Timber frame houses - Structural

STEP lecture E10
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Objective

To describe the structural behaviour of timber frame house construction.

Summary

This lecture describes, in principle, how timber frame houses are constructed and designed. It is based mainly on the Scandinavian tradition. It contains a brief description of the main calculation methods concerning timber frame walls, floors and roofs, and also a brief description of other materials which form part of the timber frame house.

Introduction

Timber frame housing is the traditional type of construction in North America and Scandinavia, where more than 90% of all homes are built this way. Timber frame housing has also increased its market shares in a number of other European countries, particularly in the United Kingdom. Fast and dry erection, good thermal insulation and suitability for all types of architectural designs are important factors for making wood frame construction a strong alternative in house building.

Construction principles

The most commonly used method of building timber frame houses is the platform method shown in Figure 1. Platform construction means that the walls are placed directly on a sub-floor which acts as a working platform during the erection of the house. Originally an American method, platform construction is now becoming the normal way of building in most countries, because it combines better safety during erection with the possibility of using either prefabricated panels or on-site assembly.

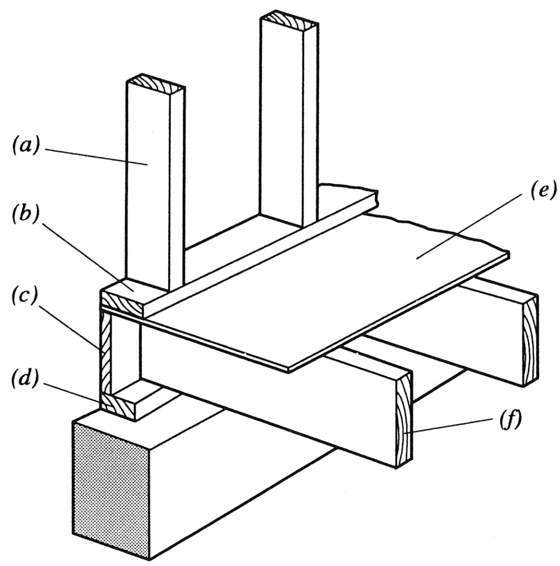

Figure 1 *Platform construction (NBI Handbook 38 Timber Frame Houses). (a) Stud, (b) bottom rail, (c) perimeter beam, (d) sole plate, (e) subfloor, (f) floor joist.*

Timber frame construction uses timber members and components to form a structural frame which transmits all vertical and horizontal loads to the foundations. The exterior cladding is non load bearing; it is used to weatherproof the building and provide the desired external appearance.

Conventional timber frame walls are constructed of vertical timber studs, breather membrane and sheating on the outside, vapour barrier and lining on the inside and with the cavity filled with mineral wool. Timber joists make the floor. Roof trusses or rafters are spaced at 0,6 *m* or 1,2 *m*, depending on snow loads and/or tradition. Roof structures correspond with the position of wall studs in well designed houses, in order to avoid unnecessarily large head sills and the possibility of visible deformations.

Walls

Load bearing walls - structural requirements

Load bearing walls support roofs and/or floors. The studs are designed as columns (STEP lecture B6) with buckling length the same as the length of the stud. One assumes that the studs are prevented from buckling in the wall plane by the sheathing. The slenderness and buckling capacity are only calculated for buckling perpendicular to the wall plane.

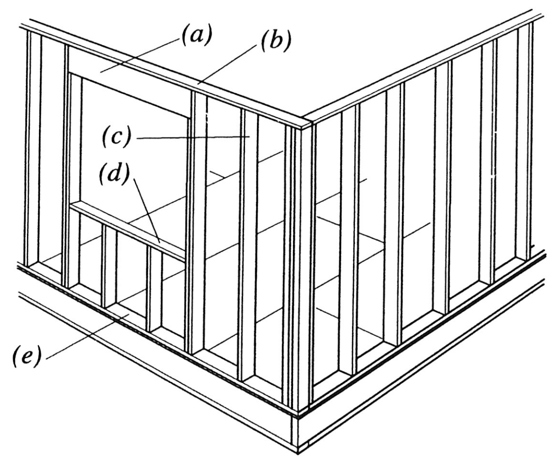

Figure 2 Timber frame wall (NBI Building Details A 523.251). (a) Lintel, (b) top rail, (c) stud, (d) nogging, (e) bottom rail.

Load bearing walls in low-rise houses in Scandinavia are designed for vertical loads only, and not in combination with horizontal wind load. The argument for this is that the probability for the occurrence of both wind and snow-load at their maximum values at the same time is very small. Also, the wall sheathing gives extra safety against buckling perpendicular to the wall plane. This is not considered when designing the studs as simple columns.

The wind load on external walls of normal height is never decisive for the stud size in a timber frame house. For houses with especially high walls the studs must be checked for wind load too, that is combined compression and bending (STEP lecture B6).

In addition to buckling, compression perpendicular to grain on the bottom rail must be checked.

Lintels over openings in load bearing walls are designed as simply supported beams across one span. In reality, the top rail, the wall sheating and the roof construction's load distributing ability, all contribute to increased load capacity. As long as the spacing of the roof rafters is no more than 0,6 *m*, the lintels may be calculated with a uniformly distributed load. This is much simpler than designing with point loads from each rafter because the exact position of the rafters does not need to be known.

In addition to the bending moment, compression perpendicular to grain at the support of the lintel must be checked. Calculation of deflection may be omitted, as the top rail, sheathing etc. provide sufficient stiffness.

External walls

External walls are constructed from vertical studs, normally at 400 *mm* or 600 *mm* spacing, nailed with simple butt joints to top and bottom rails. Strength graded timber must be used. In Northern Europe, it is the requirement of thermal insulation which in practice governs the size of the studs, along with the need for satisfactory butt-jointing of sheathing and plasterboard, not the structural design and needs for load bearing capacity. The normal sizes are 48 *mm* x 98 *mm* or 36 *mm* x 148 *mm*. Tables are given for load bearing capacity and stud sizes (NBI Building Details A 523.251, TRADA (1989)).

Where openings occur in load bearing walls, they must be spanned by suitably designed lintels, and the load on the lintels should be transmitted to the foundations by cripple studs. The cripple studs should be of the same cross-section and at least the same number as those removed from the opening.

Wind bracing is usually provided by a wood based sheet material or plasterboard, normally nailed to the external face of the frame. All four walls of a house must have at least one layer of sheet material nailed along all four sides of the sheet and along each stud.

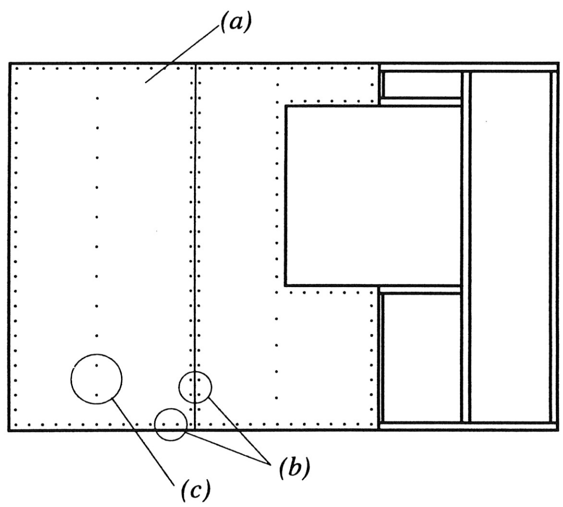

Figure 3 *Wind bracing with sheet material (NBI Building Details A523.251). (a) Panel sheathing, (b) nail spacing approx. c/c 100 mm along the edges of the panels, (c) nail spacing approximately c/c 200 mm along the middle of the panels.*

Internal walls

Internal load bearing and non load bearing walls may be constructed simply by using a stud frame lined on both sides with a sheathing material.

Separating walls

Separating walls are commonly constructed from two separate stud frame walls with a cavity between. Depending on the requirements for fire resistance and sound insulation, the cavity is filled with insulating material and one or more layers of adequate lining is applied.

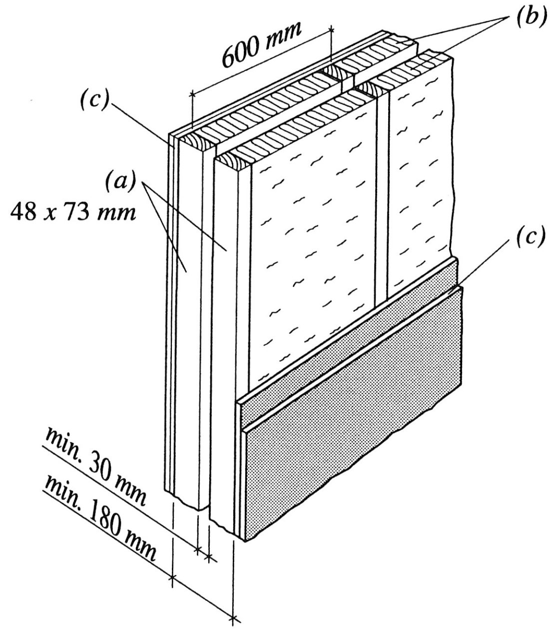

Figure 4 *Separating wall (NBI Building Details A 525.301). (a) studs 48 mm x 73 mm, (b) mineral wool, (c) lining.*

Floors

Floors are made of joists or I-beams with spacing 400 *mm* or 600 *mm*, with or without thermal insulation. On top flooring is applied and underneath ceiling lining.

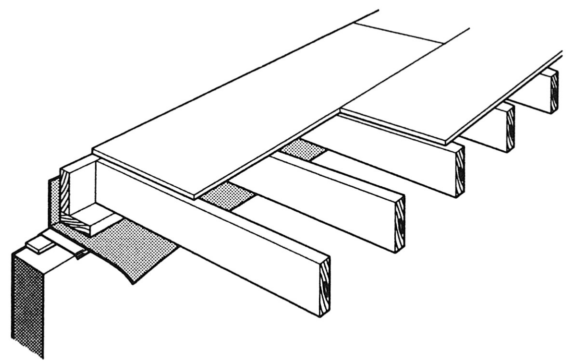

Figure 5 *Floor construction (NBI Building Details A 522.351).*

Intermediate floors shall be calculated with an imposed floor load of 1,5 kN/m^2 for one-family dwellings. In normal dwellings, it is not the need for load bearing capacity which is decisive for the design of wood joist floors, but the need for stiffness of the floor. A floor designed for a uniformly distributed load can give floor joists with such a span that deflection and vibrations will be unacceptable for normal use.

It is very complicated to decide what the acceptable stiffness for a timber joist floor is, as the acceptable level of vibrations and deflections is very individual.

Vibration may be experienced as jingling in cupboards, light furniture which moves and the feeling of vibrations by the inhabitants themselves. The Norwegian Building Research Institute (NBI) uses a maximum deflection of 0,9 *mm* under a point load of 1,0 *kN* as a design criteria for timber joist floors. The deflection depends on the flooring and ceiling linings load distributing and stiffening ability. An accurate calculation is complicated and special data programs have been made to calculate joist span tables (NBI 1990), table 1 and 2. Due to the consideration of vibrations, the capacity of thin-webbed I-beams and box beams can not be fully utilised. The point load criteria should not be used uncritically especially for long spans (> approximately 5 *m*).

In the serviceability limit states part of EC5 an investigation method for the vibration of residential floors is presented, see STEP lecture E11.

Roofs

Pitched roofs may be constructed using prefabricated or site-constructed trussed rafters or with traditional rafters and purlins.

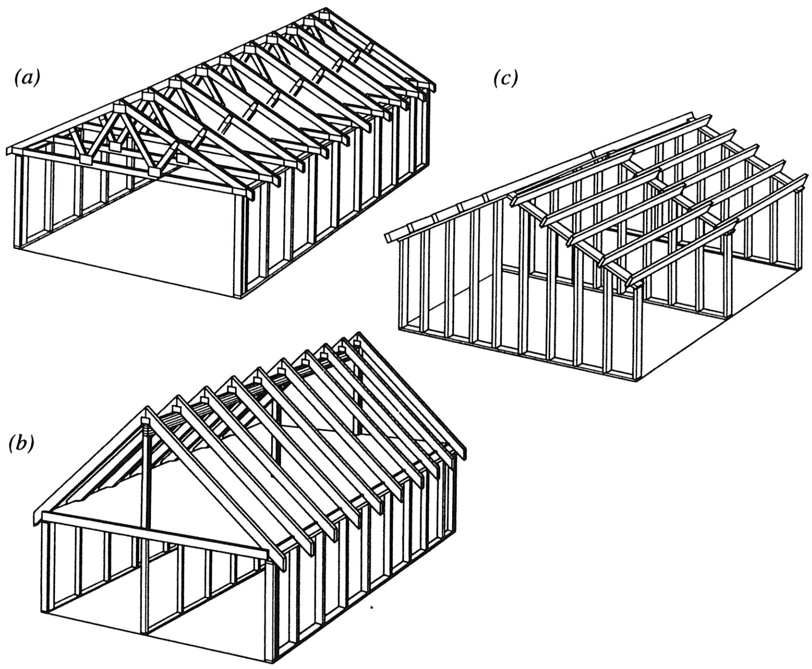

Figure 6 *Roof constructions (NBI Handbook 38 Timber Frame Houses). (a) Trussed rafters, (b) rafter roof, (c) purlin roof.*

Accurate calculation of trussed rafters is quite complicated and is usually done with specialist computer programs (see also STEP lecture B12). The manufacturers of prefabricated trussed rafters design these by the use of data programs and deliver them according to the purchasers specifications of load, roof pitch, span etc. For site-constructed trussed rafters there exist design sheets (NBI Building Details, TRADA Design Sheets etc.).

Traditional rafters with supports at each end are designed as simply supported beams across one span. When calculating the bending moment, any overhang should be ignored. The load bearing capacity of the overhang should be designed separately as a cantilever beam. The load sharing factor k_{ls} may be used for rafters and purlins with a spacing no more than 0,6 *m*.

EC5: Part 1-1: 5.4.6

When designing purlins, the fact that the load is applied at a slope to the cross-section must be taken into account. If the roof has panel sheathing providing diaphragm action, the load component perpendicular to the purlin height may be reduced slightly.

For steep roofs (pitches greater than about 40°) the combination of snow load and wind load may give the ultimate design load. For low rise timber frame houses, it is assumed that sufficient safety is obtained when the load bearing capacity for snow load and wind load is checked separately. Design sheets with tables for rafters and purlins exist (NBI Building Details, TRADA Design Sheets etc.).

Other components

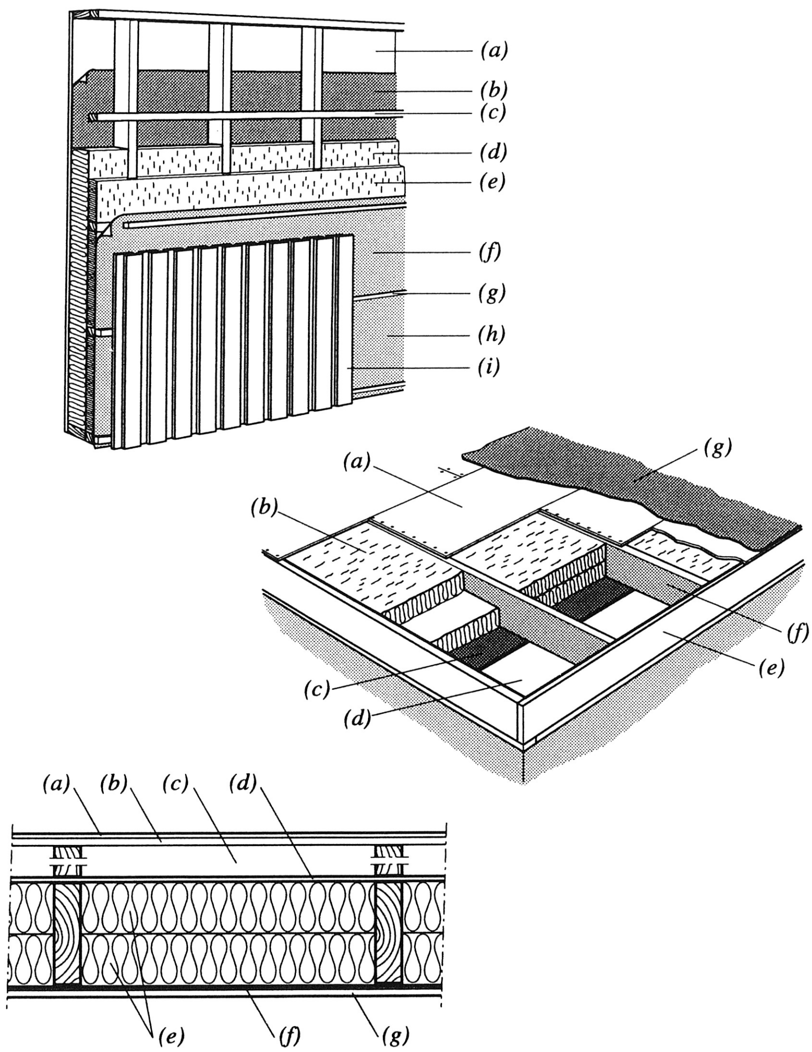

Figure 7 *Timber frame wall, floor and roof - components (NBI Building Details A 523.255, A 522.355 and A 525.100).*
Wall: (a) Internal lining, (b) vapor barrier, (c) furring strip, (d) mineral wool 100 mm (e) mineral wool 50 mm, (f) wind barrier, (g) batten, (h) ventilated space, (i) external cladding.
Floor: (a) Subfloor, (b) thermal insulation, (c) wind barrier, (d) ceiling, floor joist, (e) perimeter beam, (f) floor joist, (g) flooring.
Roof: (a) Roofing, (b) sheathing, (c) ventilation space, (d) wind barrier, (e) insulation, (f) vapour barrier, (g) ceiling lining.

Cladding

External cladding can be chosen from a wide range of materials, including brickwork, tiling, timber boarding or cement render. External cladding in Scandinavia usually consists of timber boarding, either vertical or horizontal. This is supported on counter or horizontal battens fixed to the studwork to provide a drained and ventilated cavity. This is to ensure that any water or vapour that has penetrated the cladding can evaporate or be drained away.

Wind barrier

The wind barrier must be strong enough to resist site and wind damage, be waterproof but allow the escape of any water vapour. Building paper or sheet materials are used as an external wind barrier. The material must to some extent be able to withstand the effect of moisture - also in the form of water. The most common products are:

- Asphalt impregnated breather paper,
- 12 *mm* bitumen-impregnated porous fibreboards with windproof coating,
- 9 *mm* plaster board with impregnated cardboard.

Thermal insulation

Thermal insulation requirements of the building regulations are achieved in timber frame construction by placing insulation materials in the walls, ceilings and floor cavities.

Most countries have experienced a strengthening of building code requirements concerning thermal insulation performance, and it may often be economical to insulate better than the minimum code requirements. Insulation thickness in walls is now 100 *mm* minimum as a standard for wood frame housing in most countries, while 150 *mm* and more is the norm in northern areas.

Mineral wool is the most commonly used insulation material, and used in the form of bats or rolls. Standard thicknesses are 50, 75, 100, 150 and 200 *mm.*

Vapour barrier

The importance of an airtight vapour barrier increases with better insulated low energy houses. Polyethylene sheeting has proved to be the most versatile material for vapour barriers, because it can overlap the critical joints between building components and is easy to install. Polyethylene sheets are often exposed to damage during construction, and thicker qualities (0,15-0,20 *mm*) are now commonly used.

The vapour barrier is placed on the warm side of the insulated wall and ceiling, directly behind the internal lining, to minimize the passage of air with high vapour content into the structure. Air with a high vapour content will condense when it is cooled inside the structure.

Lining

Internal lining materials may be wood panel, plywood, fibre board, particle board or gypsum plaster board.

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