# Limnologen – Experiences from an 8- storey timber building

## Limnologen potpourri – Praktische Erfahrungen von 8-geschössigen Holzhäusern

## Limnologen potpourri – Expériences pratiques: immeubles en bois de huit étages

## Potpourri limnologico – Esperienze pratiche con case in legno a 8 piani

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## 1. Background and introduction

### 1.1. Välle broar – Limnologen – Modern timber construction[1]

The town of Växjö is situated in southern Sweden, approximately 200 km northeast of Malmö, and approximately 230 km southeast of Gothenburg. In Växjö the area between two lakes "Trummen" and "Växjösjön" is called Välle Broar. This area was for a long time somewhat overseen in planning, due to its location between the Town Centre and the suburban Teleborg area. About 2002 this changed when the municipality of Växjö, in order to develop a town planning strategy, announced an architect competition.

Already at a very early stage, when the architects' contributions where received, the parties involved felt that the area should be used for projects using timber construction. The great interest in wood and timber available in the region, led to the municipality starting to work with a local timber construction promotion strategy. This strategic work drew the attention of the Swedish parliament, leading to a similar strategic work being initiated – and eventually finalised – on a national scale. The aim with the national timber construction promotion strategy was to increase the R&D efforts within the field and to increase the amount of timber and wood based products used in construction. After a 120-year period of prohibition there was a need for giving timber a chance to compete with other building materials (concrete and steel). Such efforts could, if successful, also lead to increased profits for the wood-based industry by increasing their market shares in Sweden, but also abroad.

In Växjö, the work with the local strategy continued and resulted finally in 2005 in a programme called "More wood in construction" ("Mer trä i byggandet"). The local strategy is closely connected to the Välle Broar area, and it states that in *all* construction, wood should be *considered* as one alternative. Within Välle Broar, all construction realised *must* be based on the use of timber or wood based products. This was motivated by the following facts:

- Växjö is situated in a region dominated by large forest areas and by companies within the wood-working sector. A large number of smaller towns within the region and the rural areas are dependent of this industry. If Växjö can contribute to the development of this industry both the community and the industry would benefit.
- Promoting the use of timber in construction is in line with the environmental policies set by the municipality of Växjö.
- Realising projects based on modern, industrialised timber construction, would draw the attention to Växjö, giving the town a clear profile
- Wood-related research is one of the focus areas at Växjö University. Thus, the municipality of Växjö and the university can support each other.
- The municipality of Växjö is a large property developer and building owner, and thus has a clear interest in reducing building costs.

The Välle Broar project started in autumn 2006, and is planned to run for at least ten years, finalising one or two building projects every year. Välle Broar is a good example of what the academy, the municipality and industry can realise in a joint effort. The Välle Broar programme has drawn a considerable amount of attention from all around Sweden, but also from abroad.

[1] The text is based on [3], [4], [6] and [11].

The first building project being realised within Välle Broar is the construction of the tallest timber building ever built in Sweden in modern times – Limnologen. Limnologen consists of four eight-storey houses, seven timber storeys on a concrete foundation and concrete first floor. The company Midroc Property Development owns the project, which apart from the 134 apartments also consists of a parking deck and community facilities.

The Välle Broar programme is open for those who are interested in developing timber construction. Every building project being realised will be open for R&D activities, making it possible for universities and research institutes to perform research during a long time. In addition, the research can include all parts of the building process from town planning to real estate management.

## 1.2. The documentation and evaluation project

This article, which is an excerpt from [14], gives a short overview of the Limnologen project, and on the content of the different research and information activities that have been performed at Limnologen[2]. The Limnologen building project has given an important - and unique – opportunity for full-scale development of timber construction. The Limnologen project has also been followed by The Educational Programme of the National Timber Construction Strategy (Nationella träbyggnadsstrategins fortbildningsprogram). By being able to offer such full-scale R&D, evaluation and documentation, Växjö plays an important role in Sweden – and Europe – for the development of modern multi-storey timber construction. Similar R&D efforts are foreseen for the upcoming building projects at Välle Broar.

## 1.3. Limnologen – Short facts

### 1.3.1. Structure

The load bearing structure consists of CLT-elements (Cross Laminated Timber), delivered by the company Martinsons Byggsystem. The CLT is used in both walls and floors. In addition, traditional timber framed walls are used in some walls (those separating apartments). The bottom floor is made of concrete; mainly due to the increased self-weight thus facilitates the anchoring of the above storeys.

The relatively complex geometry of the Limnologen buildings, means that it is far from optimal for the building system used.

Since also inner walls are used for stabilisation, but at the same time an open floor plan is desired – it is of utmost importance that the dialogue between the architect and the structural engineers works well. All exterior walls are parts of the load bearing system. Some of the vertical loads are also taken by interior walls. The stabilising system consists of, the exterior walls, the floors and the apartment-separating walls. The horizontal loads are transferred by the floors - acting as stiff plates – to the top of the walls. In some parts of the buildings, glulam columns and beams have supplemented the load bearing system in order to reduce the deformations.

### 1.3.2. Stabilisation

In order to handle the lift-up as a result of wind loading, 48 tie rods have been mounted in every building. These tension rods are anchored in the concrete of the first floor, and extend all the way up to the top floor – inside interior walls. In this way the force is transferred between the storeys and down to the foundation. This design means that load-transferring connectors between the wall elements are not needed. The tension rods must be re-tightened after some time due to relaxation in the steel, creep deformations in the woos and due to possible drying of the wood.

[2] The final report of the documentation project is available in fulltext via the library of Växjö University. http://vxu.diva-portal.org/smash/get/diva2:234455/FULLTEXT01

### 1.3.3. Fire

The Limnologen complex is equipped with residential sprinklers. This is not needed according to the Swedish legislation, but it has made it possible to use designs that would otherwise not been possible. As examples, the south façade is made of wood, the vertical distance between the windows on the north-west façade has been minimised and the wooden surface of the CLT-slabs of the balconies are visible from below. These redesigns are possible since it can be shown that the total fire safety of the building sufficient.

The requirements of the legislation on fire safety are independent of the material used in the load bearing structure. Since the buildings are of more than three storeys they are classified in class BR1, a class having the highest requirements. The apartments are separate fire cells, and are according to the Swedish building code designed in class EI60, the only exception being a pram storage room on the first floor which is classified as EI30.

### 1.3.4. Acoustics

Acoustics in large building with timber based floor systems could be a problem. Examples of this include the risk of flanking transmission and impact sound transmission.

Already at the very early stages did the property developer put forward the demand that at least sound insulation class B should be achieved. (Class B means R'w + C50–3150 ≥ 57 dB och L'n,w/ L'n,w + Ci,50–2500 ≤ 52 dB). The larger apartments (i.e. those having more than two rooms+kitchen) have one room that is especially sound insulated, the master bedroom. The bathrooms are also especially sound insulated.

Martinsons has some experience with the current building system from a previous project in Sundsvall ("Inre Hamnen"). In that project it has been shown that the acoustic requirements are well fulfilled. The walls are not continuous across storeys, in order to reduce the flanking transmission. Also the floor slabs are discontinuous. A polyurethane sealant, Sylomer® och Sylodyn®, is used between the walls and the flange of the floor elements. The screws and washers used to connect the floor and wall elements are also fitted with Sylomer® to reduce the sound transmission. Figure 1 shows an example of a connection used in Limnologen. Note that both the wall and the floor elements are discontinuous through the joint area. Figure 1 also shows a tie rod, which is part of the stabilising system as mentioned above.

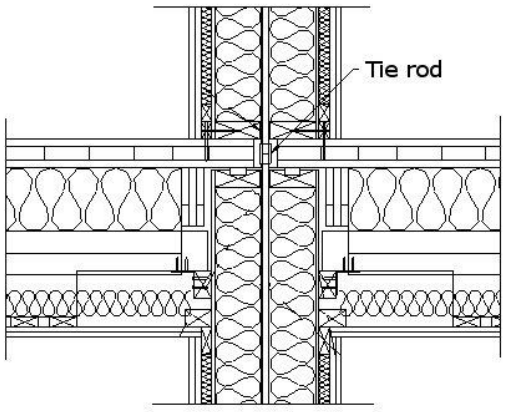


Figure 1. Connection between interior wall and floor (Martinsons)

### 1.3.5. Moisture and weather protection

It is of utmost importance that the complete building process is moisture proof, including all events from manufacturing at the production plant, transportation to the erection and finalisation on site. The wall and floor elements are manufactured indoors, and are stored before being transported to Växjö. The wall elements are wrapped in plastic film, covered by a tarpaulin for transportation and transported in vertical position with open trucks. The floors elements are covered by tarpaulins, stacked one on another and are transported with covered trucks.

Unloading on the site is done using a forklift, and the elements are put on the ground without any additional covering until being moved to the lifting zone for assembly. The weather protection system being used involves a large tent with an integrated overhead crane, a system that has been a prerequisite in the project. The crane has a maximum capacity of 3,3 tonnes (the maximum weight of an element is 2 tonnes).


Figure 2. The weather protection system with integrated overhead crane (Photo by J. Vessby, June 2007).

### 1.3.6. Installations

Most of the installations running in the lengthwise direction of the floor elements are installed already at the production plant. Installations running across the elements are mounted on sites. The installations are for ventilations, water, electricity and sprinklers.

### 1.3.7. Walls

Three main wall types are used in Limnologen for the load bearing structure. These are (a) exterior walls of 3-layer CLT, (b) apartment separating timber framed walls and (c) 3-layer CLT interior walls, see Figure 3. The façades are either plastered or covered by wood panels. All walls are finished on site by being covered with gypsum boards.

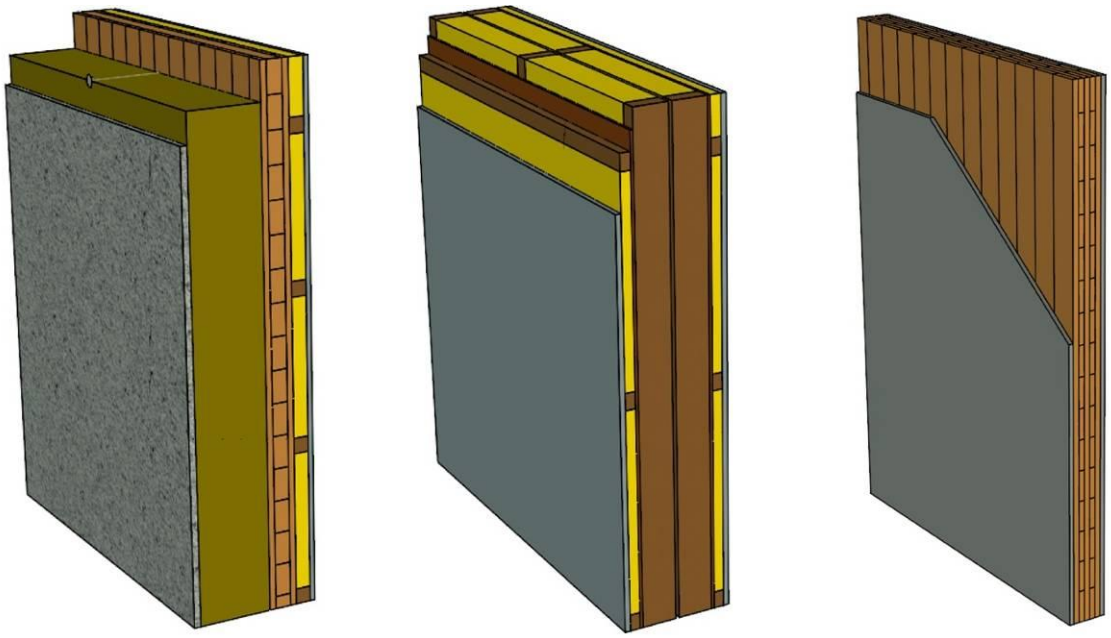

Figure 3. Exemples of (from left to right) exterior wall, apartment separating timber framed wall and interior partition wall within an apartment (also stabilising).

### 1.3.8. Floor structure

Every floor consistis of a total of 30 floor elements. All storeys are equal in plan, except for the top storey. The 30 elements per storey are all different, however. The load bearing part of the floor element consists of a 3-layer CLT slab strengthened by T-shaped glulam beams, which are fully interacting with the top slab. The glulam beams are placed with a distance of 600 mm, see Figure 4. At delivery to the site the floor element includes parts of the installations, see description above, and parts of the insulations and the self supporting ceiling.

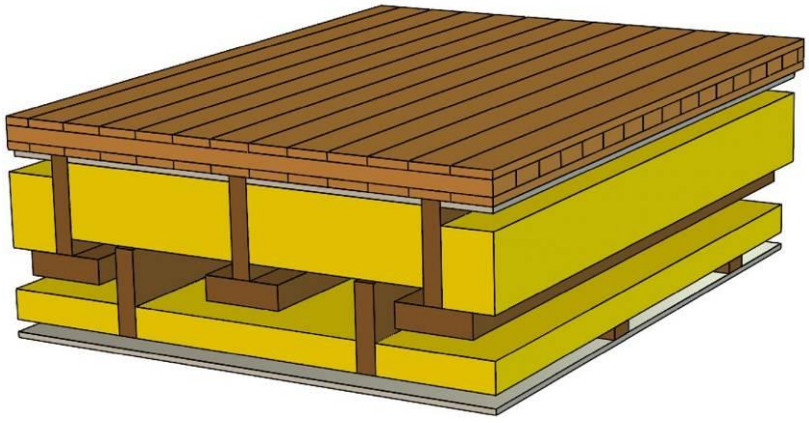

Figure 4: Floor elements used at Limnologen

At Limnologen a floor heating system is used (water based). The floor has pre-cut grooves in the lengthwise direction of the floor elements for the heating tubes. These grooves are finished with additional cuts made at the site to make it possible to fit in the tubes, se Figure 5. In each apartment the central is placed in a small wardrobe-like room.

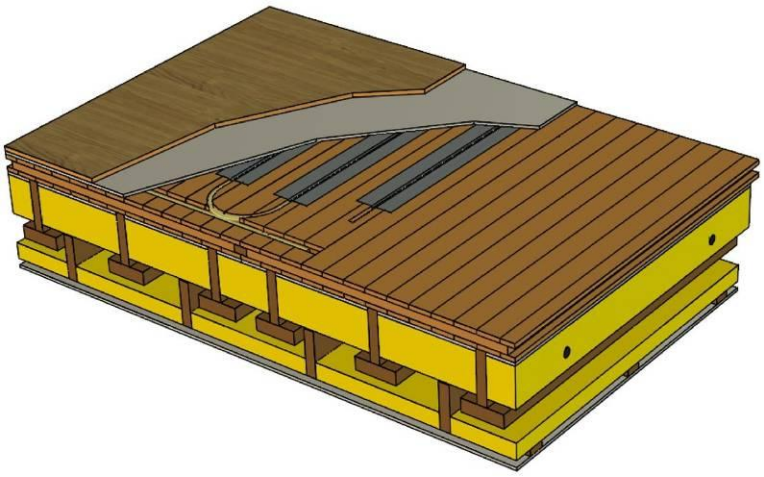

Figure 5. Floor heating system

### 1.3.9. Finishing and management

The first two buildings at Limnologen were finished during spring and early summer 2008. The second stage containing the last two buildings, were finished in the summer 2009. The buildings are owned by the tenants, who form a tenant-ownership community.

The heat and water consumption is being measured individually in each apartment. Each apartment owner has access to a private web-page for the monitoring of the consumption. It is expected that the energy consumption will be less than 90 kWh/m2 (per year) and that the individual monitoring will result in up to 30% reduction in energy consumption.

Figure 6. Limnologen, 3 of 4 buildings. Photo by K. Jarnerö, April 2008

### 1.3.10. Facts and figures

| | | |
|---|---|---|
| Number of buildings | 4 8-storey buildings | |
| Number of apartments | 134 apartments | 6 1 room+kitchen, 40 2 rooms+kitchen, 44 3 rooms+kitchen, 28 4 rooms+kitchen and 16 two-storey apartments with 3 – 5 rooms+kitchen. |
| Apartment sizes | 37 – 114 $m^2$ | |
| Total area | 10.700 $m^2$ | |
| Type of ownership | Tenant-ownership | |
| Production cost | 320 MSEK | Includes parking deck (timber) for 140 vehicles, community buildings and storage facilities. |
| Cash investment (for tenants) | 16.500 – 21.400 SEK/m2 depending on apartment | |
| Annual fee (rent) | 640 – 740 SEK/m2 and year depending on apartment | |
| | | |
| Builder | Midroc Property Development with Midroc Projects AB as main contractor | Project manager: Anders Persson, Midroc Projects AB |
| Architects | Arkitektbolaget Kronoberg | Architect Ola Malm |
| Structural engineers | Martinsons Byggsystem (timber)<br>Tyréns (concrete) | |
| Ventilation and sprinklers | Martinsons Byggsystem | |
| Subcontractors | Project manager | Thord Ljunggren |
| | Site management | NCC Construction<br>(until 13 september 2007) JSB John Svensson Byggnadsfirma (from14 september 2007) |
| | Ground works and piles | Älmby Entreprenad |
| | Foundation and concrete | NCC Construction |
| | Timber frame incl. assembly<br>- Subcontractor timber frame<br>- Subcontractor weather protection | Martinsons Byggystem<br>- NCC Construction<br>- Hallbyggarna Jonsereds och Industriteknik |

| | | |
|---|---|---|
| | Additional interior work | JSB, John Svensson Byggnadsfirma |
| | Electricity | Hallabro Elektriska |
| | Ventilation | Nalo Ventilation |
| | Plumbing/sprinklers | NVS Installation |
| | Sheet metal works | Kronobergs Förenade Plåtslageri |
| | Plastering | Karlssons Fasadrenovering |
| | Painting | Kumlins måleri |
| | Flooring | Entreprenadgolv i Växjö |
| | Roofing | Tak Rekond |
| | Lifts | Alt Hiss |
| | Autmation | ByggnadsAutomation |
| Total building time | Approx 17 months per stage | |
| One storey erection time | 10 days | |

# 2. The Documentation Project

## 2.1. Aim

The primary specific aims of the project have been to:

- to follow and document the building project by taking pictures, doing time studies etc, with respect to environmental aspects, moisture protection, deformations, acoustics, stabilisation, transportation and logistics etc.,
- contribute to the quality assurance of the Välle Broar related projects, by documentation of errors done and problems encountered,
- contribute to the development of modern timber construction including the building process,
- study the economic effects of choosing timber in construction, and,
- organize for the information activities needed in connection with the many technical visits to Välle Broar being realised.

In general terms, the aims are to:

- continuously deliver knowledge to the organisations involved in construction at Välle Broar, and to other national or international organisations that show an interest.
- create a dialogue and fruitful climate in the exchange of ideas and results between the researchers and the builders at Välle Broar, and also for other building projects in Sweden and in the Nordic countries.

## 2.2. Contents – Background and overview

The idea of performing a documentation project was put forward when the formal start at the building site of the Limnologen project took place. The general idea has been that by following and documenting the building project, the parties involved in the building project will gain knowledge: knowledge about construction in general, and about multi-storey timber construction in particular.

The following questions were identified as being of special interest:

- What can be improved in the building process and in technical solutions?
- How does the currently used building system compete economically with other previously used building systems (timber based and others)?
- What are the attitudes towards timber construction among the end-users?
- What are the environmental impacts of choosing timber and does the choice of timber contribute to the creation of a sustainable society?
- What are the main concerns in terms of managing a multi-storey timber building?

Taking into account the limited financial and human resources available, and taking into consideration that the project has been performed in parallel with the building project itself, it has not been possible to address all the above questions. Thus, the following areas have been considered in the R&D project:

- **Planning:** Documentation of suggestions put forward and decisions taken during the early stages of the planning and building process.
- **Quality:** Documentation of errors committed and problems encountered.
- **Technology, energy and environmental aspects:** Inventories of the technical and environmental performance of the different solutions chosen. This includes e.g. mounting different measurement devices to monitor performance during service life.
- **Economy and market aspects:** Customer perceptions of timber construction.
- **The building process:** Time studies, logistics etc.
- **Information:** Supplying information to visitors.

## 2.3. Findings – General experiences found so far

The results found so far from the documentation project has been reported in several reports, articles diploma works etc., see list of publications. In general terms the main conclusion has been that no alarming results in terms of economy or technical performance have been found. Thus, we may conclude that medium and high-rise timber construction is an economic, environmental friendly and technically well performing alternative to traditional (steel and concrete) construction.

Of special interest is the investigation on the life cycle primary energy use and carbon emissions, performed by Gustavsson et el. and available in [5]. Those results show that, taking into account the energy used in a 50 years life cycle (production, use and demolition), the timber alternative chosen at Limnologen does not only reduce carbon emissions, but actually can create a net uptake of CO2.

The technical evaluations performed have not highlighted any major concerns so far. Thus the technical performance of the Limnologen buildings (acoustic performance, the long term deformations in the structure and the moisture and temperature distributions in the outer walls) seems to be adequate. The only problem encountered so far, and related to the use of timber, is the design of the balconies. The balconies were originally designed with a cementitious topping, which showed to be inadequate. Due to moisture movements of the balcony timber floor slab the topping cracked. Thus, it has been decided to retrofit the balconies, covering the floors with a rubber mat instead. On top of the rubber mat, timber decking (treated) is used.

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