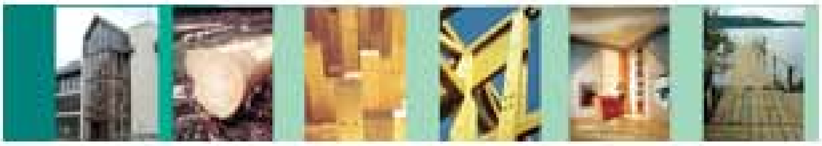


Building with wood

Modern Solutions for Wood Construction

A flexible engineering material

Using wood in building structures is nothing new. Throughout the ages, in those places where forests grow, wood has commonly been used as a building material. The international trade with timber also means that countries with limited availability of forest resources can nowadays have access to wood for building purposes, wood that comes from sustainable and certified forestry. Building with wood is energy-efficient, cost-effective and environmentally friendly.

Wood has many benefits as a building material when compared with other materials. Above all it has a low weight in relation to its strength and load bearing capacity. The material is "flexible" and can be worked and crafted with simple tools. On top of this, it is a renewable, biological material that is part of the natural eco cycle. In this way, the use of wood makes a vital contribution to the reduction of the earth's emissions of carbon dioxide.

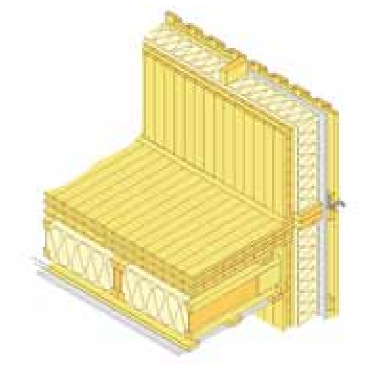
Wood constructions also have significant advantages in severe seismic zones.

Building techniques

Several common techniques are available for constructing buildings with supporting frameworks made of wood. One way is to use structural wood members to form a frame which is covered by structural wood panels. Foundations are generally concrete. This simple building technology is often used in the construction of single-family houses but also in the construction of multistorey buildings. Another technique is to use solid timber for the supporting framework. Cross-laminated boards are glued together and used to build walls and joists. The walls may need to be insulated to give the building a high level of energy efficiency. The technique is well suited to the construction of multistorey buildings.

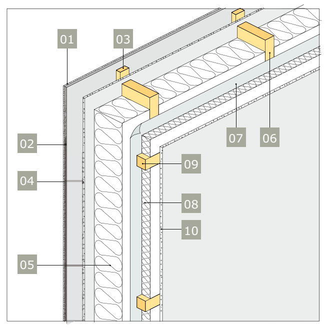
Yet another technique is the system of columns and beams. In this case cross-laminated timber in different forms is used to a large extent for the load-bearing construction.

All the named framework systems satisfy modern criteria for fire safety, noise pollution and energy efficiency. Special consideration to these functional criteria must be given in the case of multi-story buildings. Well-tested technical solutions are now widely available.

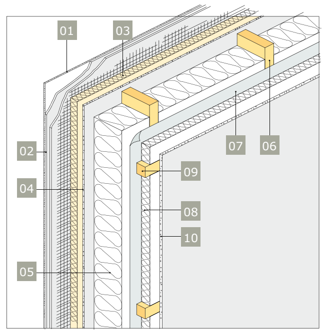


Cross laminated boards

Examples of outer walls with panelsheating and timber studs



01. Render 02. Fiber cement board 03. Nailing batten 04. Gypsum wallboard 05. Insulation 06. Vertical stud 07. Plastic foil 08. Insulation 09. Horizontal stud 10. Gypsum wallboard



01. Finishing render 02. Render with reinforcement net 03. Insulation 04. Gypsum wallboard 05. Insulation 06. Vertical stud 07. Plastic foil 08. Insulation 09. Horizontal stud 10. Gypsum wallboard

Building on-site

The building methods can vary. The oldest method is to construct the building on site. The building materials are freighted to the building site and the various elements – walls, joists etc. – are put together on site and then erected. The method requires a great deal of organization and planning on the building site. Risks associated with damage on material and prefabricated structural components, due to moisture must be overcome. Of necessity, on site construction tends to take a long time.

With the on site building technique, the wall components are generally assembled resting on the joists or the ground and then erected manually.

A wood framed construction

Off-site prefabrication

Far more common today is the prefabrication of various components; off-site building. Wall parts, floor components, trusses etc. are all built off site at a factory. The components can come prefabricated with insulation, installations, windows and doors. There is a trend towards a higher degree of prefabrication. The advantage of the technique is that the greater part of the building work takes place in an industrial plant in a well-controlled environment with approved quality assurance. The actual assembly of the building, up until the roof is laid, takes one or two days at the building site. At one extreme, entire units are manufactured at the factory and in these units not only are electricity, water and waste pipes installed but kitchens and wet rooms; floors are also laid and walls are papered.

Another advantage to building with prefabricated components in wood is that these are relatively light and can be erected at heights of several stories using simple lifting equipment such as mobile cranes, in some cases with the cranes fitted on the trucks that deliver the components to the site.

It is cost effective to build with wood. The costs for the wood frame is about 30-35 % lower than a concrete frame. The total cost is about 10-15 % lower for wood buildings. Using prefabricated modules, the total cost is 20-25 % lower. The time saving can be up to 80% and during the building phase CO2 emissions can be reduced up to 85%.

In Sweden, the market share for wood-framed multi-storey buildings has increased from 1% 2000 up to 15% today.

Prefabrication

Prefabricated modules

Single Family Houses

Wood frame is the most frequently used system for single family houses. It is also common for single family houses to be built using prefabricated components.

The construction method allows major variations in the design of the houses conforming to national and local building traditions while permitting architectural innovation. To a large extent the design determines the cost of the building and there are also variations here, from deluxe homes to extremely cost effective single family houses at prices that are acceptable to the average family.

The requirements for fire safety and noise pollution are usually lower for single family houses than for multi-story buildings. However it is harder to satisfy the demands for low energy consumption in a single family house.

Östra Kvarnskogen

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Multi-storey buildings

In many countries national building regulations have tended to restrict the use of timber frames for the construction of multi-story buildings. The reason many countries have refrained from using flammable materials is uncertainty about fires in the buildings.

However, extensive research and development has shown that material-neutral building regulations are preferable and for over a decade function-based regulations have been common in many countries. Wood as such burns, but it does so in a controlled manner. It is possible to estimate how much of the cross section will remain unaffected by the fire after one hour of burning and choose material dimensions so that the unaffected part of the cross section has the ability to bear the required load. Steel, on the other hand, loses its entire load-bearing capacity at the temperatures that occur during a fully developed fire. Non-flammable surface materials and/or sprinklers can be used to ensure safety during the early stages of a fire.

Modern building regulations have contributed to the increase, now taking place, in the construction of tall multi-storey timber buildings of between three and eight storeys. The dramatic increase can be attributed to several important factors. One factor is the lower cost of

Continue page 6

Wood burnes in a controlled manner and a cross section can be chosen so that the beam can bear the required load.

Photo by SP Trätek, Sweden, for the technical guideline Fire safety in timber buildings.

Continue from page 5

building compared with construction using other materials. Timber has shown itself to be the best material for use with industrial building methods, enabling costs to be reduced.

Another factor is the growing environmental awareness where the choice is motivated by the fact timber is a renewable material and that its use reduces CO2 emissions, provided that the timber is harvested in forests where sustainable forestry, with replanting and management plans, is practiced.

Another factor worth mentioning is the possibility of building on sites that with heavier buildings, e.g. those made of concrete, would demand extensive and expensive pile foundations. Formerly uncertain or impossible sites can thus be used for lighter timber constructions and therefore with simpler and inexpensive foundations.

The design in terms of horizontal stability is especially important because the construction is relatively light. A common practice for buildings with 6-7 floors is to build the ground floor in concrete and secure the timber structure to the concrete. The load from the wind is transformed via joist elements and shear walls to the ground. Good stability is achieved by utilizing diaphragm action.

An important consideration when designing multi-story buildings with a load-bearing wood frame is stability in relation to noise. Effective solutions are now available to prevent sound from spreading between the floors and apartments without putting the stability of the building at risk.

In the same way as with single family houses multi-story buildings made of timber can be given an outer architectural design that suits the location where the building is erected.

Seismic performance

Wood constructions advantages in severe seismic zones.

A survey was conducted following the tragic earthquake in China, May 2008. The evidence showed that wood frame buildings had outperformed buildings constructed from other materials. They suffered only minor damage, while many brick infill walls collapsed and concrete buildings suffered severe damage.

This has also been proven by tests; tests show multi-story hybrid structures can survive the most severe earthquakes[1]. A full-scale, seven-story mixed use condominium tower (six wood frame stories above a one-story steel structure) was tested in Kobe, Japan.

This was the largest full-scale earthquake test in the world. The building was subjected to a quake that was 180 per cent of the Northridge record at Canoga Park. It suffered no significant damage, demonstrating that wood buildings can survive even the strongest earthquakes.

There are solutions to reduce the impact from earthquakes. Shock absorbing is the latest technology for earthquake protection of bridges and building constructions. The figure shows an example of an anti-vibration devise – a panel with an anti-vibration unit – developed in Japan, for absorbing seismic energy in wooden constructions. When the force from an earthquake is hitting the construction, the energy is transformed via the panel to the shock absorber.

Misawa

[1] *Lentz, Shelby, Shaking it up – a test to improve mid-rise, wood framed building design, 2009. GoStructural.com.*

The full-scale earthquake test. Japan's massive E-Defense Shake Table, the largest shake table in the world

Curtain walls/Infill walls

In many countries infill walls made from timber are becoming an increasingly common solution, together with load-bearing frames made from concrete or steel. External walls of this type are designed only to take the load of the wall component's own weight and the wind loads that directly affect the component. The component has a low weight and can be prefabricated in a factory, which is a great advantage. Infill walls made of timber have very good insulation characteristics. The increasingly stringent requirements for energy efficient buildings in various countries are among the main driving forces behind the use of this wall solution.

The component can be clad with an external layer of plaster, brick, wooden paneling or other sheathing material in order to match the building's design and surrounding buildings.

There are two principally different ways of fitting timber frame elements into the steel, concrete or masonry structure. Either the panels can be fitted into or partly into the structure or outside the structure.

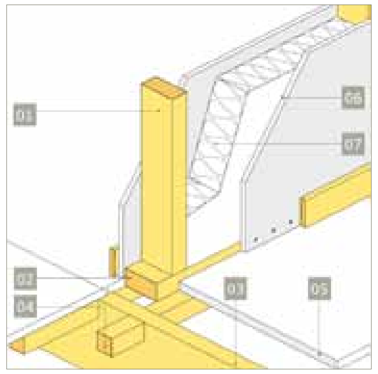
The primary benefits for the technique are

- Excellent thermal insulation properties are easily achievable
- The usable building area is significantly increased (as compared to a similar insulated building with masonry walls) because of lesser wall thickness
- Savings in on-site labour and construction time through a systematic off-site manufacturing process
- From an environmental (LCA) perspective, timber frame structures virtually always perform as best
- The in-fill timber frame wall panel technique facilitates a high degree of architectural possibilities of design and cladding materials.

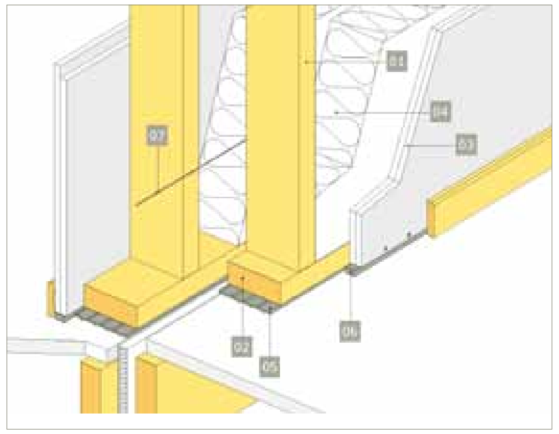
Wood infill walls in a concrete frame

Partition walls/Inner walls

Wood frame in combination with board material is a very common solution when it comes to inner walls that will not bear any loads. These walls are used for dividing up rooms but can also be designed so that they can cope with the fire and sound requirements placed on apartment partition walls.



Inner wall
01. Vertical stud 02. Sill 03. Floorjoist 04. Nogging piece 05. Chipboard 06. Gypsum wall board 07. Sound insulation



Partition wall
01. Vertical stud 02. Sill 03. 2 x Gypsum wall board 04. Fine insulation 05. Rubber gasket 06. Sound insulation 07. Net to hold fine insulation

Extensions

Timber offers great potential for changing and modernizing existing, older buildings which are often constructed from concrete. It is primarily a matter of extensions to roofs and stories.

The simplest method is to fit the old building with a new roof designed so that a number of apartments can be built into the attic space. The space can also be used for placing installations for improving energy efficiency and heat exchangers for ventilation.

As timber structures are light there are often margins for building additional stories. In such cases, the use of prefabricated components is often suitable. Naturally the design must be verified so that there is a margin for absorbing the additional vertical loads and ensuring horizontal stability.

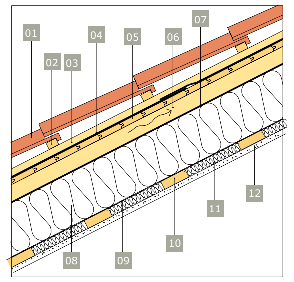


Diagramme of roof construction
01. Roof tile 02. Batten 03. Counter batten 04. Roofing felt 05. Tongued and grooved timber 06. Air gap 07. Masonite board 08. Insulation 09. Plastic foil 10. Secondary spaced boarding 11. Insulation 12. Gypsum board

Three additional storeys added to an existing concrete building

BUILDING WITH WOOD

Case-studies

There are both economic and environmental advantages building with wood. For multi-storey buildings, the construction period can be reduced up to 80% and the CO2 emissions up to 85% using wood.

Comparative research shows that using timber-framed constructions in buildings instead of a concrete or brick one is good for the climate. See examples from some case studies:

Austria

Building ground with 12 housing units: timber buildings storage 300t of carbon while brick buildings produce 54t of carbon emissions.

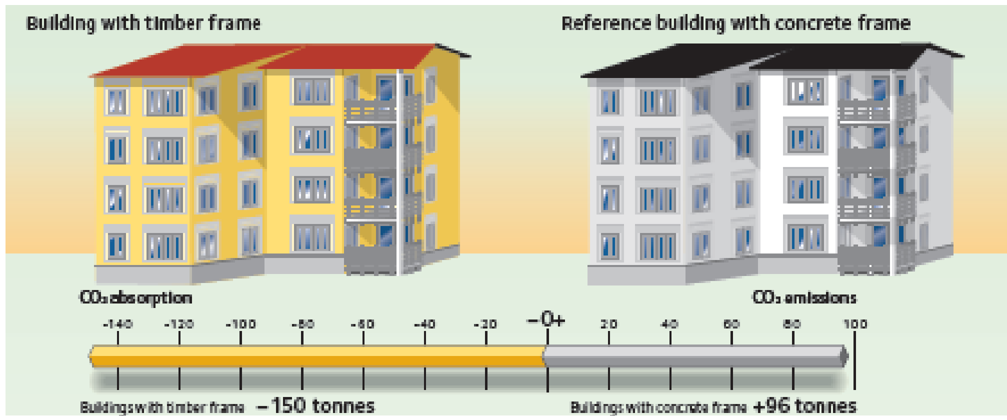
Building with 42 housing units: timber buildings storage 1.205t of carbon while concrete buildings produce 385t of carbon emissions.

Source: Dr. Erich Wiesner, Fachverband der Holzindustrie Österreich „Wood construction securing the future of the woodworking sector", CEI-Bois-European Wood Industry Leaders round table, October 2011.

Sweden

The carbon balances for two otherwise identical houses, one with a timber frame and the other with a concrete one, have been compared over a 100-year period.

The timber frame house storages 150t of carbon while the concrete frame building has produced 96t of carbon emissions.



Source: Skogsindustrierna, "The Forest Industries-A natural part of Sweden", 2008.

United Kingdom

Murray Grove (London), a nine storey residential building made of cross-laminated timber is currently the world's tallest modern timber residential structure. For erecting the structure frame it only took 24 days with a team of 4 professionals.

The building storages 188t of carbon in structures. A similar concrete building would have produced 124t of carbon emissions.

Source: KLH

Source: Stora Enso

Bridport House (Hackney, London), an eight-storey residential building finished in September 2011, constructed entirely from CLT. Had the building been of conventional reinforced concrete frame, the materials required would have incurred an additional 892t of carbon. This is equivalent to 12 years of operational energy required to heat and light all the dwellings at Bridport House; alternatively it would take 61 years to save the same amount of carbon as the planning requirement of 20% renewables.

And when the sequestered carbon locked up in this 1576m³ m timber structure is added to the carbon avoided, the total figure is 2113t of carbon and this is equivalent to 29 years of operational energy, or with 20% renewable energy, it would take 144 years to save the same amount of carbon.

Skogs Industrierna
SWEDISH FOREST INDUSTRIES FEDERATION