TreProX: Innovations in Training and Exchange of Standards for Wood Processing

MULTISTOREY BUILDINGS, MODULAR AND CLT TIMBER

JOHAN VESSBY, SIGURDUR ORMARSSON

TREPROX WORKSHOP – ICELAND - OCTOBER 2021

Treprox
Landbúnaðarháskóli Íslands Agricultural University of Iceland
skógræktin ICELANDIC FOREST SERVICE
Trétækniráðgjöf slf. Wood Technology
UNIVERSITY OF COPENHAGEN
Linnæus University
Erasmus+

Multistorey buildings, modular and CLT timber

211013, Erasmus+ kurs på Island 10–16 oktober 2021, Project TreproX

Johan Vessby, Karlstad University

Sigurdur Ormarsson, Linnaeus University

Karlstad University

Tasks

- Education and research in collaboration with other partners worldwide.
- Strive for applied research, testing attitude and development of democracy.
- Active and responsible academic participation – national as well as international.
- Structure, focus and systematic follow-up for quality and sustainable growth.

Karlstad University

- About 16,000 students
- 270 doctoral students
- 1,300 employees
- Constituted in 1999.

From red simple buildings…

Architect: ?
Home for 90% of Värmlands population

… to urban topp notch!

Architect: Wingårdhs Arkitektkontor, Anna Höglund
Developer: Folkhem, 2014
Photo from folkhem.se

Previously completed buildings

Wälludden, Växjö 1995, 5 våningar, ca 15 meter

Portvakten, Växjö 2009, 8 våningar, ca 24 meter

Melbourne 2012 – 10 våningar, ca 30 meter

Treet, Bergen 2015, 14 våningar, ca 45 meter

Vancouver 2017 – 18 våningar, 53 meter

Mjøstårnet, Brumunddal, 85 meter

Planned buildings

Hallonbergen, Stockholm, 22 storeys

Toothpick, London, very tall

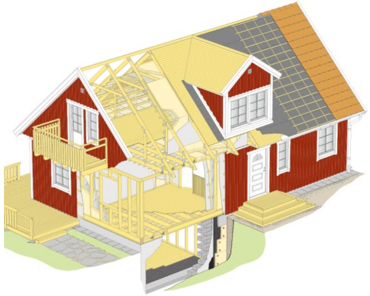
Different building systems

MHM Scandinavia
Västervik

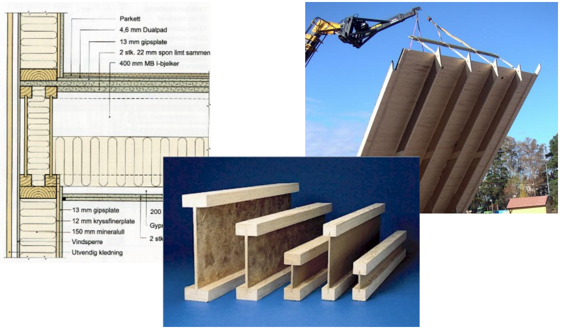
Santner, Trondheim, Norge

Limnologen, Växjö

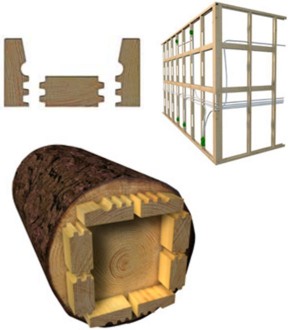
Rydebäck, Helsingborg



Stud and rail



Masonite beams



Södra Smart

Level of prefabrication

On site (Beam and post)

Planar element

Volume element http://www.kodumaja.ee

What are the challanges when building tall timber buildings?

Technical Guide for the Design and Construction of Tall Wood Buildings in Canada

Special Publication SP-55E, FPInnovation
Erol Karacabeyli P.Eng. Conroy Lum P.Eng.

Figure 38 FPInnovations testing

Stability

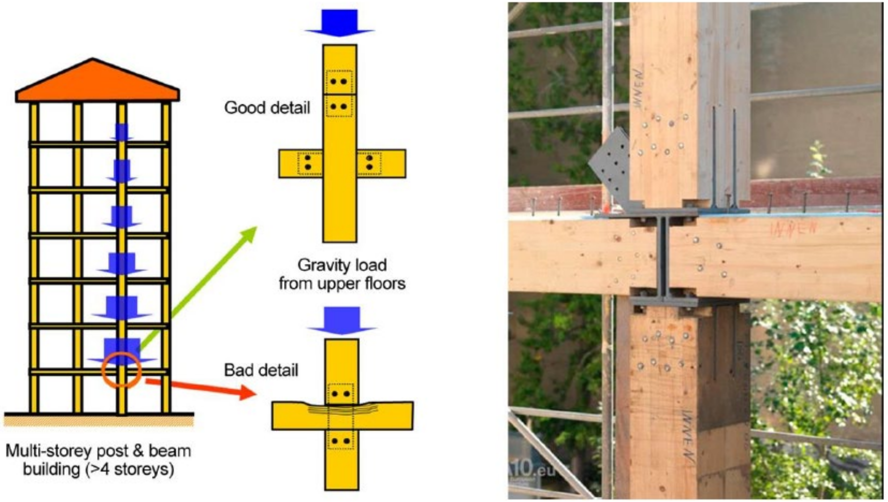


Figure 2 Post to beam connection details for avoiding excessive compression perpendicular to grain due to gravity loads

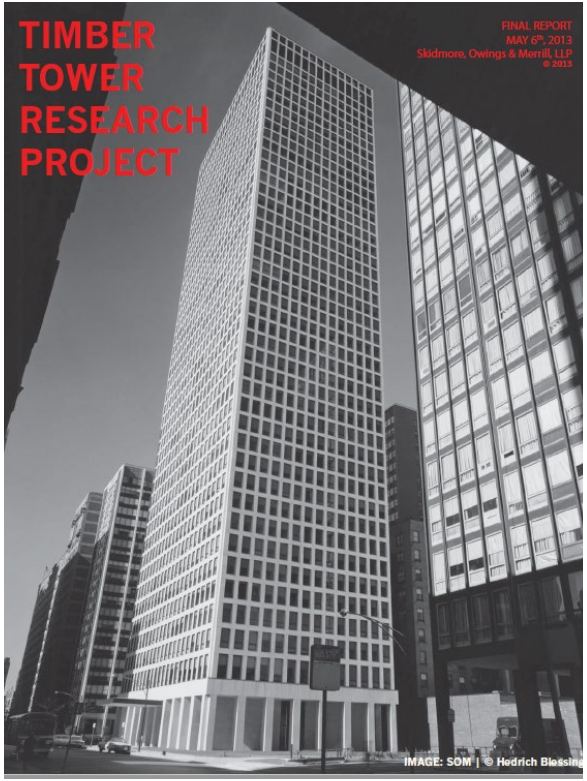
Critical design loads in a tall concept timber building

Timber tower research project, Final Report, SOM, 2013

Key Design Issues

Choosing a lateral load resisting system for a tall building requires special attention to three primary issues listed below. Additional information on these topics is included in Appendix A.

1. System strength. The system as a whole and each individual component must be strong enough to resist the necessary loads. In tall buildings using a core wall lateral system, the most difficult elements to design are often the link beams which couple the movements of individual wall panels.
2. System stiffness. The system must be stiff enough so that cladding and elevator systems are serviceable. Steel structures are more commonly controlled by system stiffness compared to concrete structures.
3. Net uplift due to lateral loads. Net uplift occurs when the lateral load overturning forces overcome the gravity dead load forces of the building. This causes the building to lift up and places the vertical elements in tension. Net uplift is further increased in seismic zones where vertical seismic loads also oppose the gravity dead load of the building. Net uplift is more avoidable in a concrete building due to additional material weight. Tension is more difficult to design for if it occurs as members in tension are difficult to design and construct.

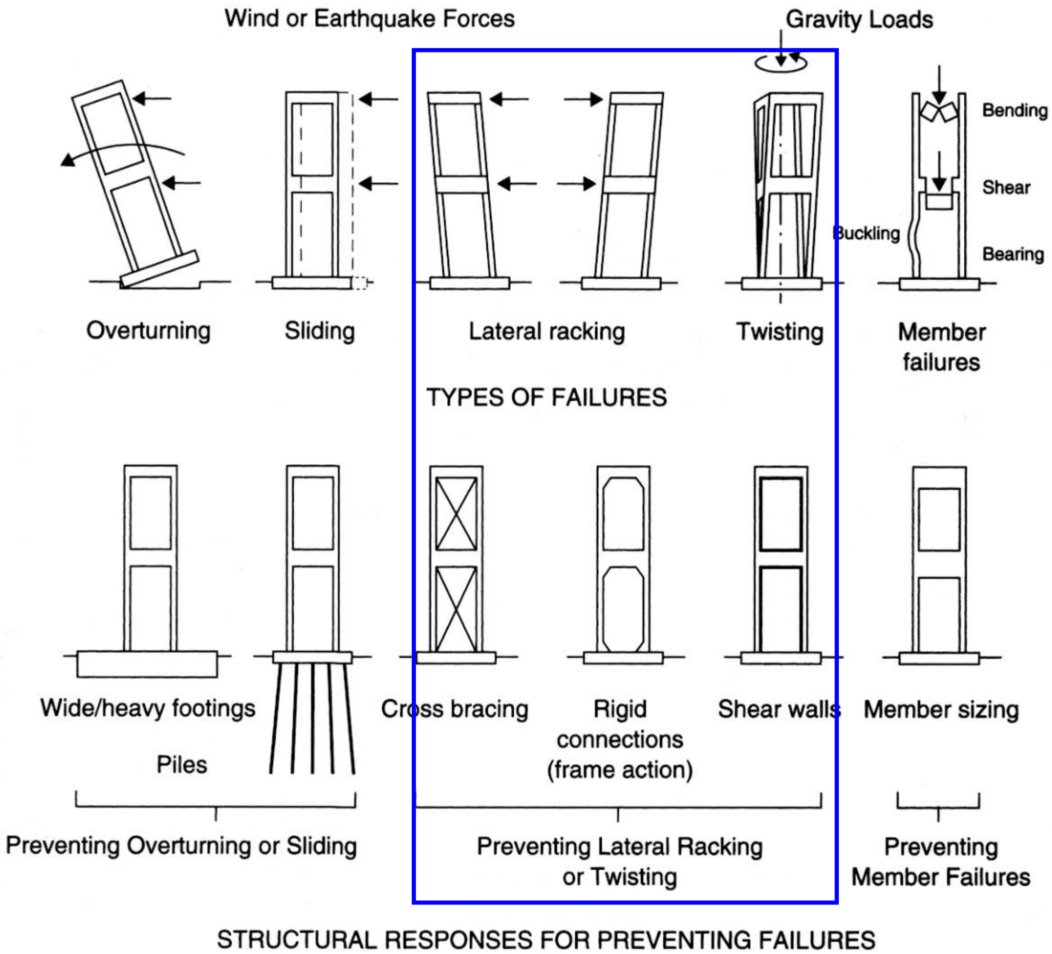


Effects of wind load

Photo of the year 2006, Photo: Joakim Berglund

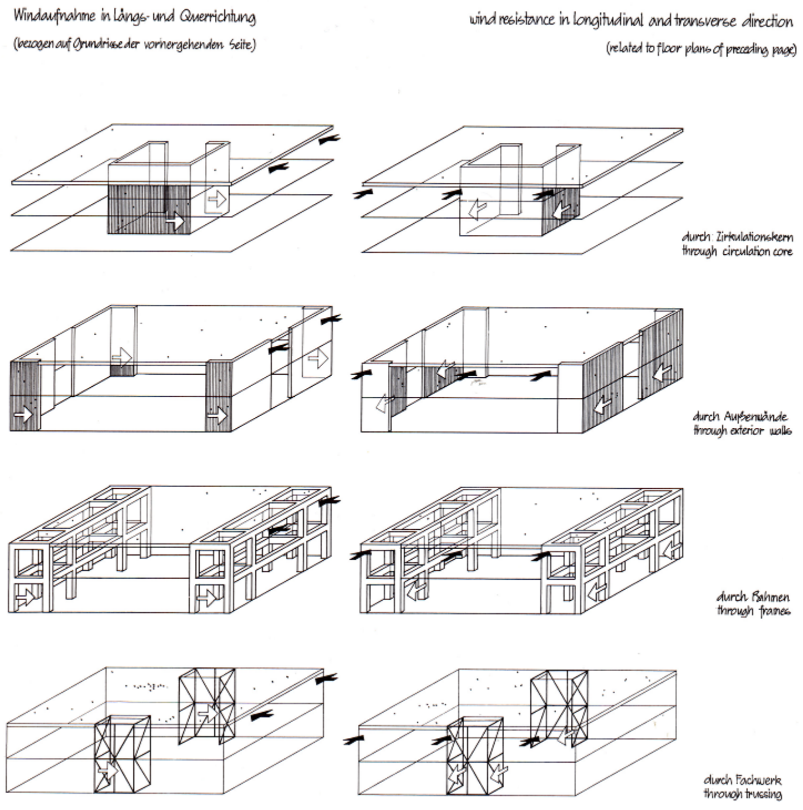
Photo: Samuel Palmblad

Methods to avoid severe effects of wind load


Wind or Earthquake Forces
Gravity Loads
Bending
Shear
Buckling
Bearing
Overturning
Sliding
Lateral racking
Twisting
Member failures
TYPES OF FAILURES
Wide/heavy footings
Piles
Cross bracing
Rigid connections (frame action)
Shear walls
Member sizing
Preventing Overturning or Sliding
Preventing Lateral Racking or Twisting
Preventing Member Failures
STRUCTURAL RESPONSES FOR PREVENTING FAILURES

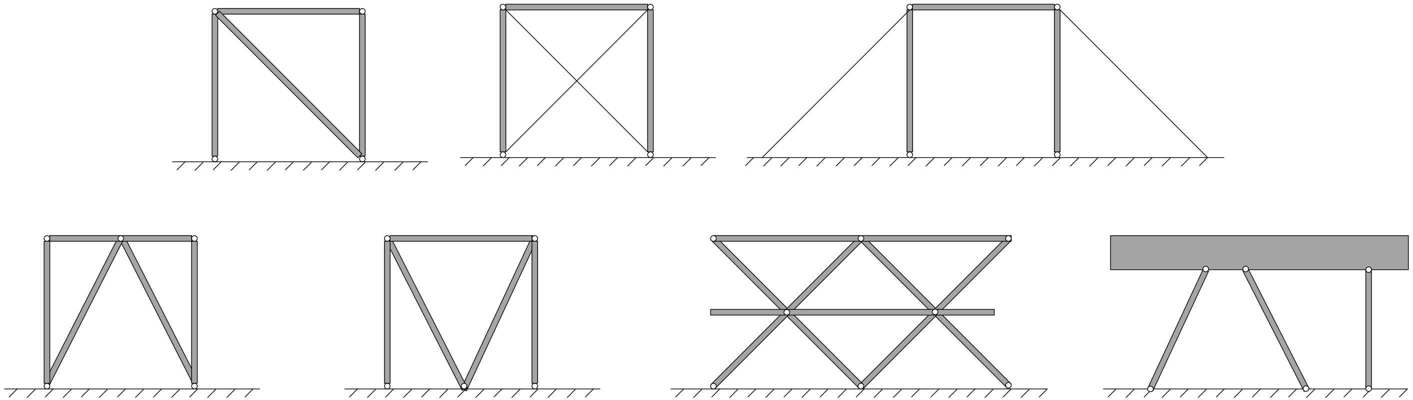
Structure Systems, Heino Engel

Divides structures according to how they resist loading.
Here horizontal loading.

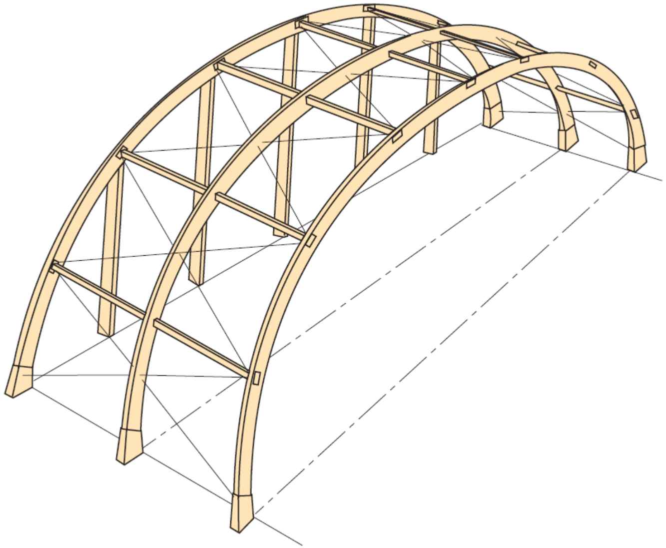


Tension rods (and other diagonal members)

- Very common in glulam structures particularilly if high stiffness is required
- Often used in combination with glass



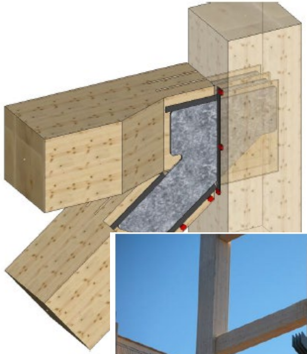
Tension in steel rods

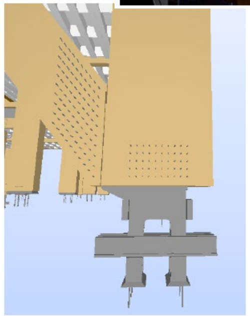


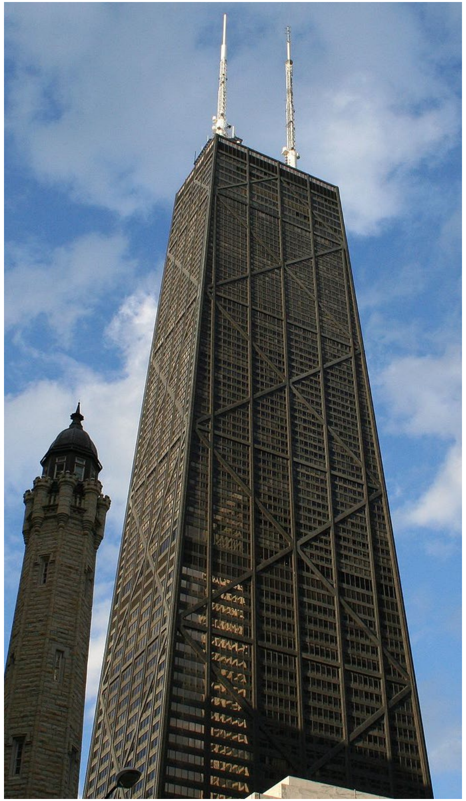
Stabilization in the construction phase

Mjøstårnet - Construction of an 85 m tall timber building,

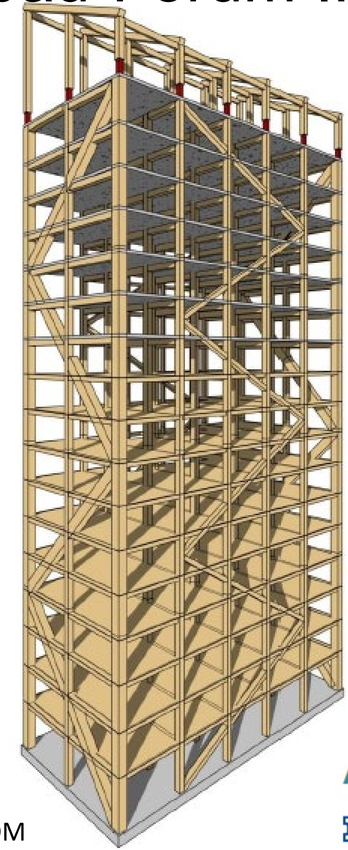
R. Abrahamsen , Internationales Holzbau-Forum IHF 2017

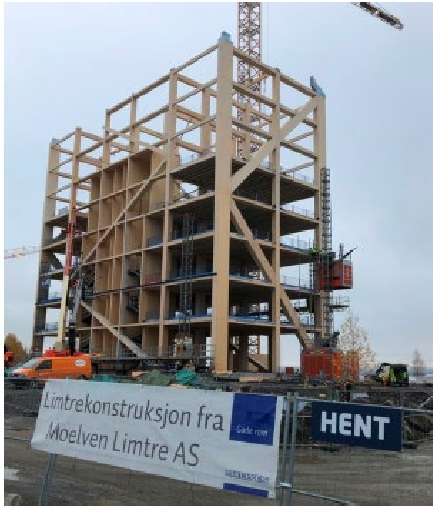






John Hancock Center, Chicago, 344 m, 1969, SOM



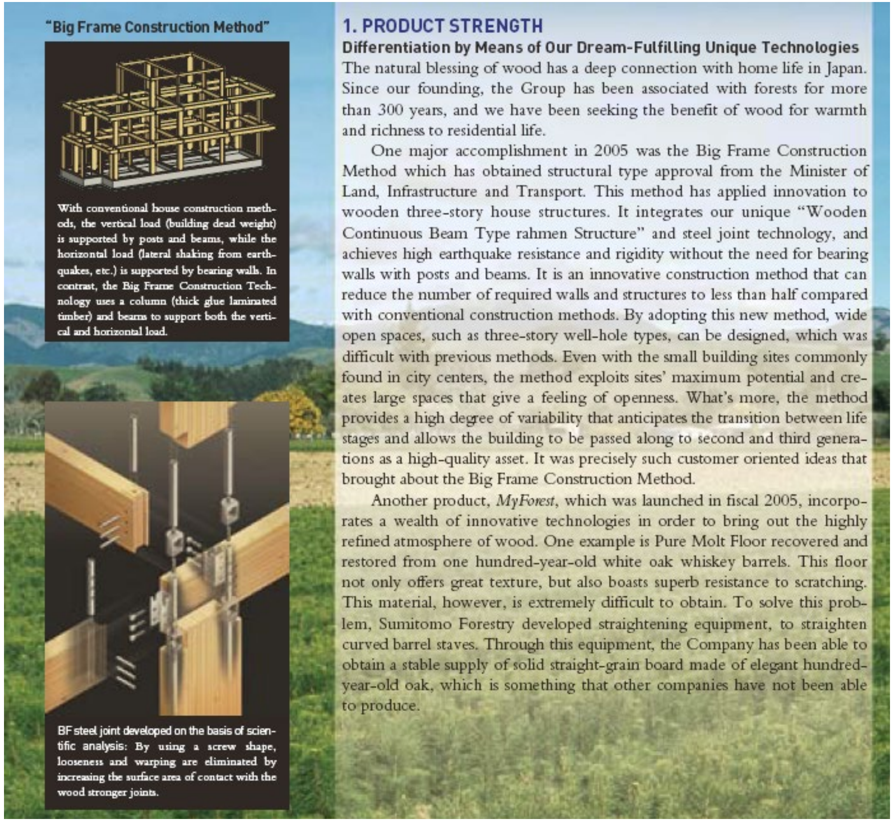


AB Invest A/S HENT
MOELVEN VOLL SWECO

Frame structure

- Not so common, mostly used in glulam structures
- Stiffness and strength is typically not so high

”Big-frame”, Sumitomo forestry group, Japan



"Big Frame Construction Method"

With conventional house construction methods, the vertical load (building dead weight) is supported by posts and beams, while the horizontal load (lateral shaking from earthquakes, etc.) is supported by bearing walls. In contrast, the Big Frame Construction Technology uses a column (thick glue laminated timber) and beams to support both the vertical and horizontal load.

BF steel joint developed on the basis of scientific analysis: By using a screw shape, looseness and warping are eliminated by increasing the surface area of contact with the wood stronger joints.

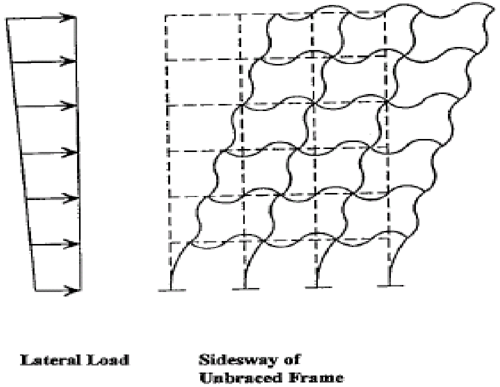
1. PRODUCT STRENGTH

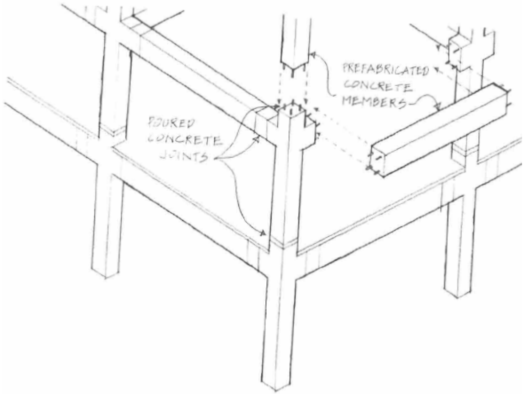
Differentiation by Means of Our Dream-Fulfilling Unique Technologies

The natural blessing of wood has a deep connection with home life in Japan. Since our founding, the Group has been associated with forests for more than 300 years, and we have been seeking the benefit of wood for warmth and richness to residential life.

One major accomplishment in 2005 was the Big Frame Construction Method which has obtained structural type approval from the Minister of Land, Infrastructure and Transport. This method has applied innovation to wooden three-story house structures. It integrates our unique "Wooden Continuous Beam Type rahmen Structure" and steel joint technology, and achieves high earthquake resistance and rigidity without the need for bearing walls with posts and beams. It is an innovative construction method that can reduce the number of required walls and structures to less than half compared with conventional construction methods. By adopting this new method, wide open spaces, such as three-story well-hole types, can be designed, which was difficult with previous methods. Even with the small building sites commonly found in city centers, the method exploits sites' maximum potential and creates large spaces that give a feeling of openness. What's more, the method provides a high degree of variability that anticipates the transition between life stages and allows the building to be passed along to second and third generations as a high-quality asset. It was precisely such customer oriented ideas that brought about the Big Frame Construction Method.

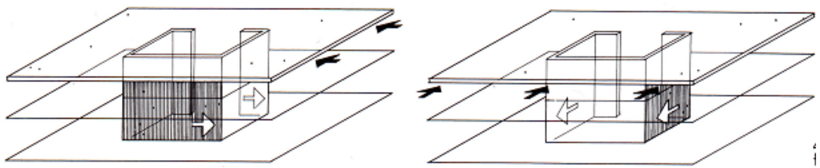
Another product, *MyForest*, which was launched in fiscal 2005, incorporates a wealth of innovative technologies in order to bring out the highly refined atmosphere of wood. One example is Pure Molt Floor recovered and restored from one hundred-year-old white oak whiskey barrels. This floor not only offers great texture, but also boasts superb resistance to scratching. This material, however, is extremely difficult to obtain. To solve this problem, Sumitomo Forestry developed straightening equipment, to straighten curved barrel staves. Through this equipment, the Company has been able to obtain a stable supply of solid straight-grain board made of elegant hundred-year-old oak, which is something that other companies have not been able to produce.

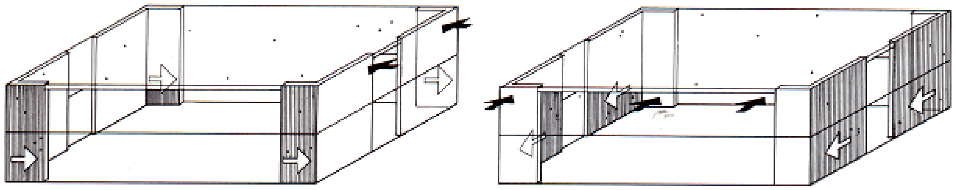




Shear walls

- Very common in case of residential housing.
- High stiffness, but dependent on sheathing material and type of fastener.
- Assumed to take load in plane and not out of plane.

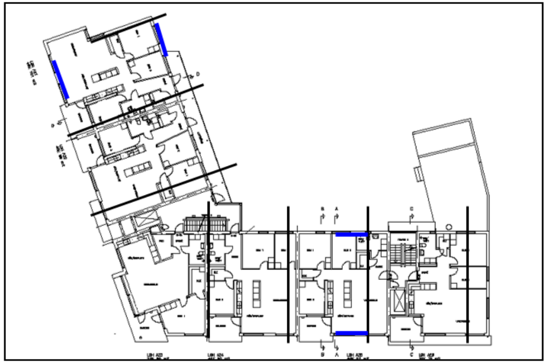




Shear walls are the dominating stabilizing system for residential buildings

Pelarsalen, Växjö, Sweden, Derome

Stiff and strong walls in the perimiter of the building



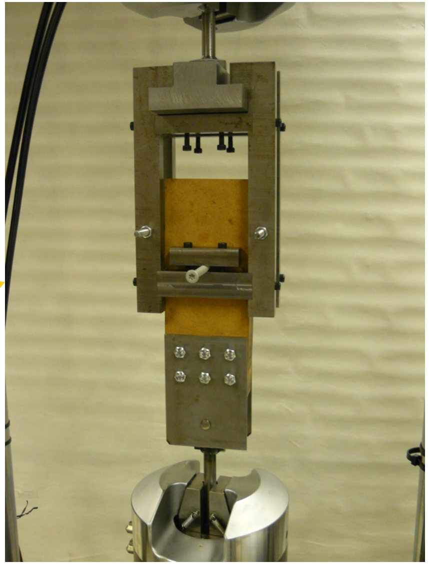

NCC
GUARD

…however at times their is not much space for a sheeting material.

Wisa Wooden Design Hotel
Helsinki, Finland, 2009

Research regarding stability in tall timber buildings

We try to work in close coorperation with industry…



Moelven Byggmodul, Nykvarn

…in courses…

Study visit
Trivselhus

Bjälklag från
Myresjöhus

Kirsi Jarnerö,
labansvarig
SP/Trä

Per Nilsson
Skanska
Agerar tyngd på bjälklag

… and in resarch projects.

Example of companies currently involved in research.

Main focus on volumetric buildings

On site (Beam and post)

Planar element

Volume element http://www.kodumaja.ee

”Self-supporting” vs. ”frame-supported”

New advancements, challenges and opportunities of multi-storey modular buildings – A state-of-the-art review, Engineering Structures 183 (2019) 883–893

(a) (b)

Fig. 1. Modular buildings [32] with: (a) self-supporting load-bearing modules; and (b) frame-supported modules.

Exempel ”frame-supported” Treet, Bergen Norge

Malo, K.A., Abrahamsen, R.B. & Bjertnæs, M.A. Some structural design issues of the 14-storey timber framed building “Treet” in Norway. *Eur. J. Wood Prod.* 74, 407–424 (2016). https://doi.org/10.1007/s00107-016-1022-5

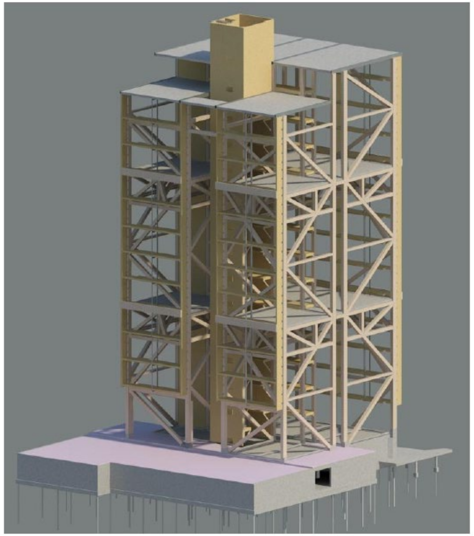


Figure 7: *Timber truss work and concrete*

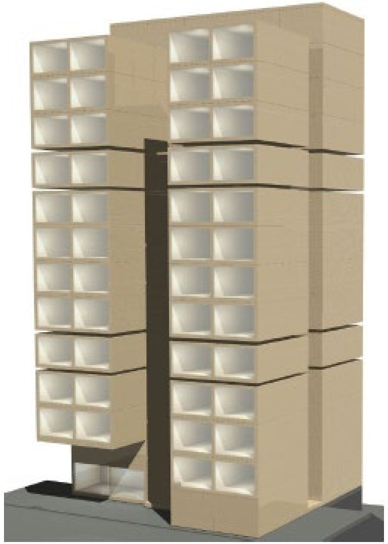


Figure 8: *Stacked modules*

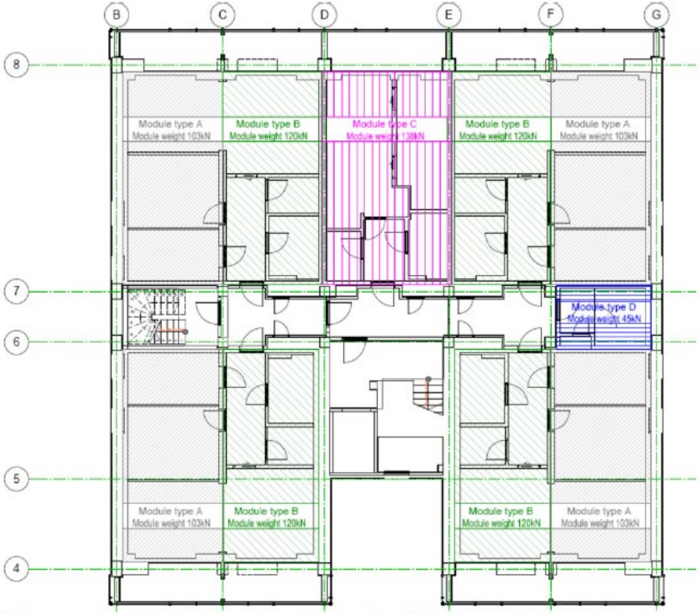


Figure 6: *Typical plan of the building with modules*

Exempel ”frame-supported” Treet, Bergen Norge

Malo, K.A., Abrahamsen, R.B. & Bjertnæs, M.A. Some structural design issues of the 14-storey timber framed building “Treet” in Norway. *Eur. J. Wood Prod.* 74, 407–424 (2016). https://doi.org/10.1007/s00107-016-1022-5

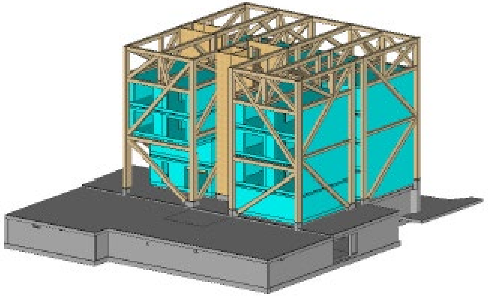


Figure 14: Step 3

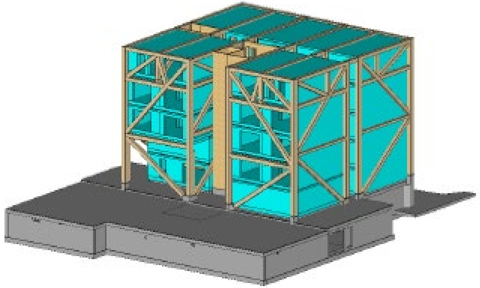


Figure 15: Step 4

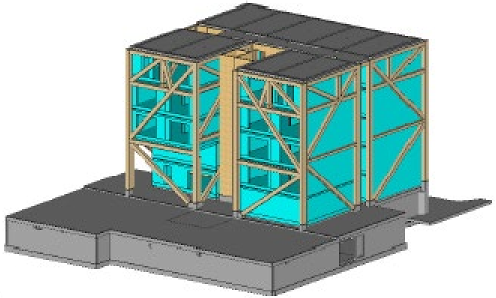


Figure 16: Step 5

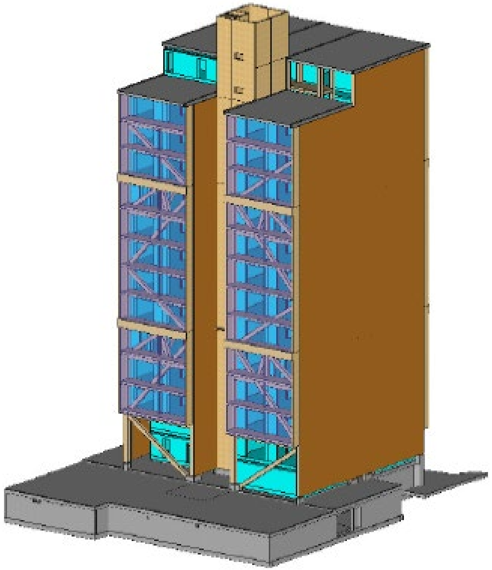


Figure 20: Step 9. Glazing

Exempel ”self-supporting” från Canada

(https://quebecwoodexport.com/en/products/wood-construction/light-wood-frame/modular/)

…but is the code sufficient even in this case?

- Large openings
- Double layer sheathing with different material and with non-coincident edges
- Platform built structures / baloon frame structures
- Fasteners threw one and/or two of the sheathing layers
- High height-to-width ratios
- Etc.

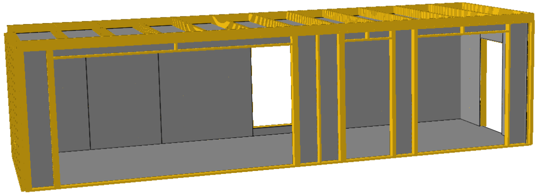
Background for ongoing resarch

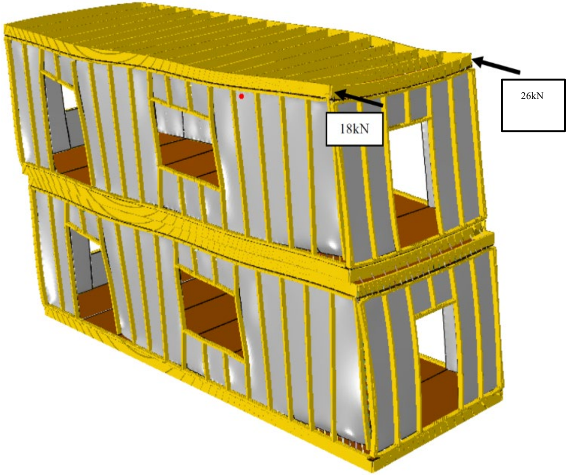
*

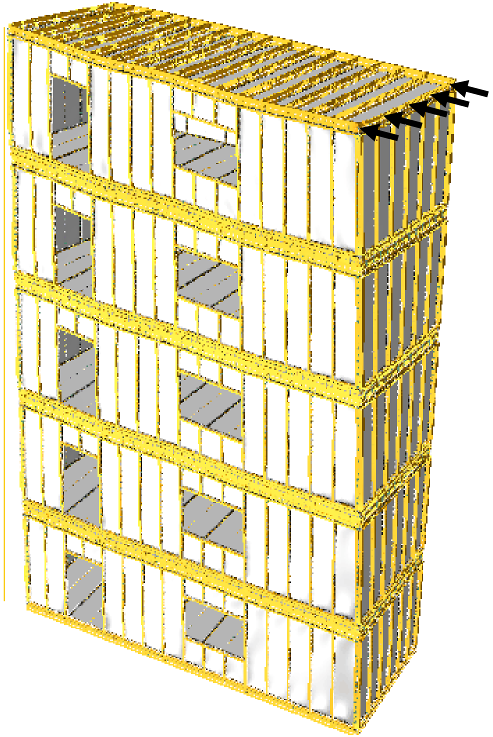
- **A number of modular house manufacturers** are expanding their production to multi-family houses on **several floors (up to 6-8 floors).**
- Improve the understanding of the **overall structural behaviour** of the individual modules and the entire building including **mechanical joints** between the volume modules.
- The numerical and experimental results from this research project will be used as a base for new **design of the volume modules**, especially regarding the connection design.

* https://gbjbygg.se/projekt/kv-docenten-248-studentbostader-och-ica-kvantum-i-vaxjo/

The aim of the research





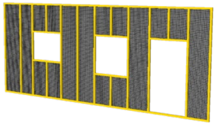


- The aim is to create an **effective and flexible simulation model** able to simulate **overall (and detailed)** structural behavior of (light frame) modular based multi-storey timber buildings.
- To create a flexible model, the model has to be fully **parametrized** and experimentally verified at different structural levels.

Modelling steps

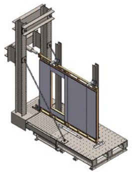
STEP1

- Development of parameterized FE-models for different light-frame timber walls



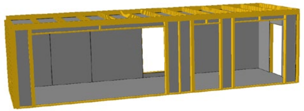
STEP2

- Model verifications based on experimental data from single wall tests and test-modules



STEP3

- Parameterized modeling of modular based timber structures based on the verified models



python

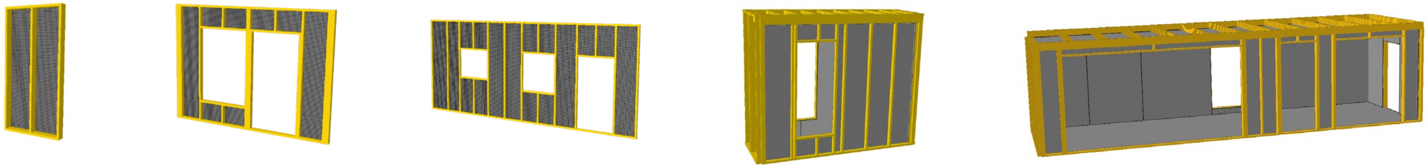
Frame geometry

Sheathing geometry

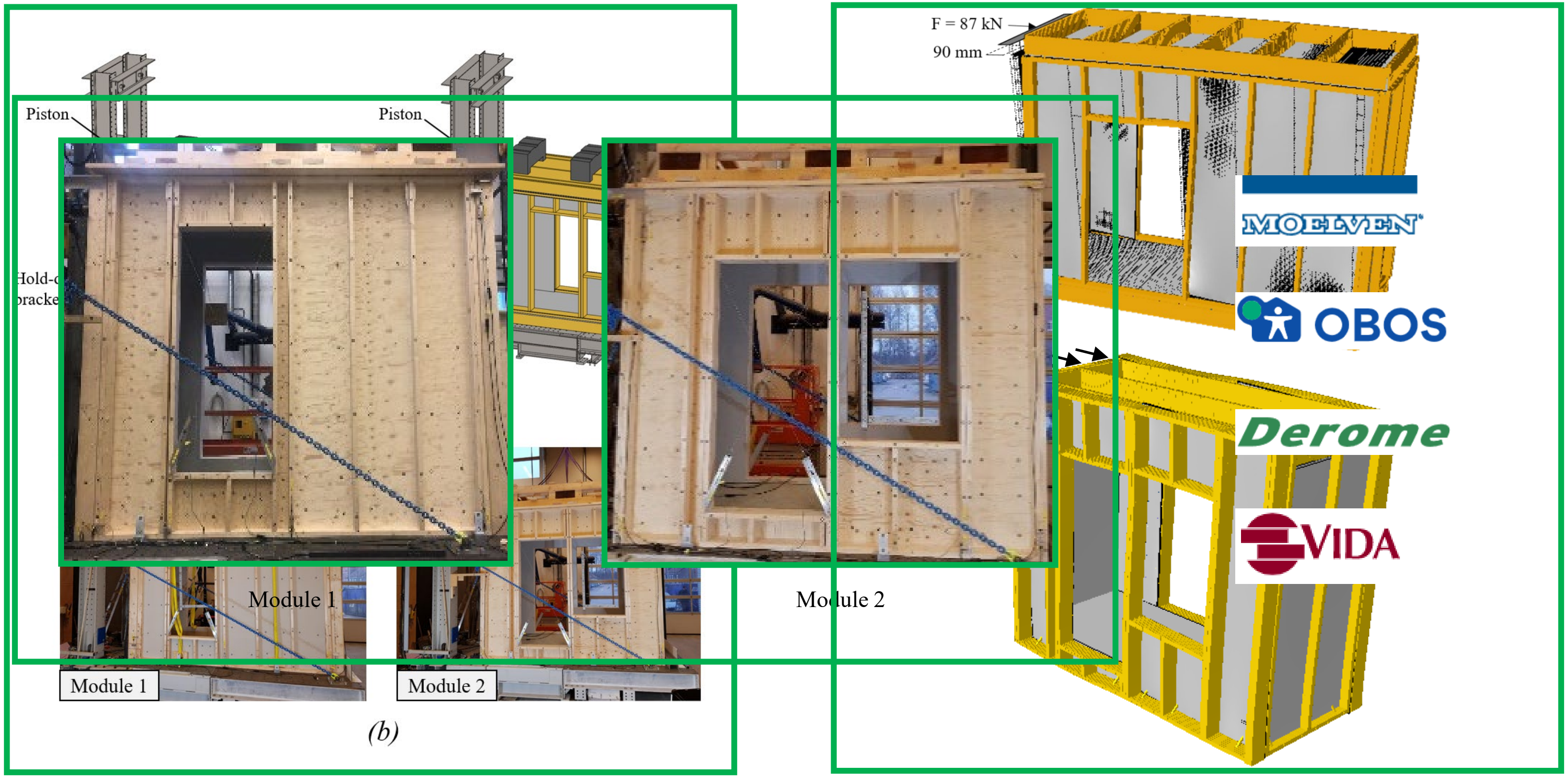
Load and boundary conditions

Element material properties

Connection method

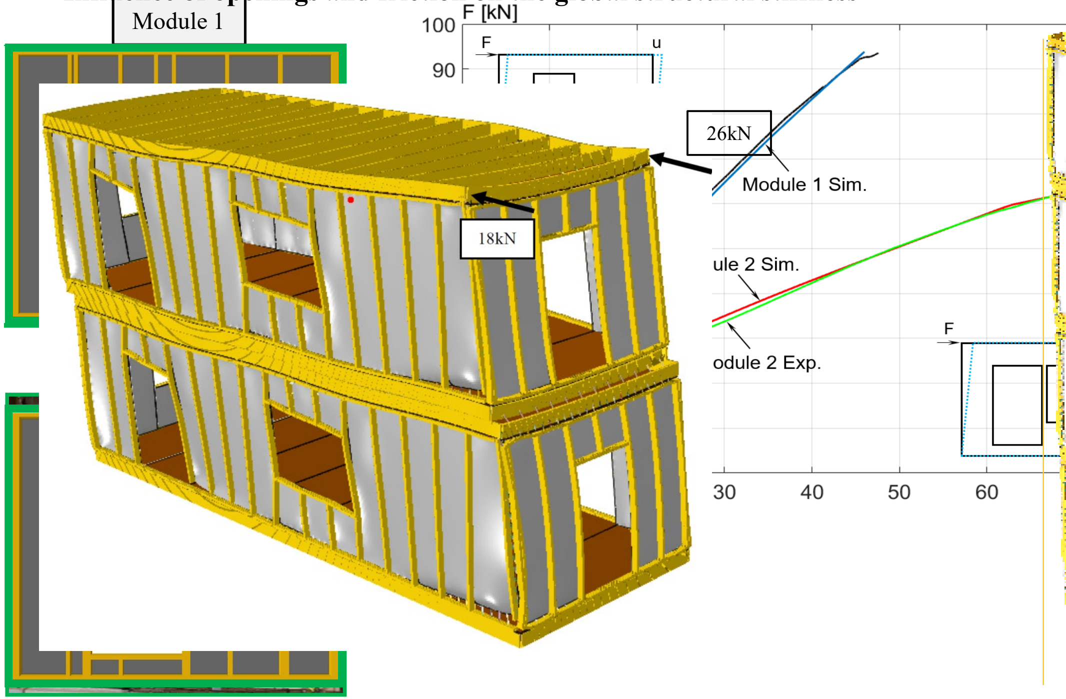


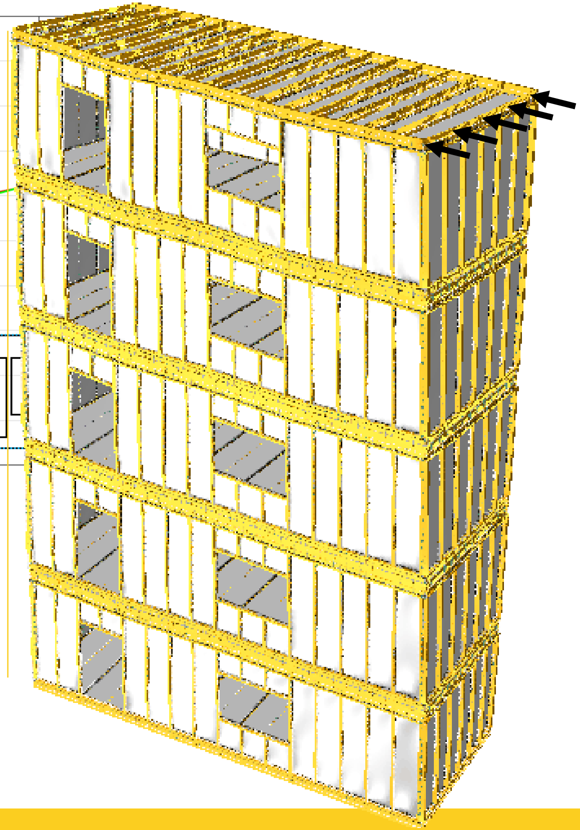
Experimental studies & Modelling of the test-modules



Numerical & Experimental results

- **Influence of openings and friction on the global structural stiffness**





High friction in the joint between the volume modules

KAU.SE

Example of buildings recently completed

Sara Kulturhus

Sara Kulturhus, 74 meters tall and 20 storeys

Sara Kulturhus

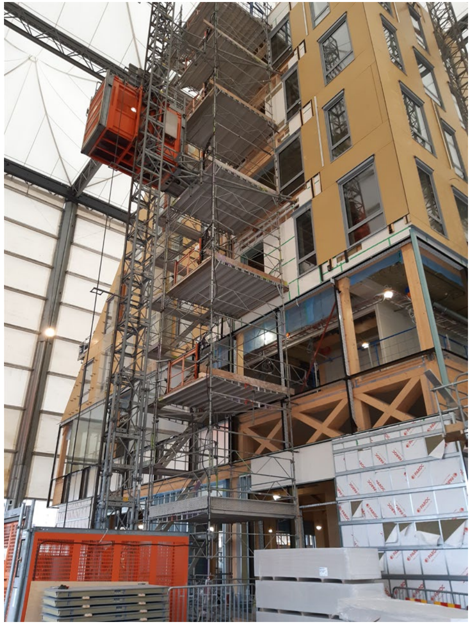
- Name from the famous author Sara Lidman
- Inagurated autumn -21
- Architects: White architects
- Volumteric elements from Derome
- Total area: 25 000 m^2
- Elite hotels has 205 rooms there
- Main contractor: HENT
- Standing 80 meters tall

Volumetric elements delivered to Sara Kulturhus by Derome

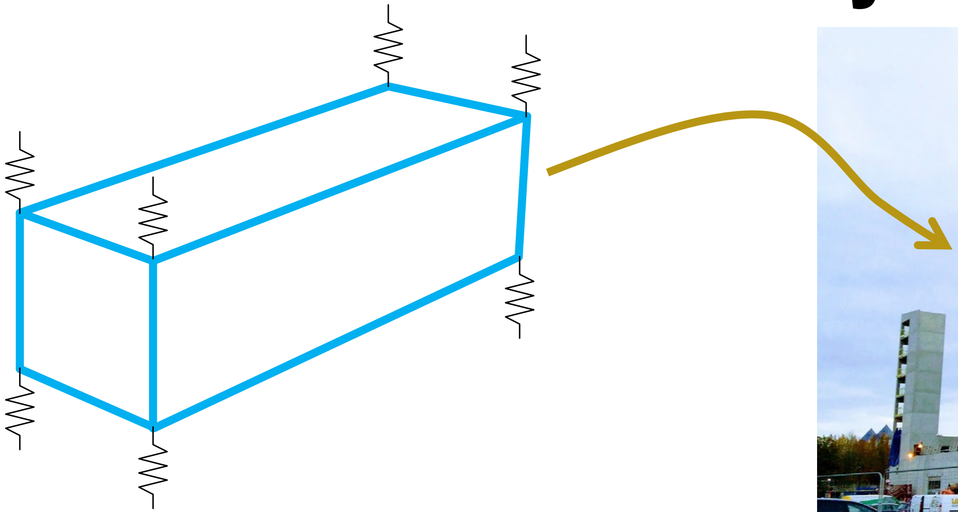
Växjö municipality, new (timber)building


WORLD TRADE CENTER
VAXJO
STEINESS
Coca-Cola


SKANSKA
BESÖKARE


Thanks for your attention!



And thanks also to the fundors

FORMAS

PAPER PROVINCE

Med stöd från: VINNOVA Sveriges innovationsmyndighet Energimyndigheten FORMAS Strategiska innovations-program