Bergen in a wood construction fever -
the first 14 storey building

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Sweco

Sweco is one of Europe’s leading companies in consulting engineering, environmental technology and architecture

9,000 employees in 12 countries

1 billion € net sales

37,000 assignments per year

15,000 customers
Timber high-rise

- Sweco Norway has previously done feasibility studies on tall timber buildings

- **Barentshus** in Kirkenes, Norway. 20 storey office building

- **Rundeskogen** in Stavanger, Norway. 15 storey apartment building.
2007. Rundeskogen, Sandnes

15 storey timber apartment building with concrete core

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2010. Barentshouse, Kirkenes

20 storey office building. Timber only

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Timber high-rise

- We found that timber high-rise buildings are feasible from an engineering point of view
- Timber high-rise buildings are a good answer to sustainable building in urban areas
- The cost of building is somewhat higher than steel/concrete. But erection time is shorter.
- The carbon footprint is favourable
- These buildings can be aesthetically pleasing in their design
- Many people want such buildings.
Melbourne, Australia – 10 storey building

10 storey CLT building. Presently regarded as the tallest timber apartment building in the world.
Bergen, Norway – 14 storey building

Hot candidate to become the tallest timber apartment building this year!

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In 2010 Bergen- og omegn boligbyggelag (BOB), a Norwegian housing association, proclaims that they want to build the world’s tallest timber building.

The following project group is established:

- Sweco – engineering
- Artec – architecture
- Moelven – glulam and CLT structures
- Kodumaja – building modules
Location

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The plot in Bergen

Hurtigruten – coastal ship
Experience with timber structures

Sakyamuni pagoda - 1056

• 67.3 m tall – including the 11.3 m spire on top
• Maybe the tallest timber building on the planet today
• In Sichuan, earthquake zone in western China
Experience with timber structures

Stave churches of Norway

Hopperstad stave church
Built between 1150-1200
One of 40 remaining churches
Timber is durable!
Experience with timber bridges

1996 - Evenstad bridge. 180 m long
Designed for two lane full traffic
Experience with timber bridges

2006 – Rena military bridge. 156 m long. Designed for 100 tonn tanks! Extreme loads.
Experience with timber bridges

2011 – Bridge crossing the motorway outside Oslo airport. 50 m span

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Inspiration from timber bridges

• Technology developed for timber bridges over the last decades opens many doors.
• The experience gained from bridges can be used for tall buildings
Engineering choices - 1

We chose to use proven technology for connections of large timber structures. Slotted-in steel plates and dowels.
Engineering choices - 1

- The connection was developed for the Olympics in 1994. It handles very large forces in arenas and bridges.
We used glulam trusses for this 5 storey complex in 2005. This was a success, and was used as a basis for high-rise
To reduce the work on site and reduce building time, we wanted to prefabricate as much as possible.
Engineering choices - 3

- Conventional prefabricated building modules can be stacked up to 6 storeys high. 14 storeys is too much, therefore an additional load bearing system is necessary. Stacking 4 storeys is quite economical.

- Variants of building modules should be held to a minimum to ensure lowest possible cost. In this way a serial production of modules can be done.

- Using modules reduces the challenge with water/moisture in the building phase considerably.

- The modules from Kodumaja are based on timber frame.

- Each module/apartment complies with the passive house standard.
The basis is timber frame work. Timber beams in floor and roof. Plasterboard. Oak parquet. Dishwasher. Cupboards. Kitchen. Shower. Tiles etc. All technical installations such as sprinklers, electricity, water pipes, cable tv etc are also integrated in the modules.
A more or less regular geometry was chosen for the building.

This is easier to build and design.

Building an extravagant structure or shape would have led to increased costs. Maybe next time?
- Fire design is done according to the Eurocode.

- Timber can burn. But the good thing is that we know how it burns. In this project the glulam is so thick that we allow it to burn for 90 minutes without failing. No extra gypsum is used.

- All steel connections are hidden inside the timber. In this way it will not fail within the required fire resistance time.

- In addition there are sprinklers, pressurized escape stairs and painted surfaces to improve the fire safety.

- Norwegian regulations open up for alternative solutions as long as they can be documented.
Engineering choices - 5
- To limit the need for maintenance a permanent weather protection system was chosen.

- The north and south facades have glass to protect the timber structure

- The east and south facades have metal cladding

- In this way the timber can be regarded as protected, and a higher utilization in wood design is possible (Eurocode service class 1)
- The building has both gluelaminated (glulam) timber and cross-laminated timber (CLT, CNC). Both materials are produced with very high quality and millimeter precision.
Engineering choices - 7

- The main load bearing is handled by glulam alone. CLT is carrying the staircases, elevator shaft (15 storeys) and some inner walls, but is not connected to the glulam.

- Connecting glulam and CLT would have led to complications in our design that we are not comfortable with yet.

- Concrete decks are used on three levels in the building to improve dynamic behavior.
Typical plan
Assembly. Step by step
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Facts

- 550 m$^3$ glulam
- 385 m$^3$ CLT
- 45 m high
- The building stands on top of a concrete garage.
- Pile foundations
- Light weight building > tension anchorages
- Drawn in Revit. 3D
- Calculated using Robot Millenium Structure
More facts

- 70 mm max deflection
- Glulam carries all vertical load
- Concrete decks serve as extra weight, and platform for modules
- New expression: powerstorey
- Max acceleration in the top about 0.05 m/s²
Even more facts

- Large glulam sections are block glued
- Glulam quality GL 30c and GL 30h according to EN 14080
- Modules are stacked up to 4 storeys, and are only connected to the main structure in the lowest module
- Typical column: 405x650 and 495x495 mm
- Typical diagonal 405x405 mm.
... and then some facts

- The building is energy efficient, and meets the European demands for passive house

- Every module is insulated and almost air tight. Joints between modules are handled likewise

- The modular system gives double walls between apartments. Acoustic requirements are well within limits for apartment buildings
Structural model

Frequency: 0.89 (Hz)
Cases: 15 (Modal)

Frequency: 0.75 (Hz)
Cases: 15 (Modal)
Finding damping of modules
Modelling of modules

- Damping of modular walls has been physically tested and simulated
- NTNU (University of Trondheim) and Kodumaja of Estonia has contributed to this
- The building modules have a damping of about 3%
Monitoring of the building by NTNU

- Accelerometers
- Directions and speed of the wind is measured
- Gives useful knowledge for future projects
Main challenges

- Comfort criteria. Low weight -> higher accelerations
- Obtaining structural data for building modules
- Safe work operations in the air
- Avoiding moisture during erection
- Designing maintenance friendly solutions
- Project economy. Risk control to avoid overpricing from suppliers not familiar with the concept
Status today

Practically all costs have been covered by BOB.
Building costs are somewhat higher than steel+concrete
Detailed design is finished and approved by third party reviewers.
The project was put out for sale summer 2013.
31 of the 62 apartments are sold as of Jan 19\textsuperscript{th} 2013
An additional 3 apartments must be sold before construction work can start.
Construction will most probably start this spring
Buy your apartment here: www.treetsameie.no
Conclusive remarks

Timber high-rise buildings are for real!

Timber high-rise is a sustainable solution

Start planning your high-rise timber buildings

Take the wood industry of North America to the next level, so that you can build using local material!

Challenge the world record!
Thank you for your attention!

Visit us next year!