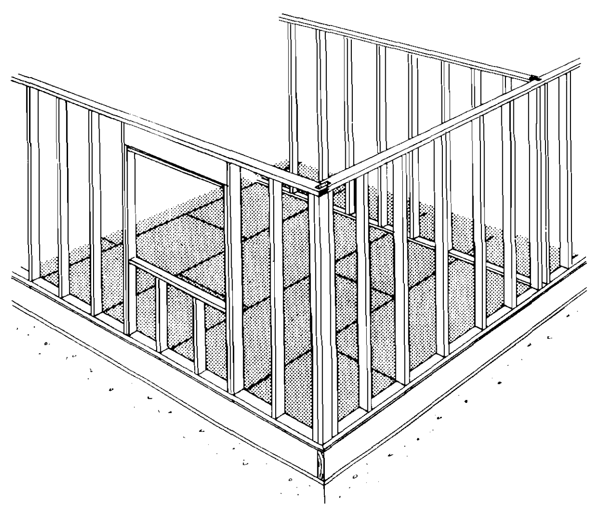

Fig. 1. Basic structural timber wall frame. Walls can be build in «stick» on site, or prefabricated. The degree of prefabrication may vary from the basic frame with one layer of sheathing to completely finished wall panels. Wall frames are erected directly on a concrete floor slab, concrete floor elements, or on a timber floor structure as shown here.

Timber floor and roof construction is based on the same design concept, by completing a load-bearing structure of wood beams or trussed rafters with additional materials on both sides and filling the cavities with thermal insulation. An important feature of this design is the very large number of different building products and makes which can be utilized. With the same basic construction technique and design work the choice of materials can be adjusted to local material supplies, product prices at the time of buying, special appearance requirements etc. Timber frame structures are dry construction and light in weight. The same

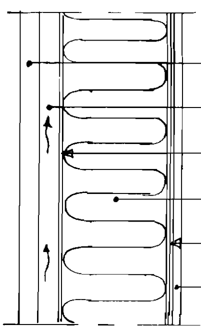

Fig. 2. Construction of timber frame exterior wall, in principle. Several building products are combined, each product serving only a limited number of functions.

basic design concept is used whether the house is to be built completely on site with a minimum of tools, or being prefabricated in a factory with highly automated machinery. The dissimilarities in how timber framed houses are built, both within Scandinavia and between various other countries, reflects mainly the difference in local availability of building products and materials. But there is also significant differences in a number of construction details, particularly in connection with external appearance. The design principle is nevertheless mainly the same.

Materials and construction details in current use

Traditionally the balloon frame construction has been used, where wall studs and the roof are erected before the subfloor panels or the floor boards are fastened to the floor joists. During the 1970's, however, the platform frame method has become very common. By using water-resistant materials the floor is made to form a working platform before starting the erection of walls and roof, *figure 3*. The advantage are faster erection and increased working safety. On the other hand the method requires more expensive floor materials and often more work on floor finish.

A typical section of a house from the 1970's is shown in *figure 4*, while *figure 5 a, b and c* show the most typical materials currently in use. These different alternatives are combined in almost all possible ways.

Timber frame construction is limited to two-storey houses by fire safety regulations. As foundation are basements widely used, particularly in detached house construction, while alternatives are slab on the ground or suspended timber floors over foundation strips, piles or a crawl-space. Houses are usually designed for snow loads in the range 1.5 kN/m^2 to 3.0 kN/m^2, and a maximum basic wind load about 0.60 kN/m^2 – 0.85 kN/m^2.

Wind bracing is given much attention in many countries. Experience from the timber frame house construction in Scandinavia shows there is few or none problems related to horizontal wind forces on a completed house, and structural calcualations are normally not carried out regardless the size and shape of the house. With a minimum of one layer with any of the ordinary sheet type materials as sheathing or lining on all exterior walls the wind bracing is considered satisfactorily. Let-in corner bracing is used only when there is timber boards both for cladding and lining, breather paper and no sheathing.

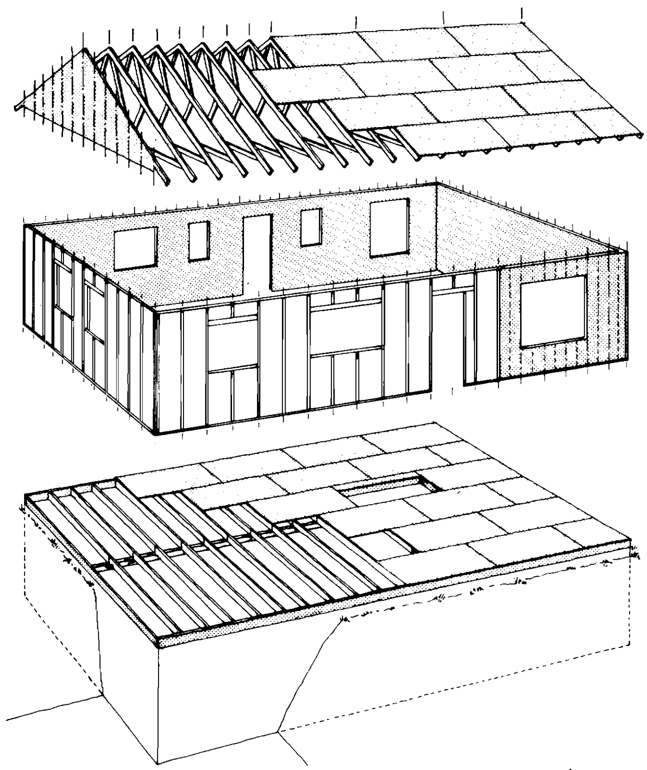

Fig. 3. Platform frame construction. All walls are placed upon the subfloor, built in «stick» or as prefabricated panels. Partition walls are usually erected after roof completion when they are built on site.

Preservation by design is given high priority in all detailing. This include good ventilation of the roof structure, ventilation of external cladding, emphasize on water drainage at window and exterior door details and at plates and foundations, entrance-doors covered by roof, etc. Special durable wood species are not used, while utilization of preservative treated timber being pressure impregnated normally is limited to base plates and balcony structures.

In cases where fire safety requires special measures to be taken it is common to find solutions with plasterboards covering the timber structure. In row-houses and other type of dense housing the permissible area (horizontal projection) between non-combustible fire walls usually range from 600 m^2 to 800 m^2, depending upon size and design.

Acoustic insulation requirements are normally met by the use of double separated framework designs, for walls as well as for floors.

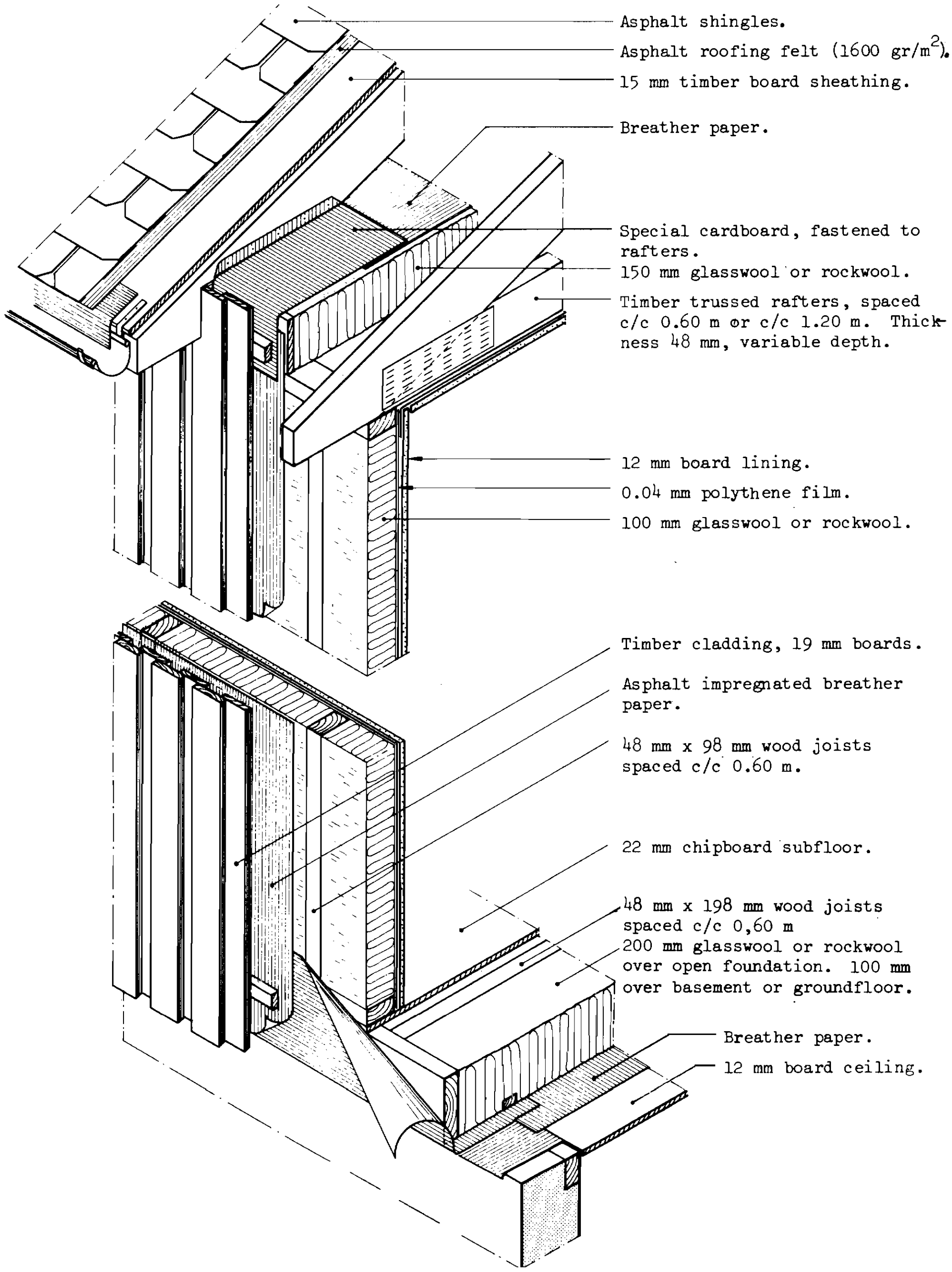

Fig. 4. Typical Scandinavian timber frame design from the 1960's and the 1970's. Alternative materials are shown in figure 5.

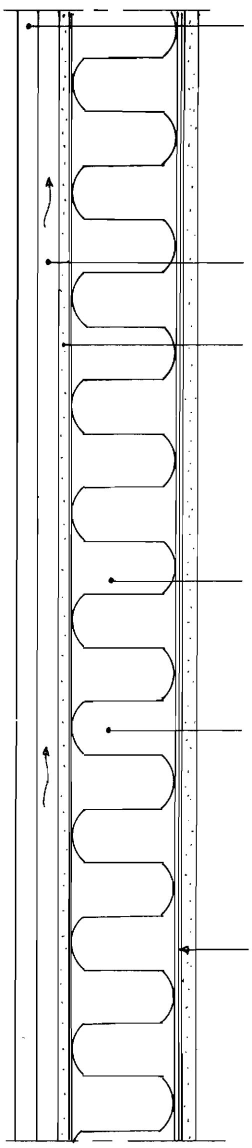

Fig. 5 a. **Alternative materials in current use for exterior wall designs.**

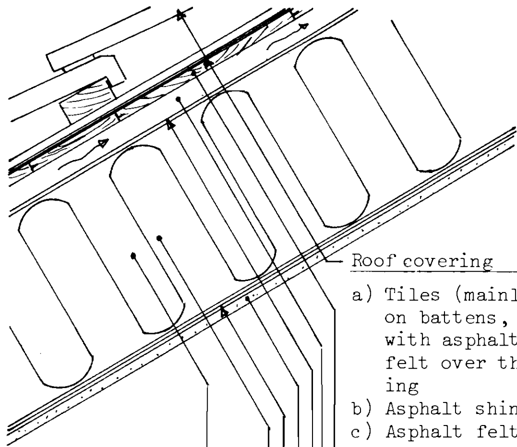

Fig. 5 b. **Alternative materials in current use for roof designs.**

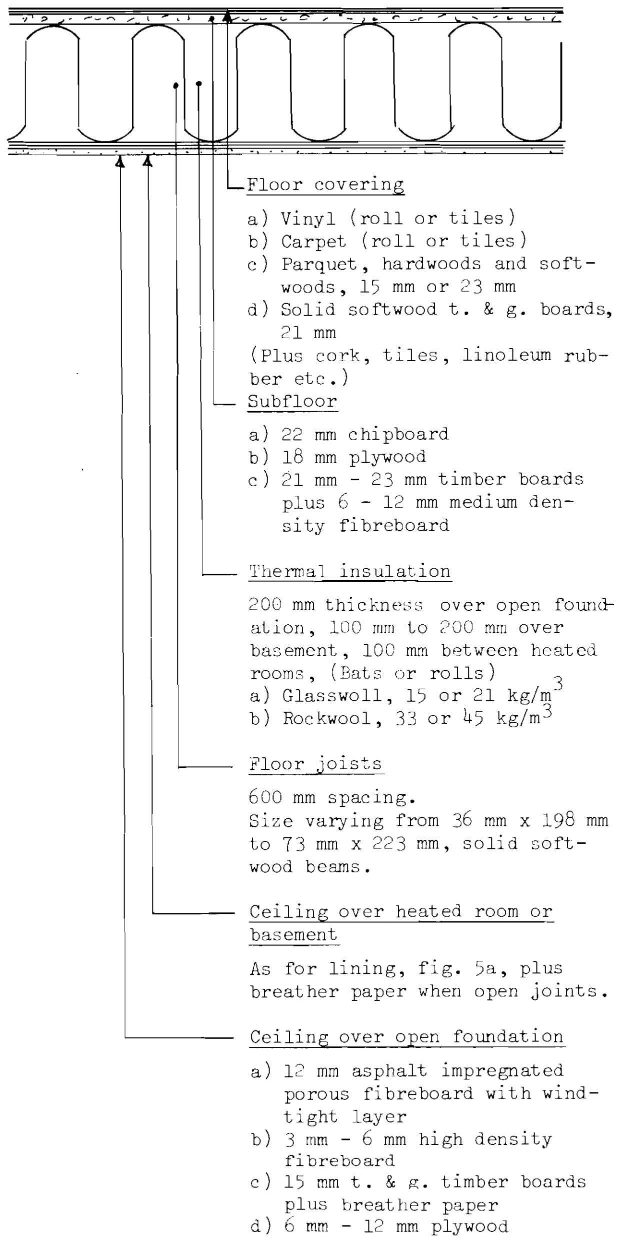

Fig. 5 c. Alternative materials in current use for timber floor designs.

Competitive position

Wood has always been the traditional building material in large parts of Scandinavia, due to availability from local resources. But a prime reason for today's strong position of timber frame house construction in Scandinavia, as indicated in the introduction, is its adaptability to changes in technology and requirements.

The construction principle allows the designer and builder to select between various materials and construction techniques to provide an optimal performance/cost solution. One result of this process during the last 25 years has been a reduction in wood material used for an ordinary house to about one half, while construction time has been cut to one third.

Building timber frame means the use of light materials, which is equally important in transportation as for the handling on site. This allows also small builders with light and inexpensive equipment to operate effeciently. The dry building process allows fast completion as problems with the drying of in situ concrete etc. are minimized. It is also important that timber frame construction can go on continuously through the cold winters.

The quality of framed houses depend on skilled workers who understand why good workmanship is needed in a number of critical details. This may be details related to air-tightness, to avoid excessive moisture content causing rot or paint blister, squeaking floors etc. Lack of skilled workers may sometimes favour other building systems. On the other hand prefer most habitants houses made of wood because they are familiar with this material and are able to carry out maintenance, rebuilding and alterations themselves.

One of the most important competitive features of the timber framed house is the adaptability to increasing thermal insulation requirements. Design work is easier than with other construction systems, especially because the structural components do not form severe thermal bridges.

Total cost figures from Norway, including the running cost of maintenance and heatloss, shows well insulated timber framed walls to be the cheapest external wall construction on the market, along with steel framed systems based on cold-formed steel profiles. Economic considerations indicates that timber frame construction will continue to keep its strong competitive position in Scandinavia.

Future trends and new designs

It is believed that the following factors will be among the most important affecting the further development of timber frame design as far as materials and construction techniques are concerned:

– *Energy conservation.* New building code requirements with lower U-values are already introduced to save energy on a national level. The effect of heating cost on private economy may even result in the use of better thermal insulation than the minimum code requirements. Better control of air infiltration and ventilation may also affect the design of joints between building elements and the use of materials for barriers against air penetration.

– *Skilled work force.* A shortage of skilled carpenters and other specialized building workers is foreseen as an increasing problem. This leads to stronger efforts in the development of prefabricated components where fast and simple erection on site is a primary goal. More prefabrication is also required to meet demands related to more stationary jobs and sheltered working places.

– *Individual house design.* Areas with a large number of houses looking almost totally standardized are now being avoided. There is a need for using systems which offer maximum opportunities in individual design, combined with the economic benefits of using long series of standard building operations and purchasing materials and components in as large quantities as possible. Effective combinations of prefabrication and building on site are required.

– *Timber resources.* A shortage of sawn wood with large dimensions and good quality is gradually becoming more significant. At the same time new technology leads to more possibilities in automatic production of composite materials and components, in particular based on gluing techniques combined with automatic handling and quality control.
The effect of new thermal insulation requirements in national building regulations have already had a noticeable effect on Schandinavian timber frame design. The thickness of mineral wool in external walls is now increased to 150 mm or more. This is obtained by switching to wider studs and/or placing horizontal ribbons to one or both sides of the studs as indicated in figure 6.

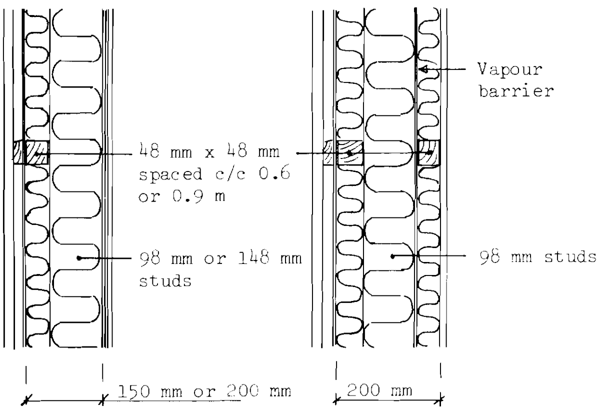

Fig. 6. Examples of external walls with horizontal ribbons to provide space for increased thermal insulation.

Increased thermal insulation in roofs is now resulting in larger members for the lower chords in trussed rafters as the thickness of mineral wool and not structural calculations are governing the design.
I-shaped profiles made of wood and structural, woodbased sheet material have so far mainly been utilized as plywood beams for more specialized structures. Time seems now more ready for the introduction of I-sections in ordinary timber frame house building. It is now possible to produce this type of members to a competitive cost when thick walls (minimum 200 mm) and high roofbeams or floor joists (minimum 250 mm) are required. An example of commercially available I-sections are shown in figure 7. This type of members combine high strength and stiffness, little shrinkage and accurate dimensions, and they can be produced by using rather small timber dimensions. Another I-section design, from USA, is using a plywood web and flages of «micro-lam» instead of solid wood to ensure a more uniform quality.

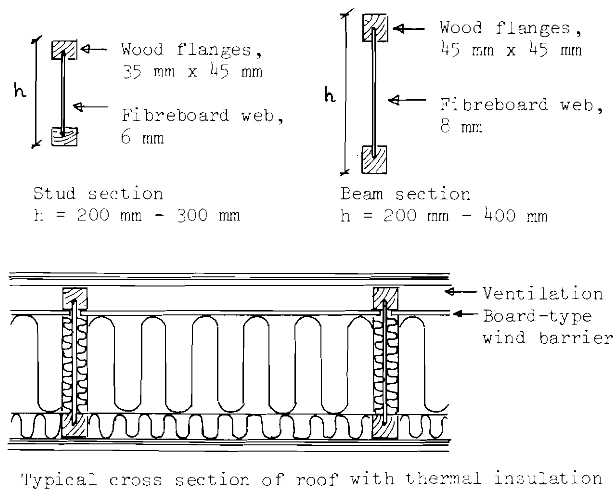

Fig. 7. Example of I-sections for studs and beams, commercially available for timber frame housing (Masonite of Sweden). The beams will have a longer permissible span than solid wood members, thus providing better opportunities for roof and floor designs.

Laminated timber may be more widely used in ordinary house construction. Laminated members are often used for the architectural effect and the appearance alone, particularly in more expensive house design. However, the effect of high material cost for lamination can partly be offset by fast erection. The use of a simple load-bearing structure of large laminated beams and posts combined with prefabricated elements and components is a concept that already has proved to be economically interesting. New developments in stressed-skin and sandwich panels are expected to appear on the market in increasing numbers. Specialized sealing systems for joints, like polyurethane foams, rubber sealing strips etc., will probably be more widely used in wodden house building.
Solid timber boards are still the most popular external cladding in Scandinavia, particularly in Norway and Sweden, even for the most expensive houses. Brick veneer does also have a strong position, having good appearance and virtually no need for maintenance, which partly make up for a high initial cost. A number of new cladding materials are marketed every year, mainly metal- and woodbased sheet materials. These are often claimed to require very little maintenance. However, it looks like private house owners in particular are ready to do the necessary maintenance themselves on traditional timber claddings, as well as other parts of their wooden houses.