Challenges in timber construction

Herausforderungen im Holzbau

Les défis pour la construction en bois

Sfide nella costruzione in legno

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Multi-storey wooden houses in Sweden – Technical data

A number of major wood construction objects built within the framework of the Swedish National Wood Construction Strategy have been studied in detail with respect to construction techniques, planning and execution. The work has been carried out within the Continuing Training Programme. This document is a summary of the technical aspects.

1. Swedish National Wood Construction Strategy and its Continuing Training Programme

In 2006, the Swedish government appointed the National Wood Construction Strategy Committee, with the primary task of promoting the use of wood in apartment houses and public buildings. It is based on analyses carried out by the Swedish Ministry of Enterprise, Energy and Communications /ref 1/. A number of measures have been implemented within the framework of the strategy, including continuing training for those actively involved in the construction sector and "initiative projects" involving the construction of multi-storey buildings in the towns of Växjö, Falun and Skellefteå. In addition, joint action projects have resulted in the construction of buildings in several locations. In parallel with this, the timber industry is taking action through the Swedish Wood Construction Council. The two organisations have held a number of seminars and inspirational days throughout Sweden.

Picture 1: Wall unit on its way at Hyttkammaren in Falun

The National Wood Construction Strategy came to an end in December 2008. It is, however, continuing to operate under the name Wood City 2012, a project which will involve further municipalities and regions.

The Continuing Training Programme has been implemented jointly by Luleå University of Technology, Växjö University, Högskolan Dalarna College and SP Trätek.

This programme has been carried on in close collaboration with major wood construction projects in Skellefteå, Falun and Växjö, for the purpose of

- monitoring and recording several aspects of wood construction projects, including residential quality, planning and decision-making process, technical/functional solutions, aesthetic aspects, the environment and lifecycle targets, management and lifecycle economy, as well as wood system suppliers
- making presentations and drawing conclusions at seminars held in connection to the construction project and at specialist workshops
- ensuring the availability of records and information
- providing a natural tie-in with education and research at universities and institutes
- creating the basis for the development of strong supplier groups in the wood construction sector.

The Continuing Training Programme has been supervised by Lars Stehn, Luleå University of Technology.

Picture 2: Assembly of floor structures at Limnologen in Växjö

2. Multi-storey wood buildings in many locations

Joint action projects were set up with links to the National Wood Construction Strategy and the Continuing Training Programme. These construction projects were carried out throughout Sweden and included both modular wood-framed houses and wood-framed houses built on-site. The Continuing Training Programme recorded and analysed these joint action projects with reference to

- Technical and financial data on the project
- Project background and client motivation
- Procurement and types of contracts
- Planning methods and experiences
- Technical solutions and performance of wood construction systems
- Wood house architecture: form, function and aesthetics

A total of 15 wood construction projects, 3 initiative projects and 12 joint action projects were documented. For a full account, see the final report /ref 2/. These projects primarily involved the construction of homes: 3–8 storey buildings throughout Sweden, from low-cost to exclusive projects. Some special buildings were included, e.g. the Acusticum concert hall in Piteå. One project was the Q-med industrial plant in Uppsala, and another was a restoration project, but *no* offices were included.

2.1. Technical data for construction projects

The task performed by SP Trätek within the Continuing Training Programme was primarily to document the technical properties of the buildings. For this purpose, we developed checklists for the technical data of the various stages of the construction process. The checklists included the following

A *Documents and information relating to the building*

1. Construction documents
2. Information relating to the building

B *Technical functions*

1. Stability
2. Fire safety
3. Noise, vibration
4. Durability
5. Ease of construction
6. Moisture resistance
7. Deformations
8. Air tightness, heat insulation
9. Energy
10. Indoor environment

Technical data collected through the checklists have been recorded and reviewed in separate reports for four buildings:

– The Limnologen block in Växjö, four 8-storey residential buildings /ref 4/
– The Rya block in Rydebäck, Helsingborg, 5-storey residential building /ref 5/
– The Hyttkammaren block in Falun, 4-storey residential building /ref 6/
– The Älvsbacka block in Skellefteå, 6-storey residential building /ref 7/

SP Trätek has also carried out a comparative study of the Limnologen and Rydebäck blocks on behalf of the Swedish Forest Industries Federation /ref 3/.

Picture 3: Limnologen in Växjö consists of four 8-storey high residential buildings

Picture 4: Rydebäck in Helsingborg is a 5-storey residential building

Picture 5: Älvsbacka strand in Skellefteå is a six-storey residential building

Picture 6: Hyttkammaren in Falun is a 4-storey residential building

2.2. The progress of wood construction

Sweden has more than 13 years' experience of building tall, wood-framed residential buildings. The development of technology and methods is continuing rapidly, and new construction systems using wood as a frame material are being introduced. At present, there are reference objects throughout Sweden, where modern wood construction techniques can be studied and assessed.

Low weight and high load-bearing capacity have, in combination with environmental benefits, made wood one of the most important system-bearing construction materials in the current industrialisation of the construction sector. Increasing prefabrication of flat elements and volume units is reducing construction times drastically, and weather protection facilitates dry and moisture-proof construction.

2.2.1. Trends in multi-storey wood buildings 1995–2008

During the first decade, trends were largely characterised by

- initial traditional timber framework
- introduction of new framework systems, primarily solid wood systems and volume elements
- increased prefabrication
- improved and increased use of weather protection
- new players entering the market
- increased technical expertise among wood building suppliers.

Construction methods, stabilising and floor plans characterised by

- blend of volume and two dimensional elements
- increased degree of finishing of installations and surface finishes
- small local organisations on construction sites
- improved planning at an earlier stage in the construction process
- alternative fastenings between floors
- greater respect for the foundation and the location of walls and openings.

2.2.2. Organisation

Initially, nationwide contractors tried to find new construction methods, incorporating, among other things, influences from other countries. The result was a number of individual objects without long-term goals for further development of the technology. The entry of wood house manufacturers and material suppliers on the multi-storey building market led to long-term investment in multi-storey wood houses and improved assimilation of experiences. The material suppliers and wood house manufacturers have taken an increasing share of the total number of contracts. Partnerships with subcontractors have been established or integrated into the existing organisation.

2.2.3. Cost of foundation

With wood construction systems, the load on foundations is reduced by 30–50 %. There are two dominant alternatives for improving poor ground conditions: pile-driving and stabilisation of foundations. In Sweden, the most common method in poor ground conditions is pile-driving. By using lightweight material in the frame, the load on the foundation can be reduced. This generates significant savings, but for lightweight buildings, the reduced load may mean that the minimum number of piles is below the optimum, which means that the savings are not as great as expected.

Stabilisation of foundations through compensated foundations, lime stabilisation or other reinforcement methods may be of greater financial interest for future multi-storey wood buildings.

2.2.4. Production benefits

During the production phase, a wood construction system offers a number of benefits:

- Reduced freight costs for prefab deliveries
- Reduced hoisting costs and rapid assembly
- Reduced costs for alterations and supplementation
- Stable substrate for installation of pipes and cables, as well as straight-forward installation methods
- No cost for drying out

– Suitable construction method for winter construction
– High load bearing capacity

2.2.5. Demolition costs

The cost of demolishing buildings may seem rather irrelevant since this is something which will only happen at a much later date. The normal life of a newly-erected building is usually set at 50–70 years in Sweden. In other markets, however, buildings are regarded as consumables, with an average life of 26 years (Japan). This means that the cost of demolition and disposing of the demolition waste is of much greater significance. With today's complex designs, the sorting of demolition waste can be difficult (and extremely costly). The removal of sheet materials fastened with screws and the exposure of insulation leads to significant expenses. The aspiration is, therefore, to make designs as homogenous as possible and to ensure that every layer can be detached from the substrate as easily as possible. Concrete walls with external insulation and no joists are, from this point of view, an excellent design. On the other hand, the cost of demolition and crushing of concrete material is high. With a solid-wood system, the low cost of disposal of the joist construction can be combined with the low cost of exposing the insulation of a concrete framework.

Picture 7: Weather protection with assembly platform at Älvsbacka strand in Skellefteå

2.2.6. Environment/recycling

Wood is the only large-scale construction material which is renewable, produced locally and able to capture carbon dioxide. The increased use of wood construction can, therefore, contribute to an improved global climate. The relatively large quantities of lumber which make up a solid wood system can be recycled and require little processing energy. With a solid wood system, the number of different materials included can be reduced which facilitates recycling. Wood is a construction material which can often be sourced from local suppliers.

So far, the environmental impact of three different types of frameworks has been compared – solid wood , timber joist frame and concrete framework. With respect to greenhouse effect, acidification and overfertilisation, the environmental impact of the two wood-based framework alternatives is lower than that of the concrete alternative studied. A choice between the two wood alternatives requires an inventory of the whole life of the building. The environmental impact of wood can be reduced further through improvements to incineration and drying methods.

It is difficult to put a monetary value on environmental benefits. There is, however, no doubt that the time has come for an increased emphasis on environmental concerns and that these will increase in value. The demand for "eco-houses" is growing both in Sweden and abroad.

2.3. Key ratios for industrial wood construction

As yet, there are no or few key ratios which assess different technologies and methods in industrial wood construction. SP Trätek has, therefore, started to analyse how such key ratios can be defined and applied, both in relative comparisons between different construction projects, framework systems, construction methods etc., and as guidelines in the planning, construction and management processes. In the long term, key ratios can also be used to compare wood construction techniques and other construction techniques.

The study is limited to technical key ratios for apartment buildings. It covers key ratios related to housing, design and production, e.g. construction quality, energy consumption, foundations, horizontal stabilisation against wind pressure, fire safety, soundproofing, prefabrication level and durability of the exterior. The aim is to define key ratios in such a way that they highlight differences in the choice of method and functional solutions, and are so unambiguous that they guarantee the accuracy of the comparisons.

2.4. Further development potential and future trends

We see the following opportunities for continued development and future trends

- Prefabricated stairwell modules and roof units
- Players forming partnership and taking increasing responsibility for planning and contracting
- They can also accept the role of project developer
- Opportunities for improved and systematic feedback on experiences
- Turnkey planning at an early stage (3D CAD and 3D visualisation)

2.5. Some insights and conclusions from the construction project

It is of the utmost importance that all the players involved in the project take an active part and contribute to the development of wood construction technology and systems. Large-scale wood construction is a new area, and is currently in the introductory or early growth phase. In these phases, technology and systems continue to undergo rapid development, and many of the players on the market have limited knowledge and experience of existing products. There is only a small number of suppliers, but this is on the rise. Player roles and business models are still developing. This is what makes wood construction different from more conventional construction methods.

Every construction project involving new technology and new systems will be a learning project. This means that all players must collaborate in the areas of project development and implementation. Successful projects must be organised in such a way that the players (landowner/municipality, principal, architect, systems supplier, fitters, design engineers) work together right from the programme and planning stage.

There is a great need to document and ensure feedback from experiences in the areas of construction systems, assembly methods and management to improve next-generation technologies and systems.

Uncertainties regarding technologies and methods may require framework suppliers to accept a greater commitment to the project, e.g. to take responsibility for the erection of frameworks in addition to the supply of components. Uncertainties regarding technology require design engineers and architects to demonstrate a greater level of preparedness and flexibility throughout the project.

It is difficult to achieve benefits of scale for all new technologies and systems in an early phase. This applies equally to the wood construction technology. The competitive tools of the sector are flexibility, quick learning and continuous development, and this requires collaboration among all the players involved in a project.

Issues specific to major wood construction projects include:

– *Fire requirements* have taken a long time to solve in the initiative project. The impression is that the authorities involved are not used to interpreting legislation as it applies to higher wood-framed residential buildings. Another impression is that the application of the law varies throughout Sweden. It may, for example, be extremely difficult to build with visible wood in apartments, even if the apartments are fitted with sprinkler systems.
– *Soundproofing* is another issue which requires further research to ensure a high-quality living environment.
– *The cost of facade maintenance* throughout the lifecycle in relation to the cost of investment requires further monitoring. There is a risk that short-term decisions will create additional costs in the long term.
– *Installations* should be integrated into the framework. A higher level of prefabrication has been requested to avoid extensive subsequent installation work at the construction site.
– *Weather protection* should be specified at the planning stage and quality assured with flexible protection. Experience shows that protection by tents with overhead travelling cranes is of great benefit not only for dry construction, but also to the work environment. The speed and ease with which the height can be increased is extremely important.
– *The number of floors* in the building should be defined rather than the height of the building in metres, to prevent any uncertainty in relation to the thickness of the floors elements.

3. Further reading

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