



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

**Garmisch Partenkirchen 05.12.2013**

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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



# Melbourne, Australia – 10 storey building SWECO

10 storey CLT building. Presently regarded as the tallest timber apartment building in the world.





# Bergen, Norway – 14 storey building



Hot candidate to be the tallest timber apartment building by next year!

- Sweco 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
- 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
- These buildings can be aesthetically pleasing
- Many people want such buildings.

# Location





# The plot in Bergen



# Project group



In 2011 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 structures

Kodumaja – building modules

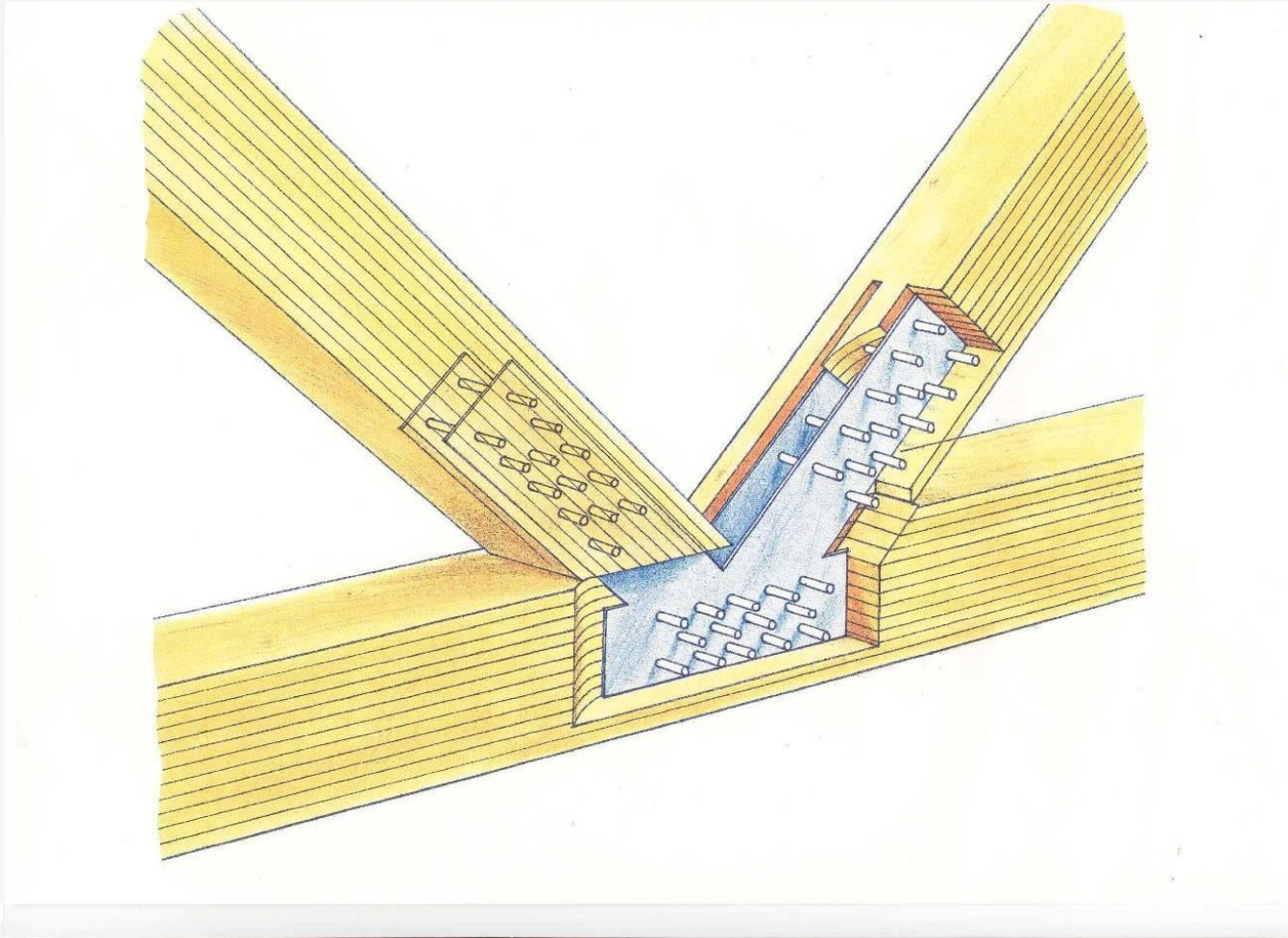


# Inspiration from timber bridges

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



- 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.





# Engineering choices - 2

- We used glulam trusses for this 5 storey complex in 2005. This was a success, and was used as a basis for high-rise



# Engineering choices - 3

- To reduce the work on site and reduce building time, we wanted to prefabricate as much as possible.



- 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 buildings 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



- 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?

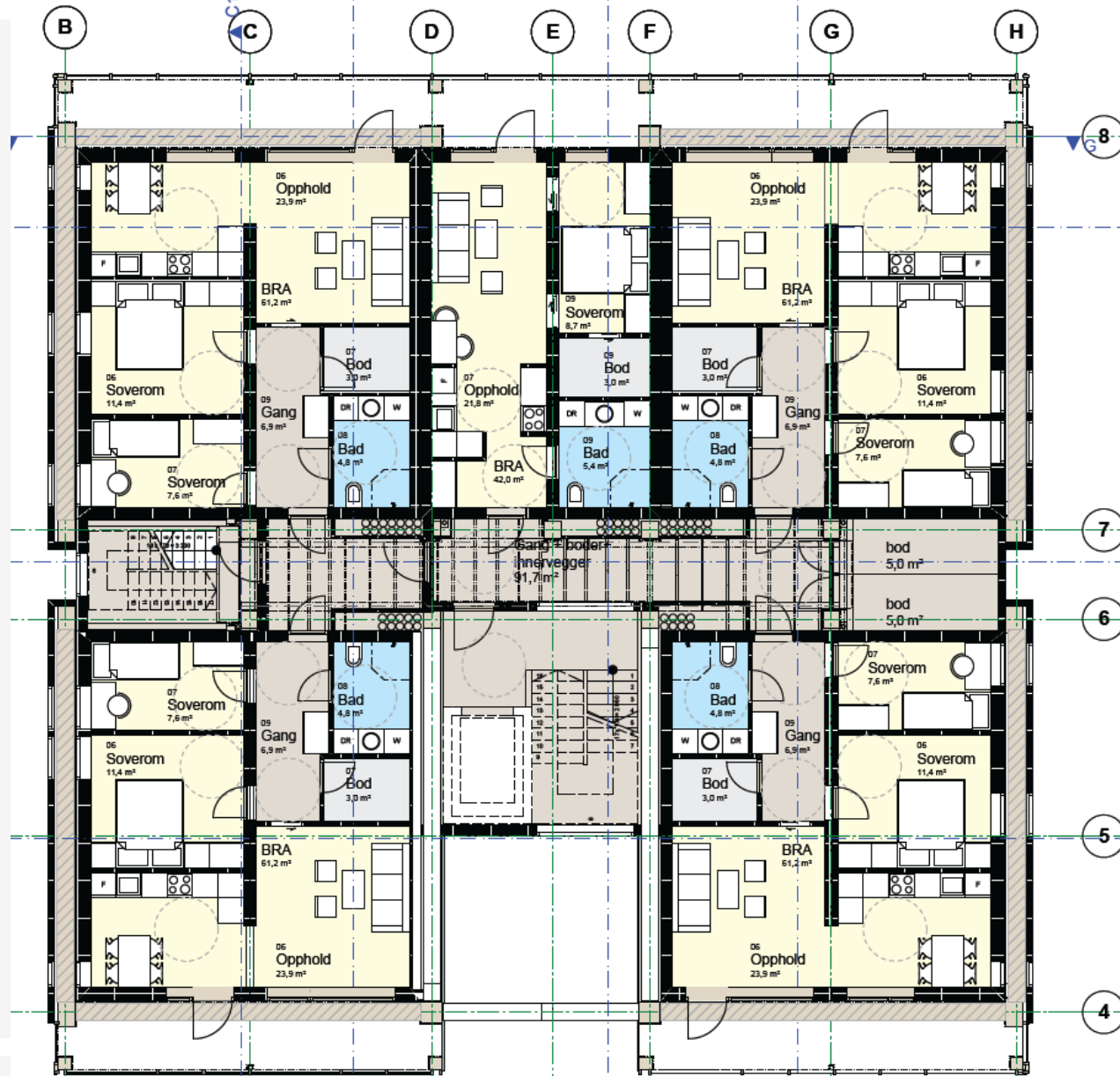
- Fire design is done according to the Eurocode.
- Timber can burn. But the good thing is that we know how it burns. In this project the glulam is so thick that we allow it to burn for 90 minutes without failing. No extra gypsum is used.
- All steel connections are hidden inside the timber. In this way 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

- To limit the need for maintenance a permanent weather protection 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 is possible

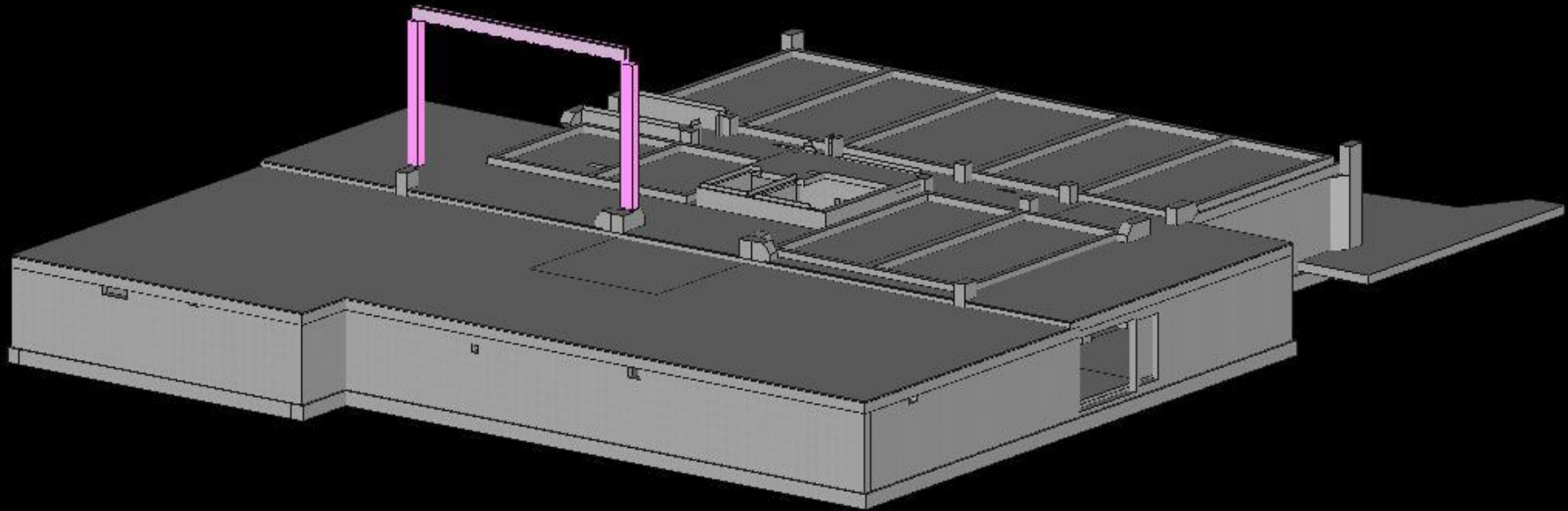


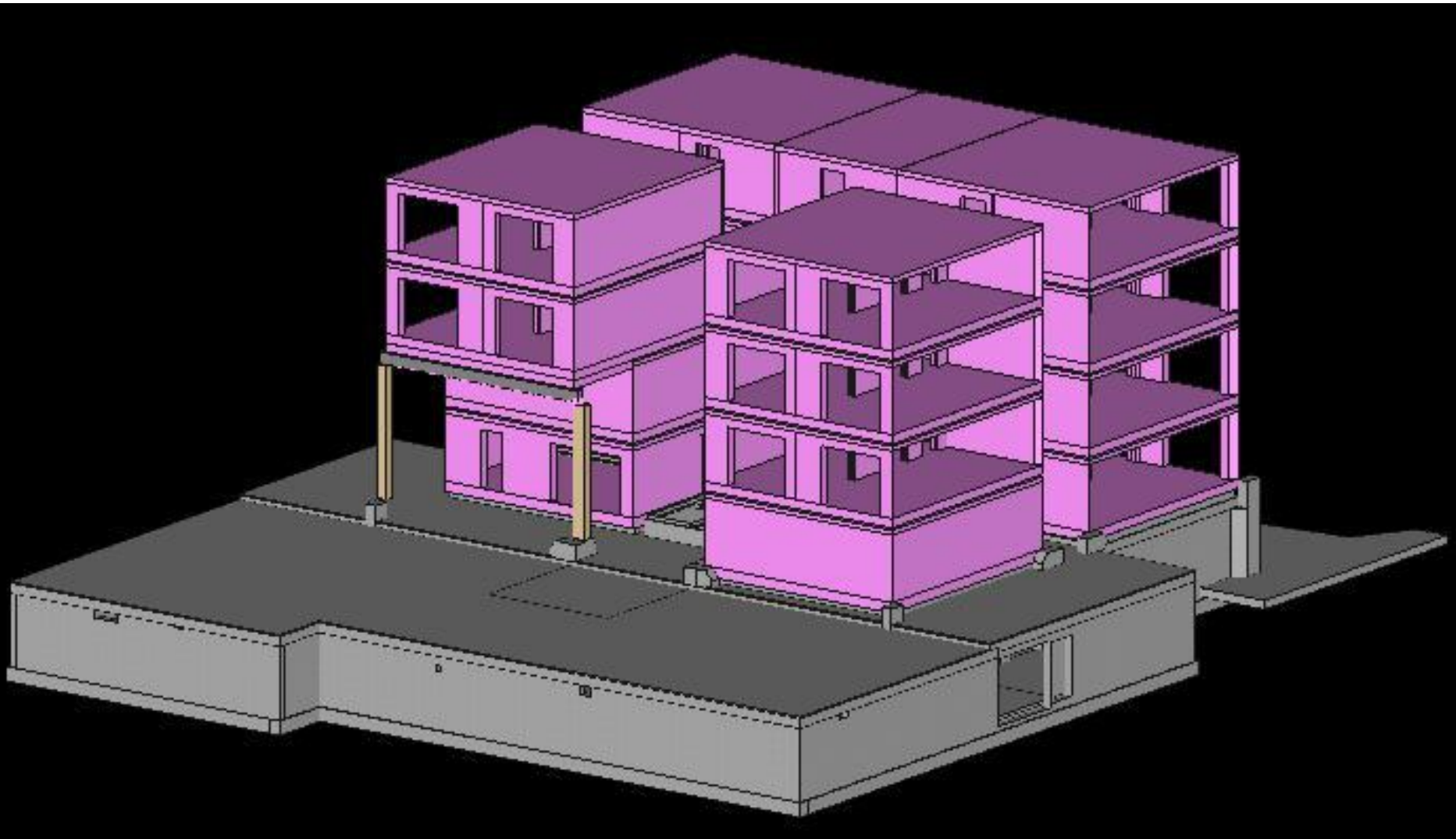
- The building has both gluelaminated (glulam) timber and cross-laminated timber (CLT)
- The main load bearing is handled by glulam alone. CLT is carrying the staircases, elevator shaft (15 storeys) and some inner walls, but is not connected to the glulam
- Connecting glulam and CLT would have led to 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

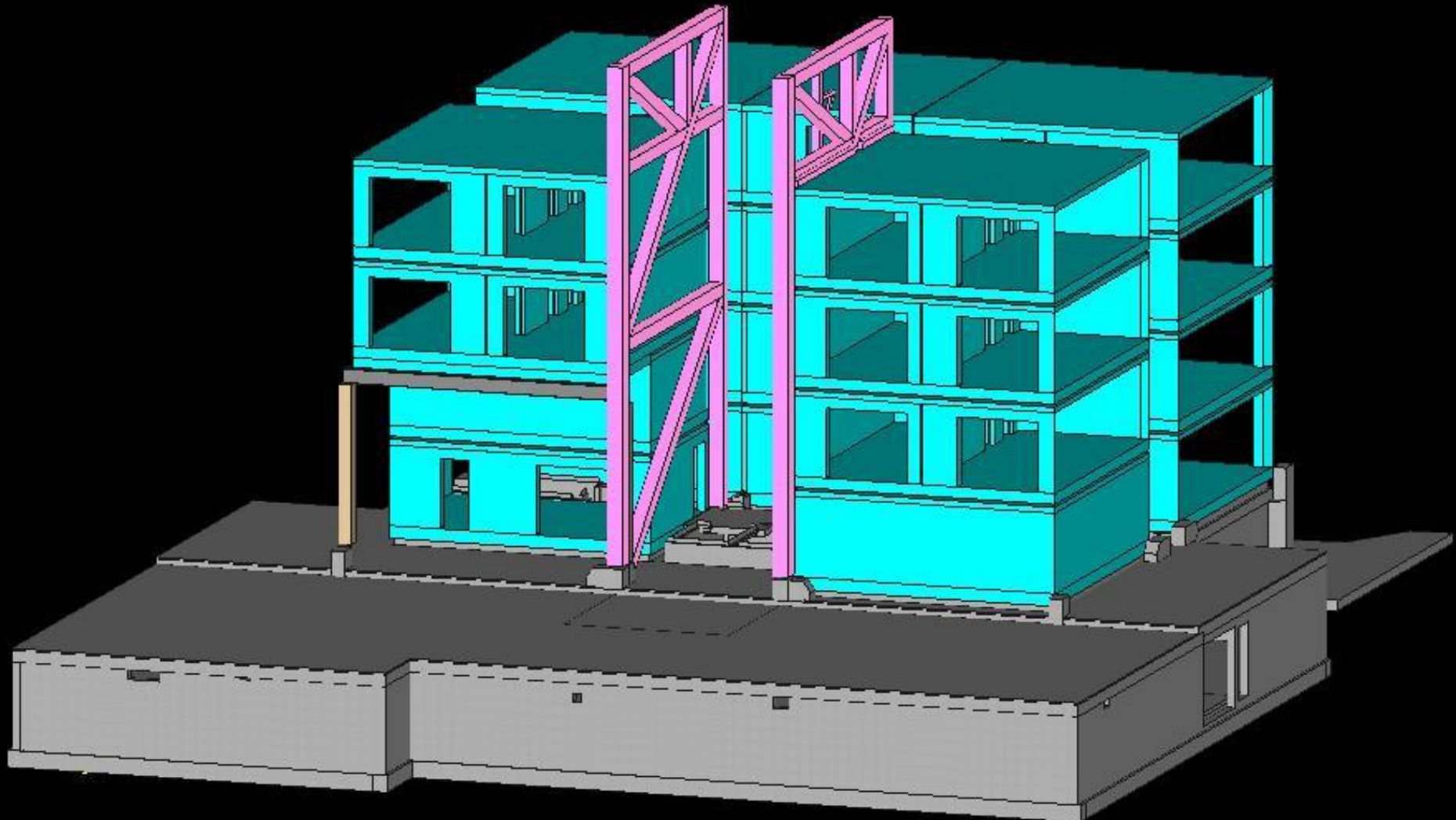


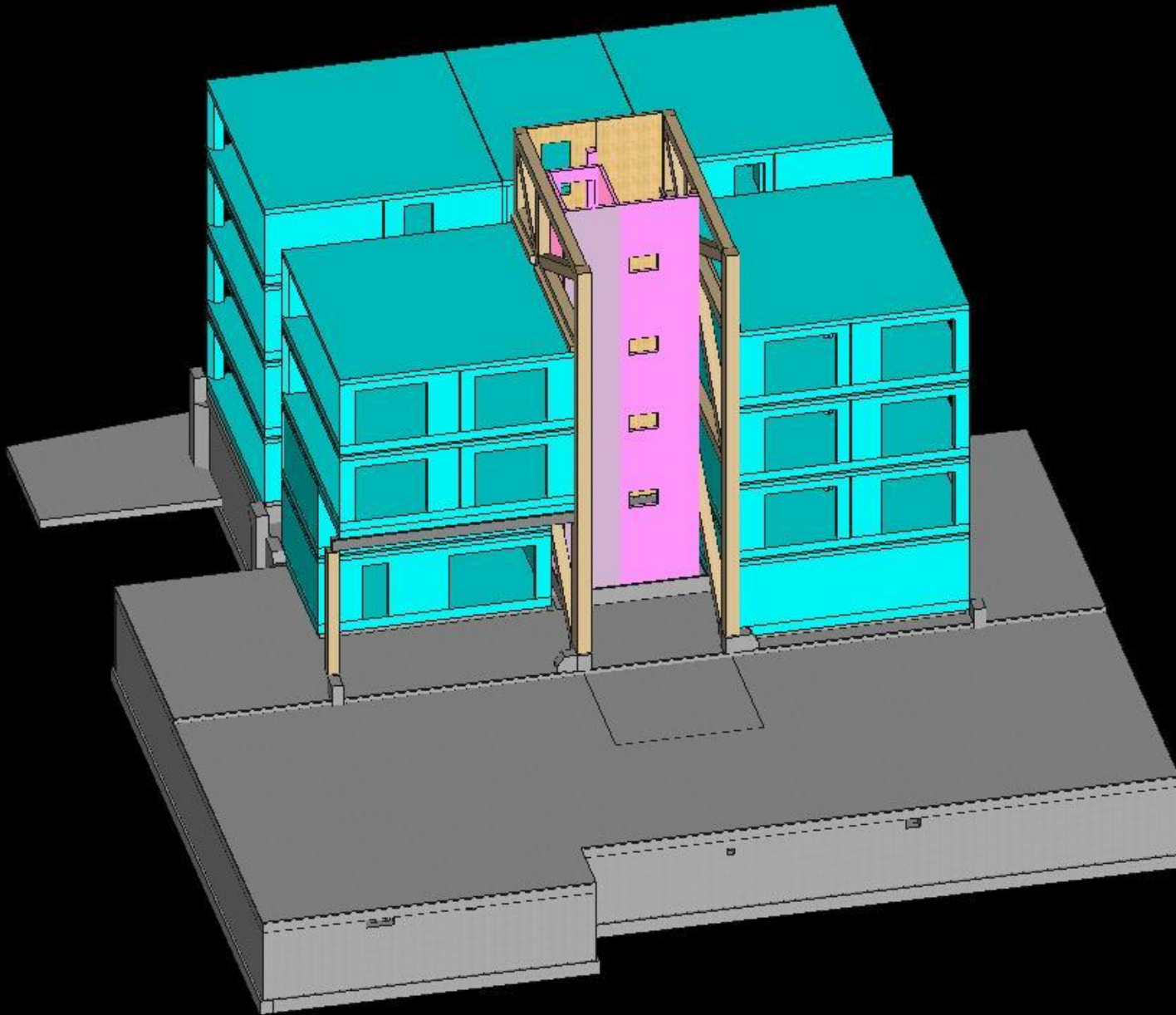
# Assembly. Step by step

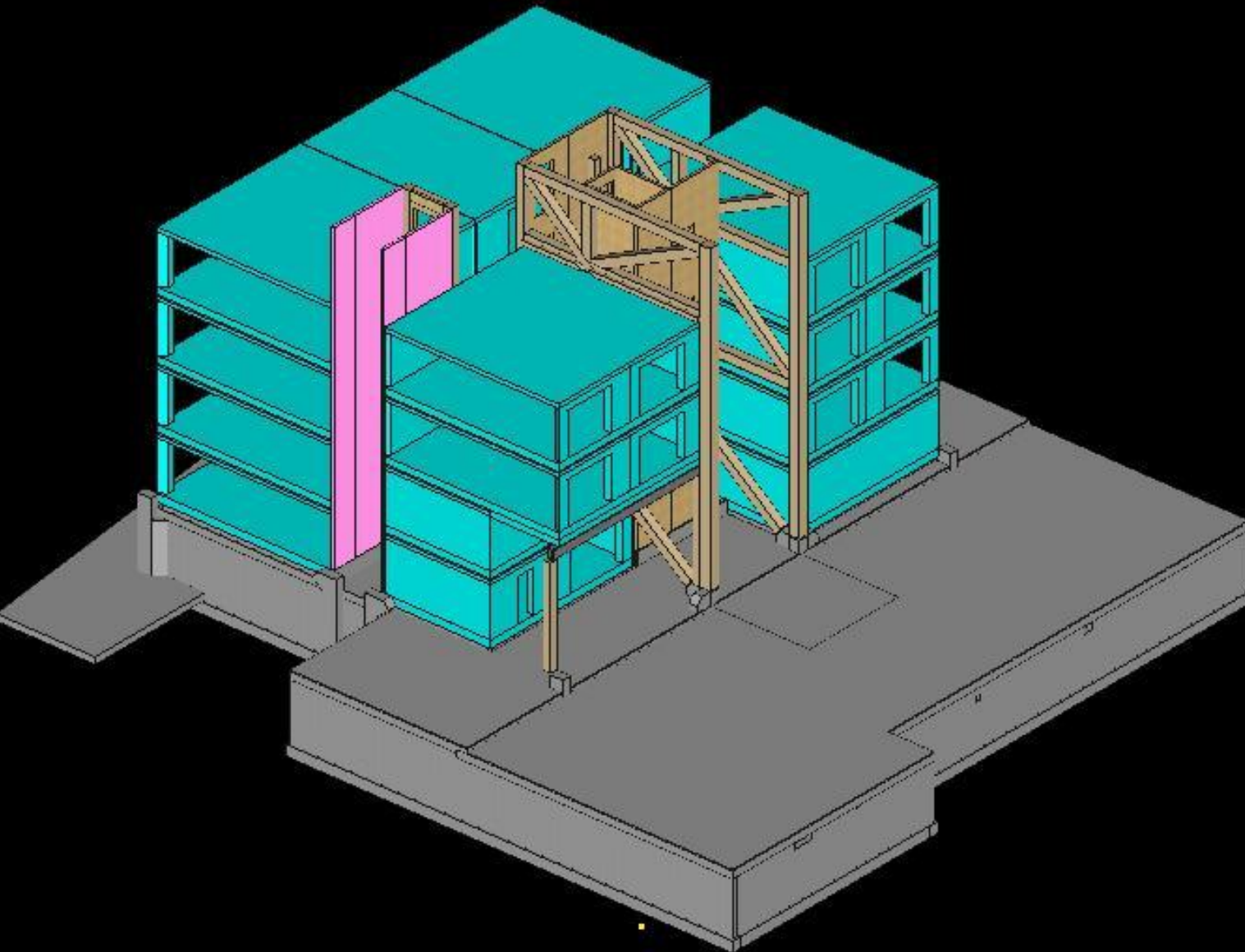




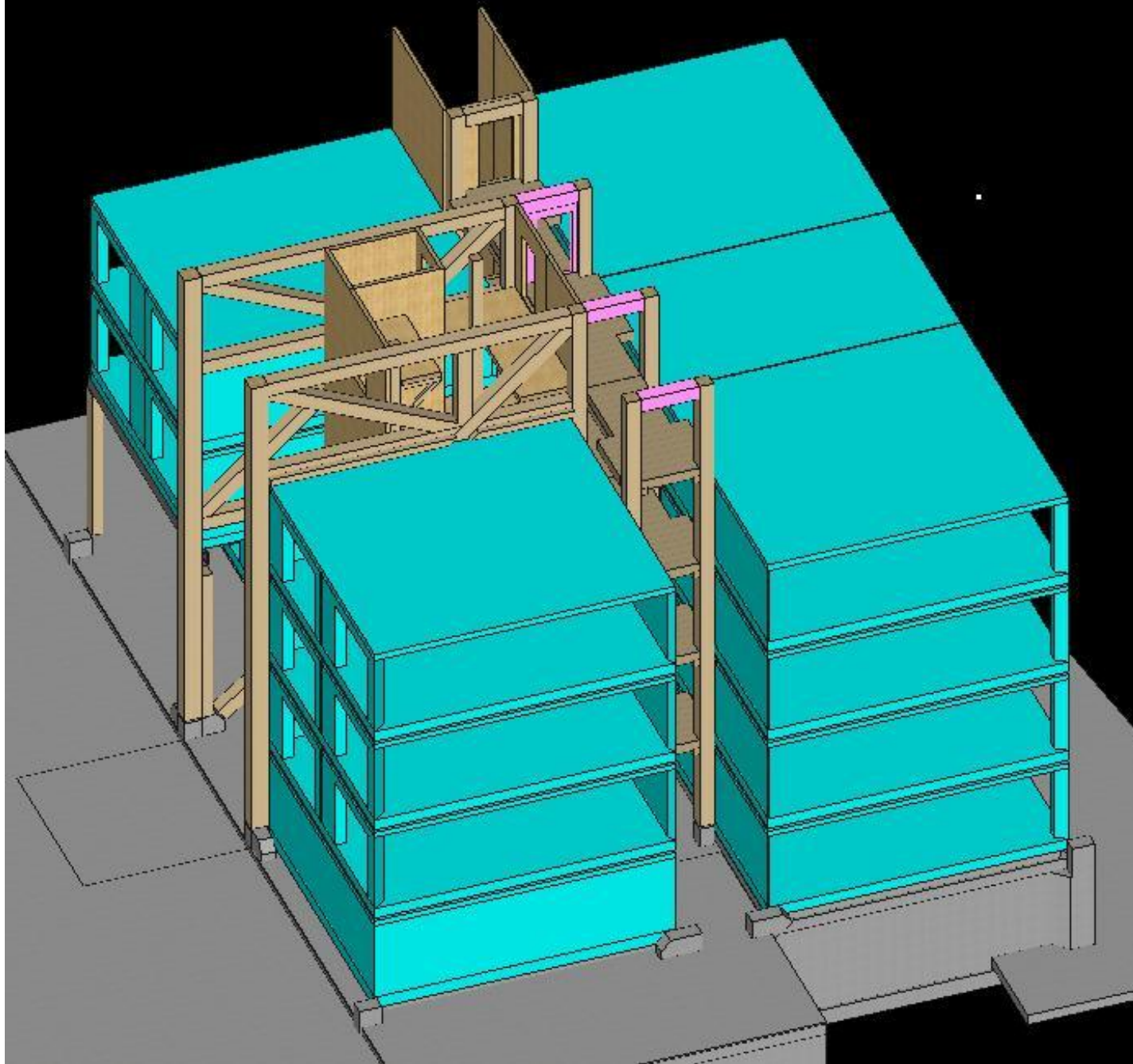




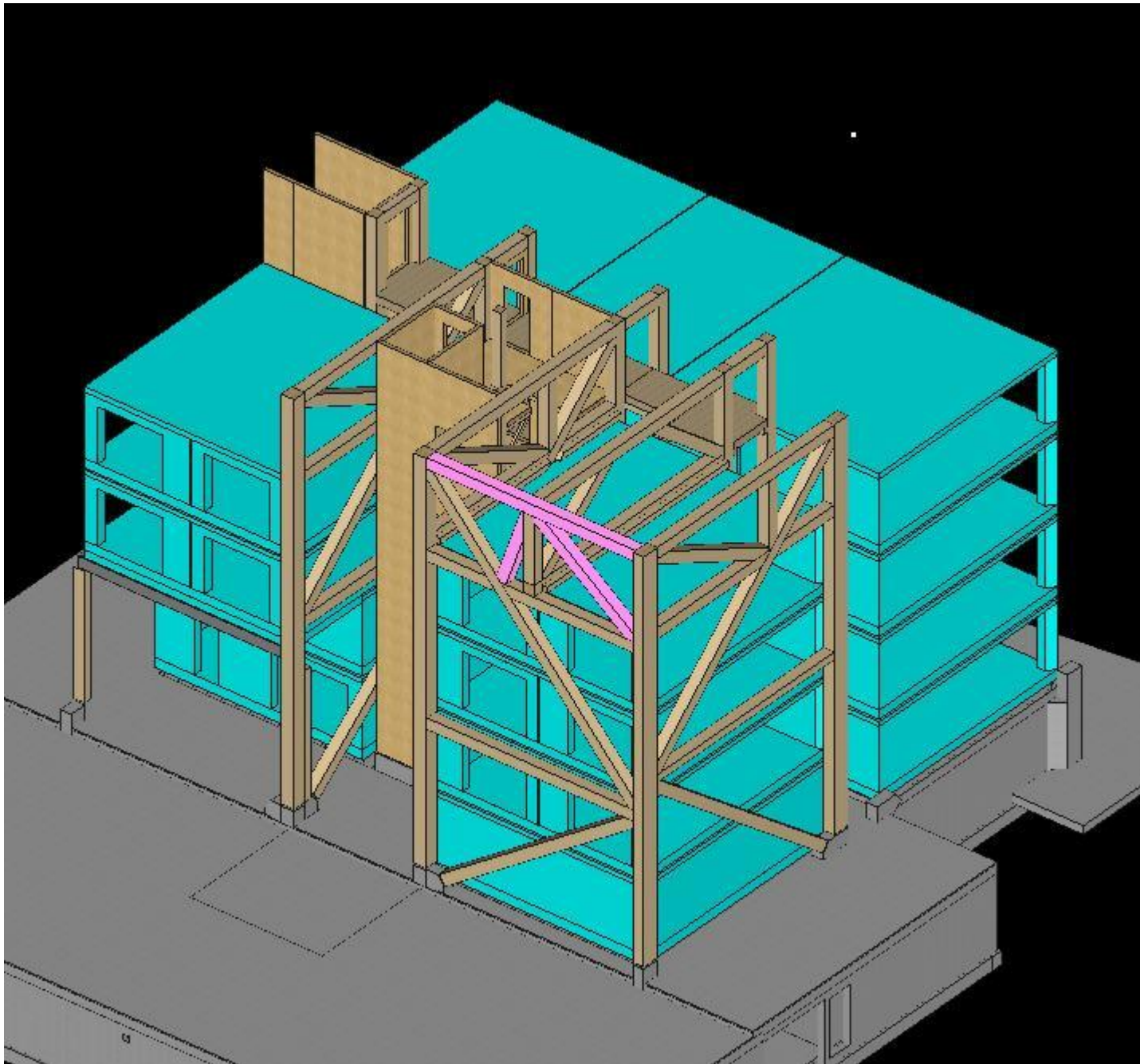


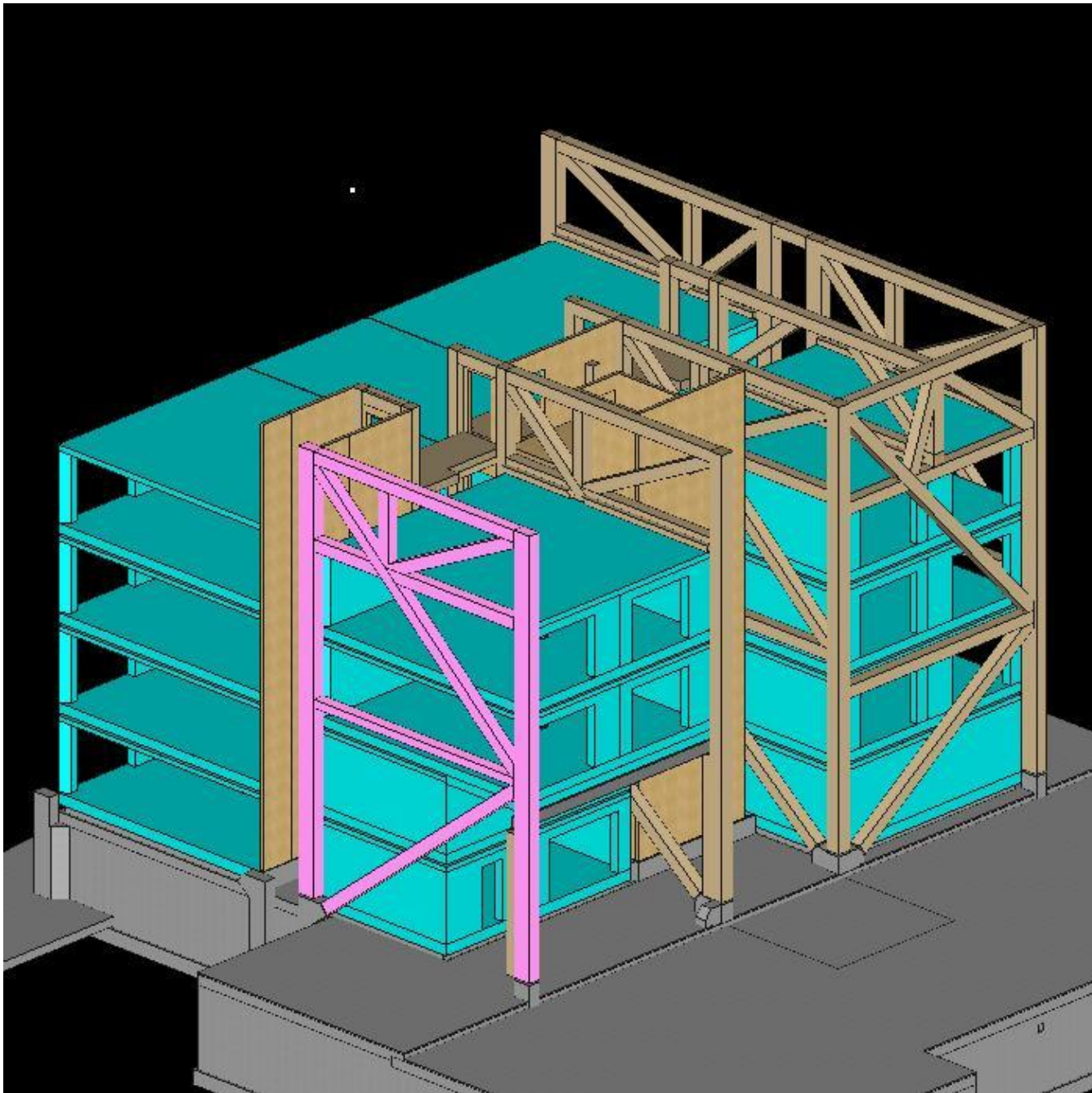




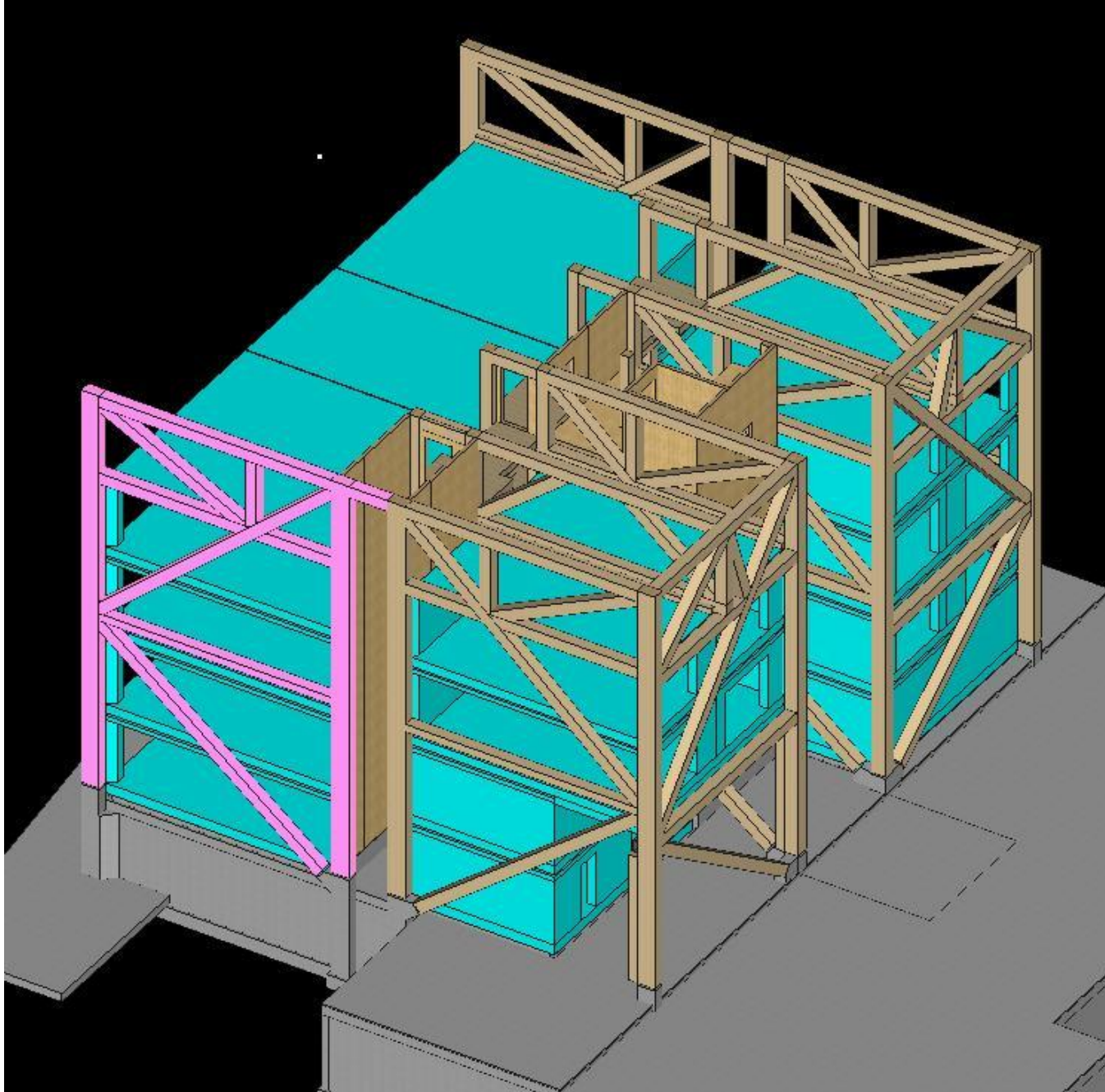




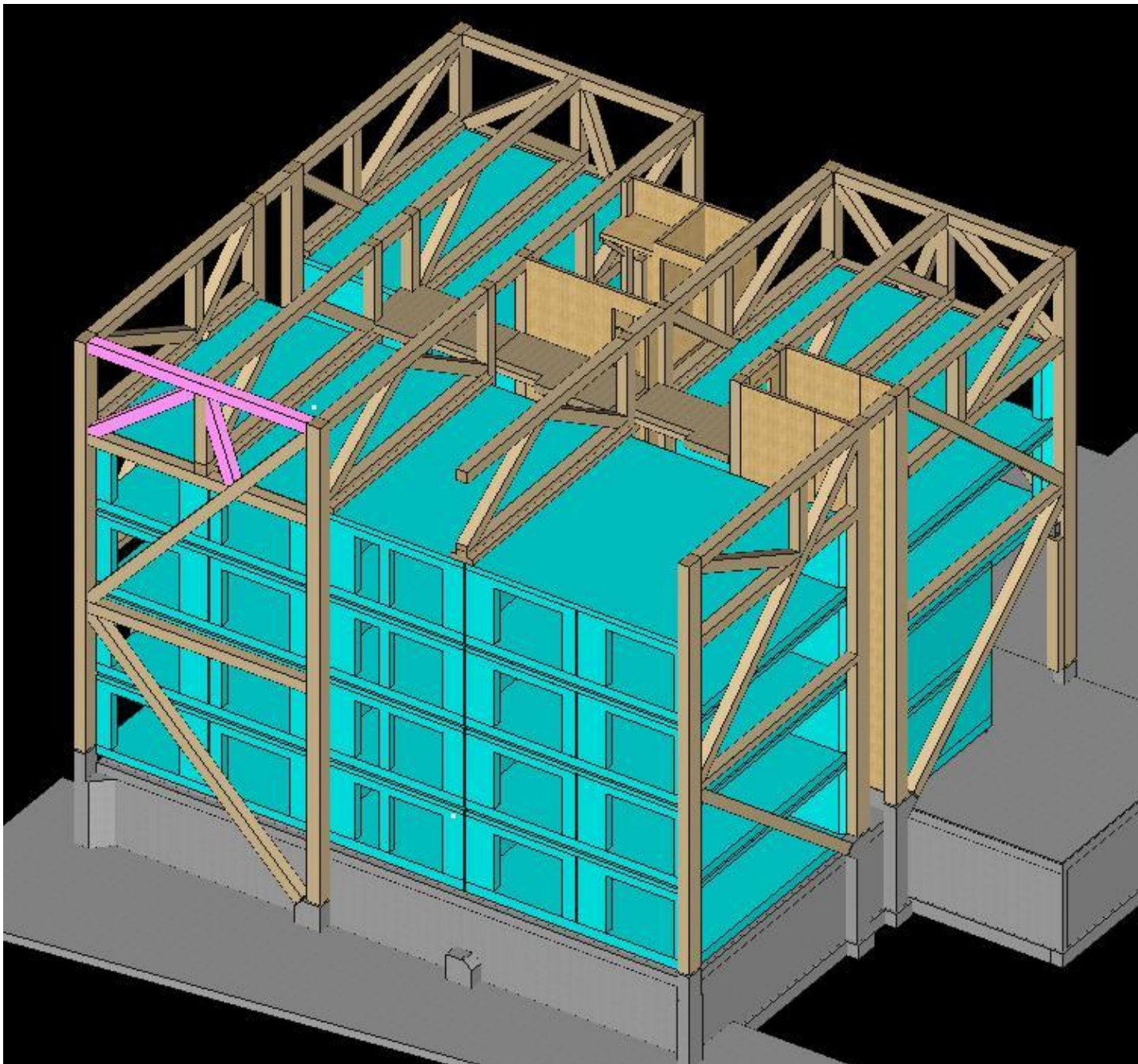


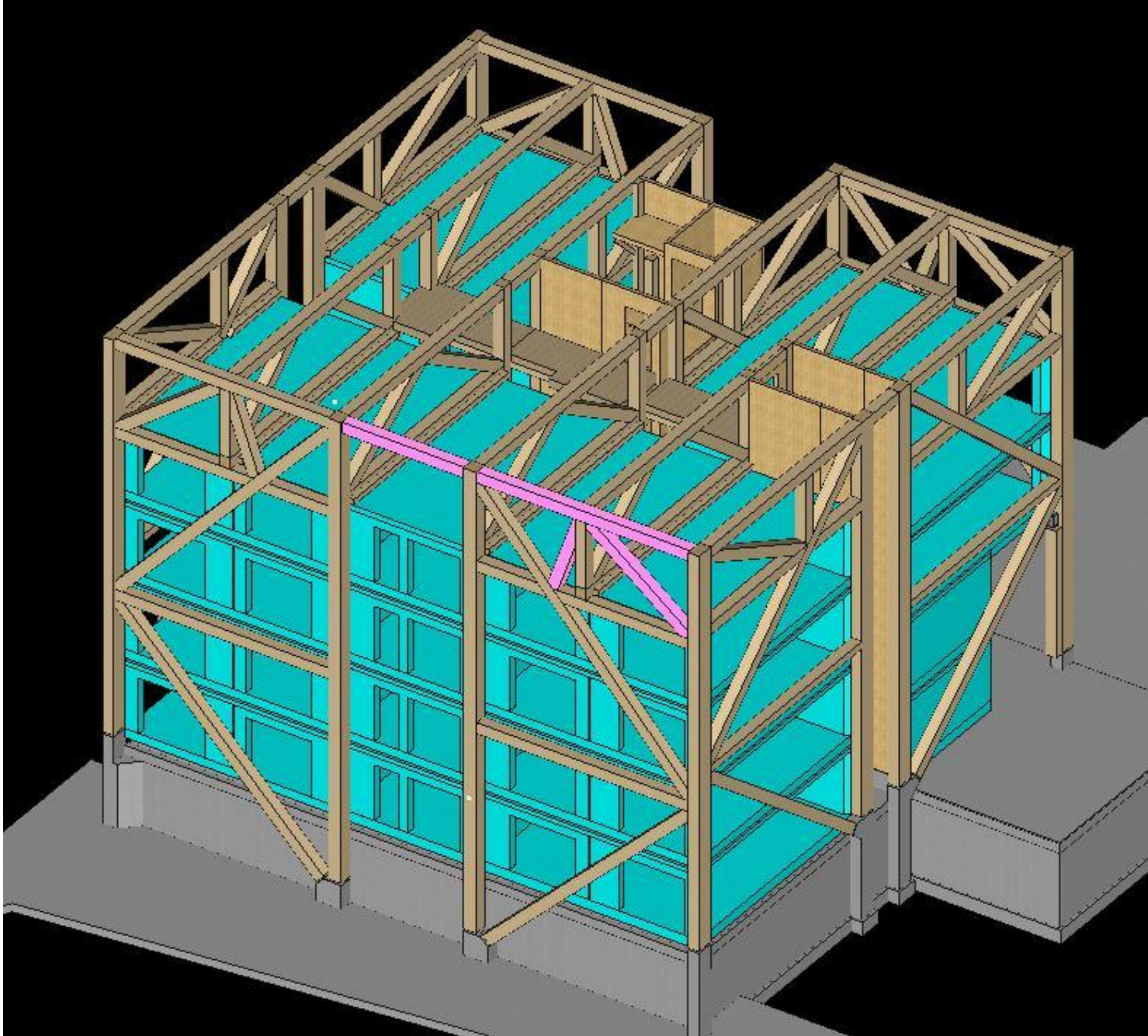




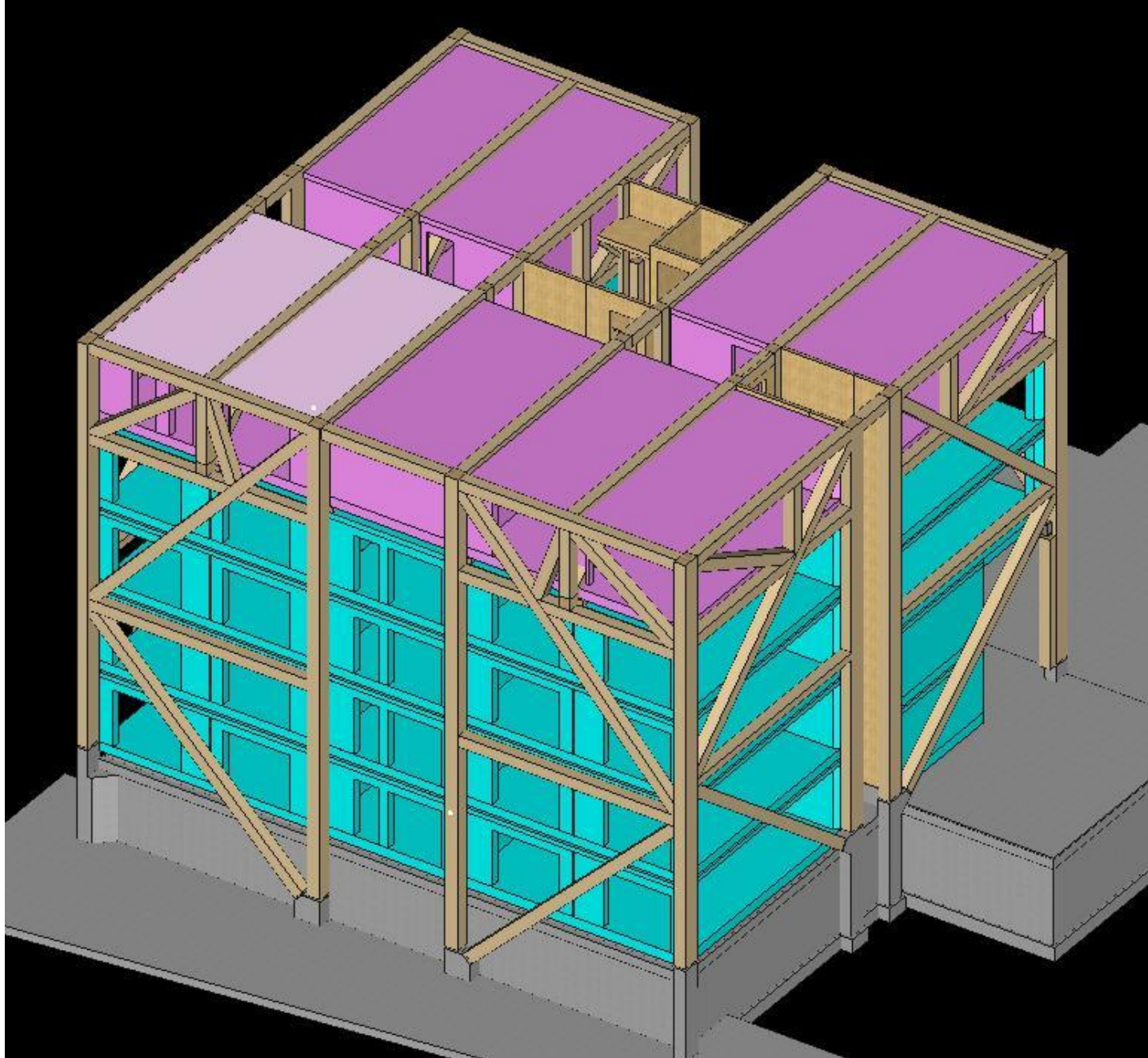




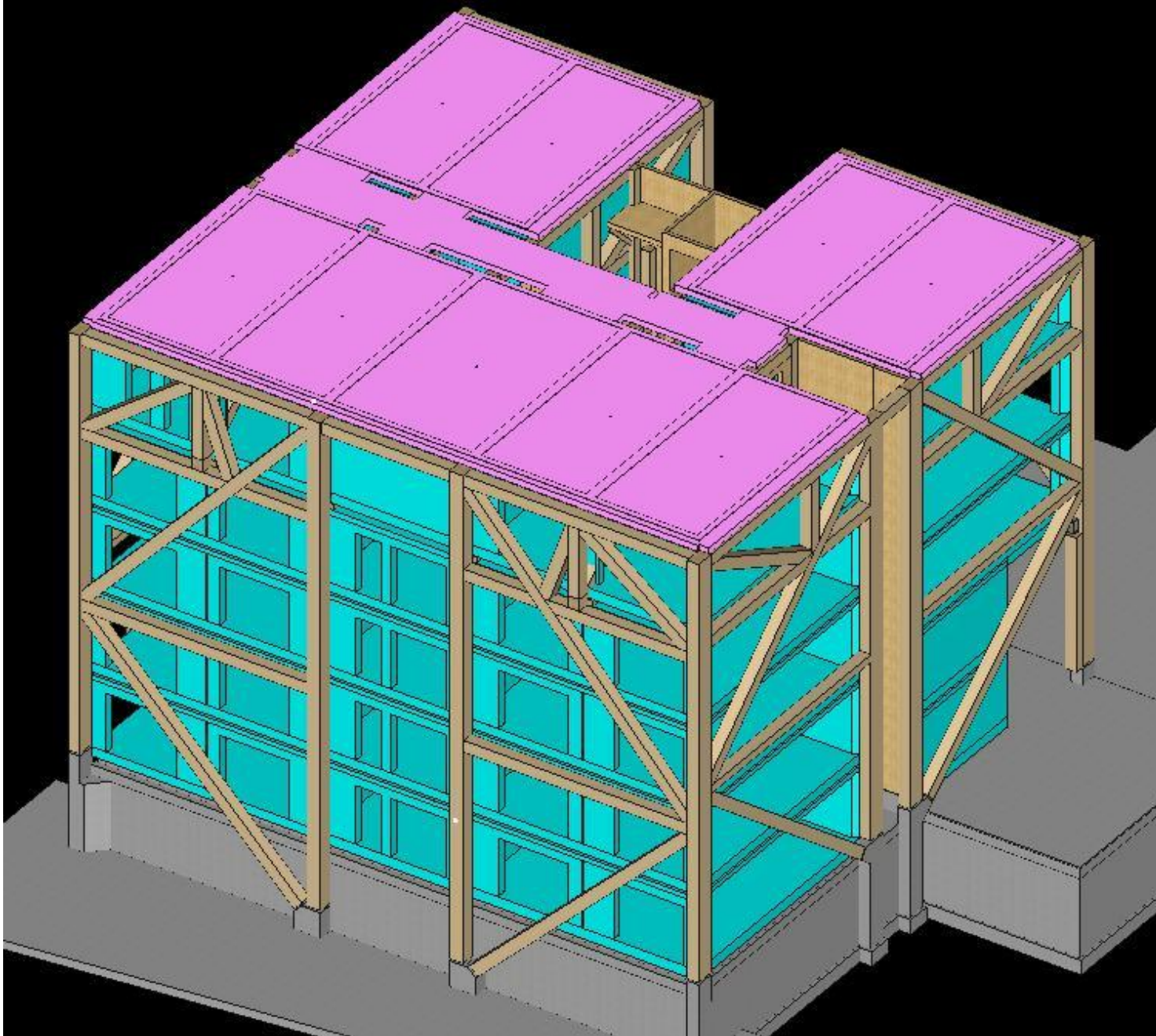


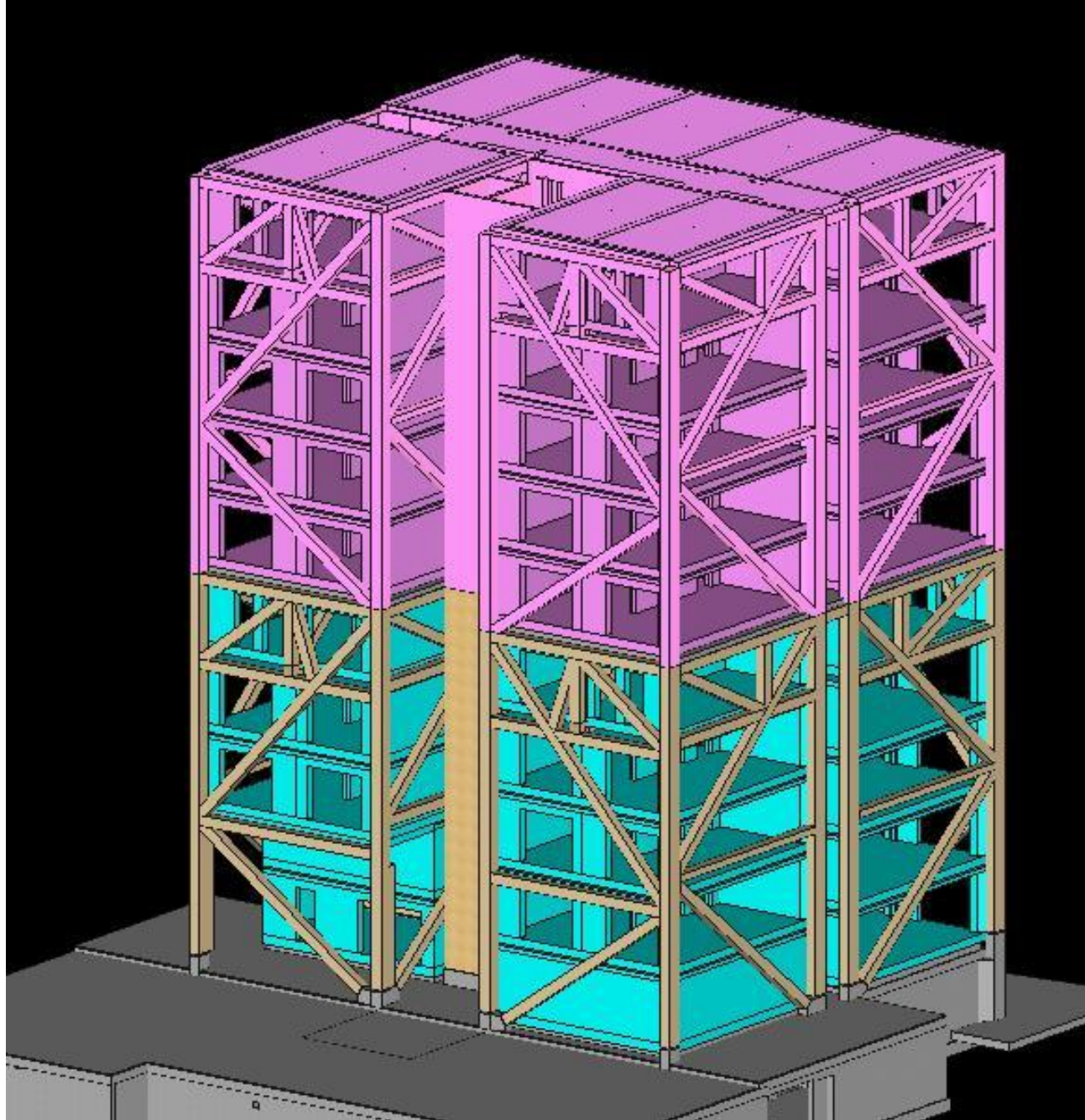




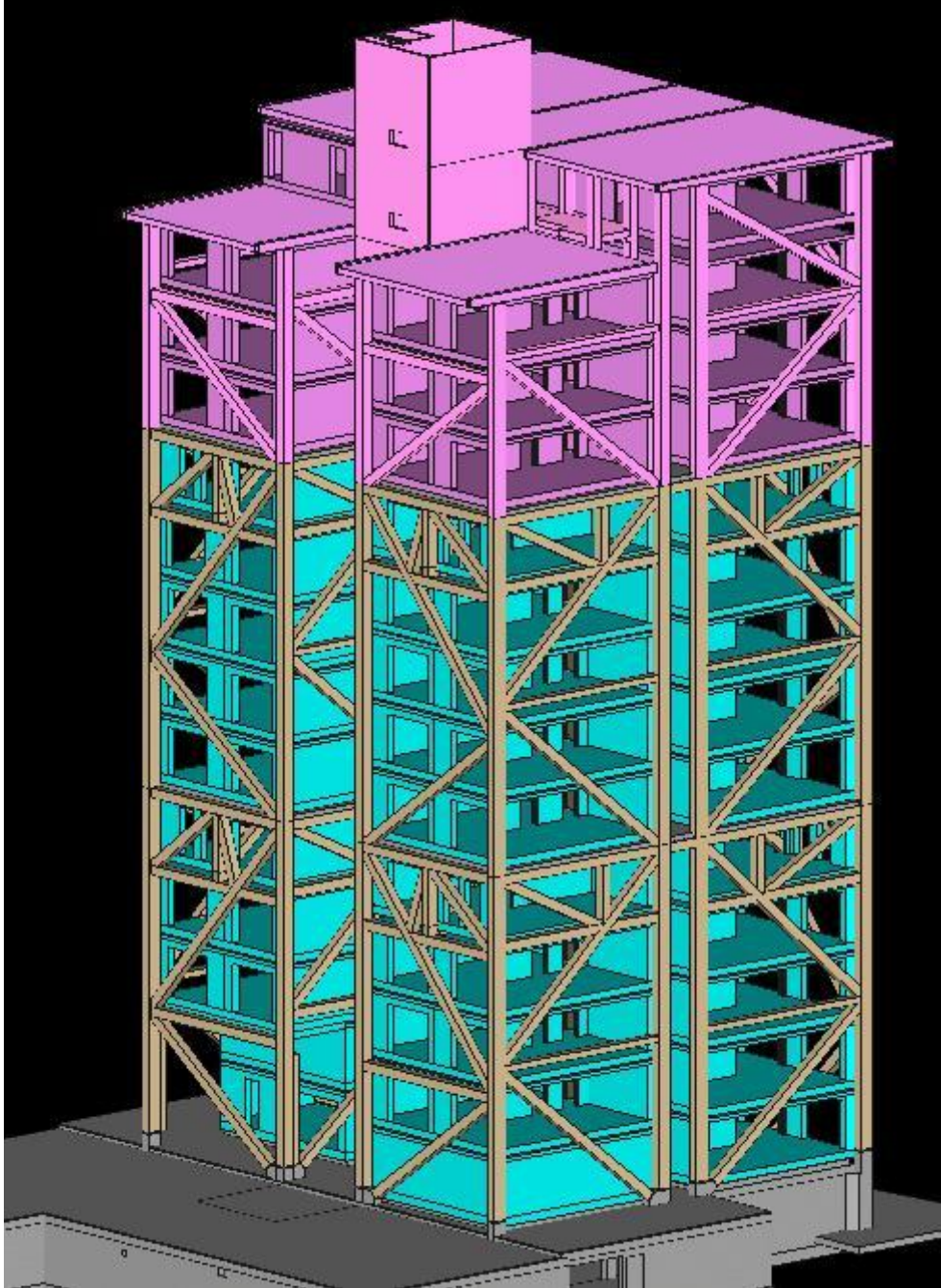


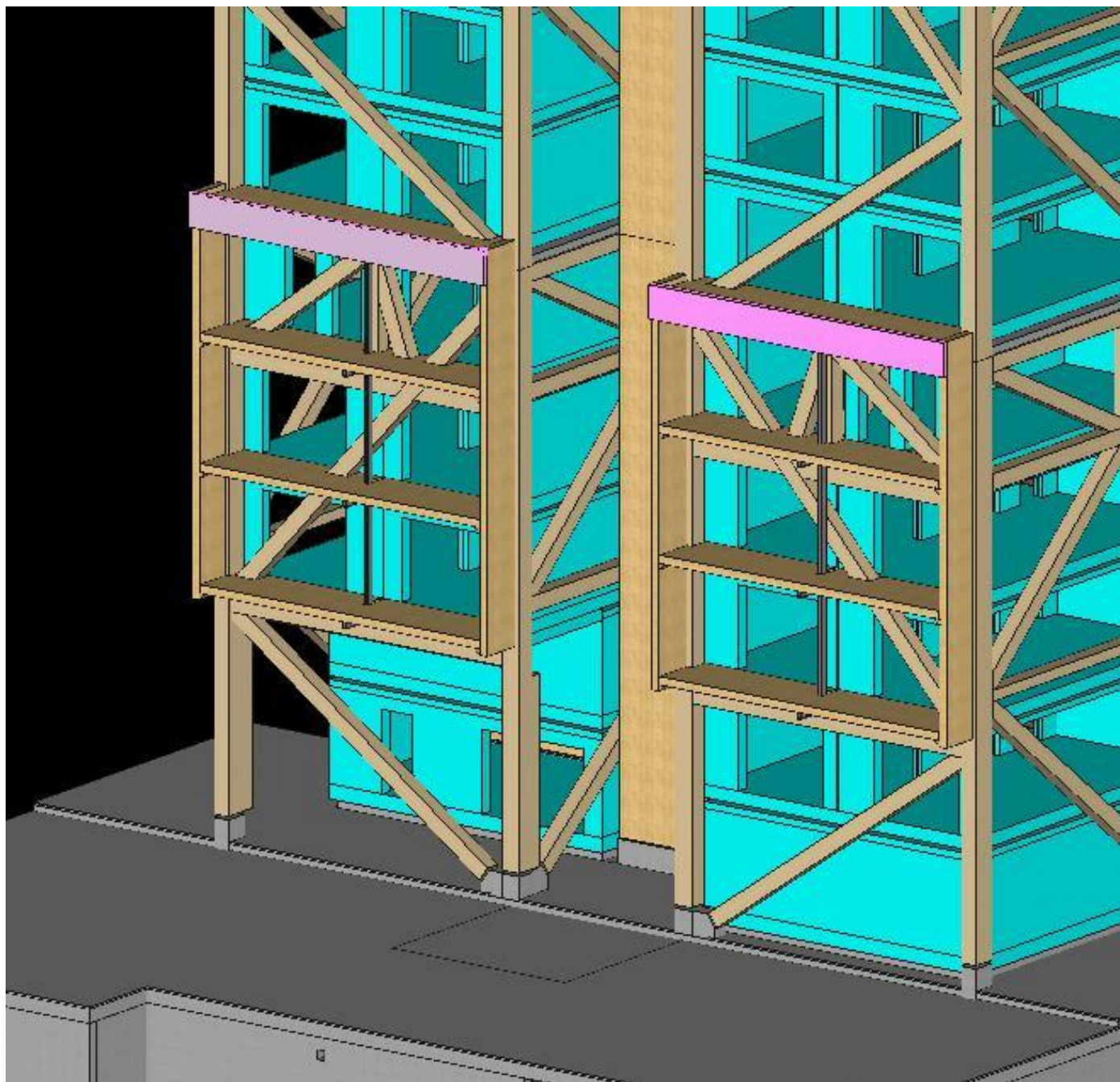




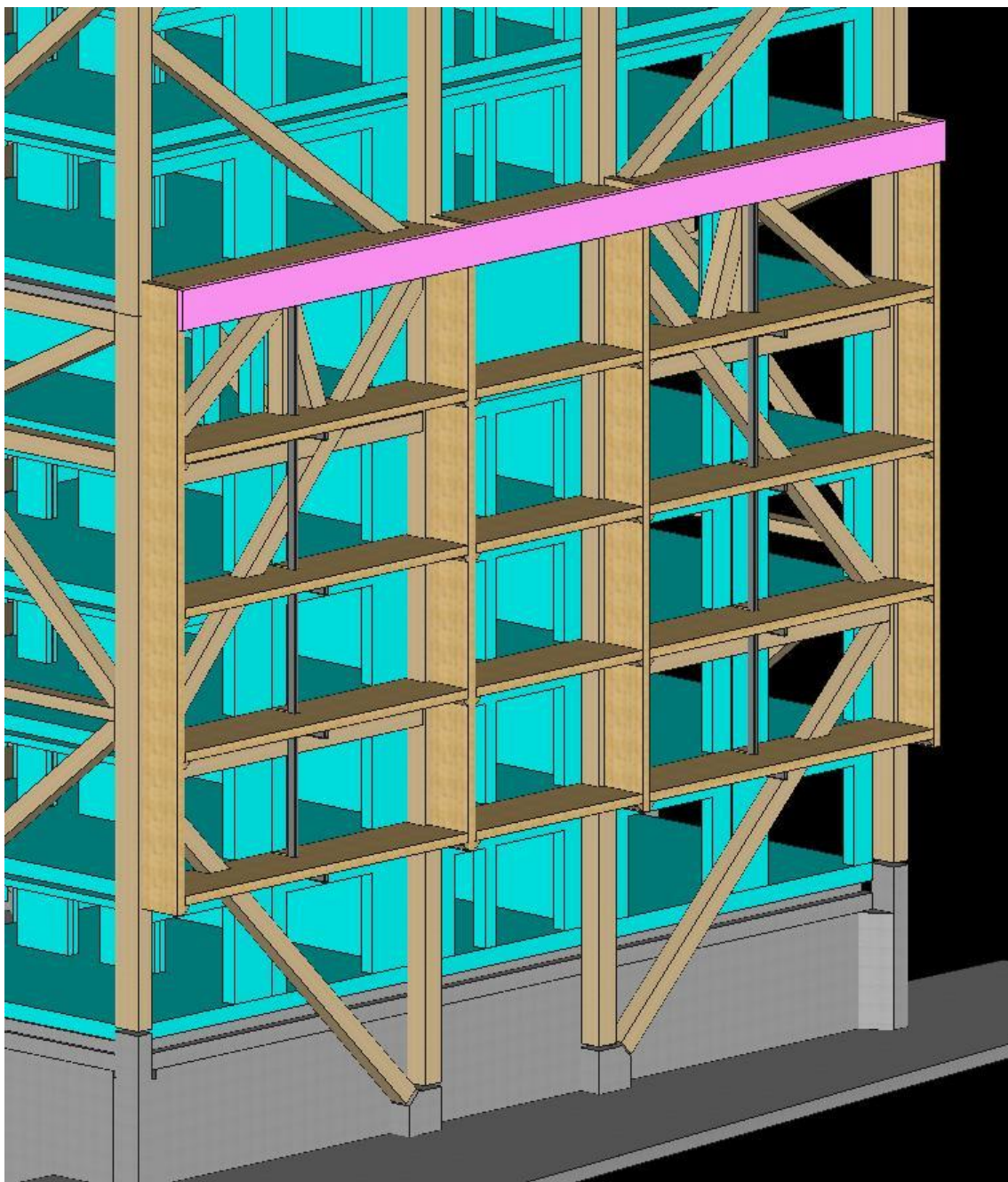


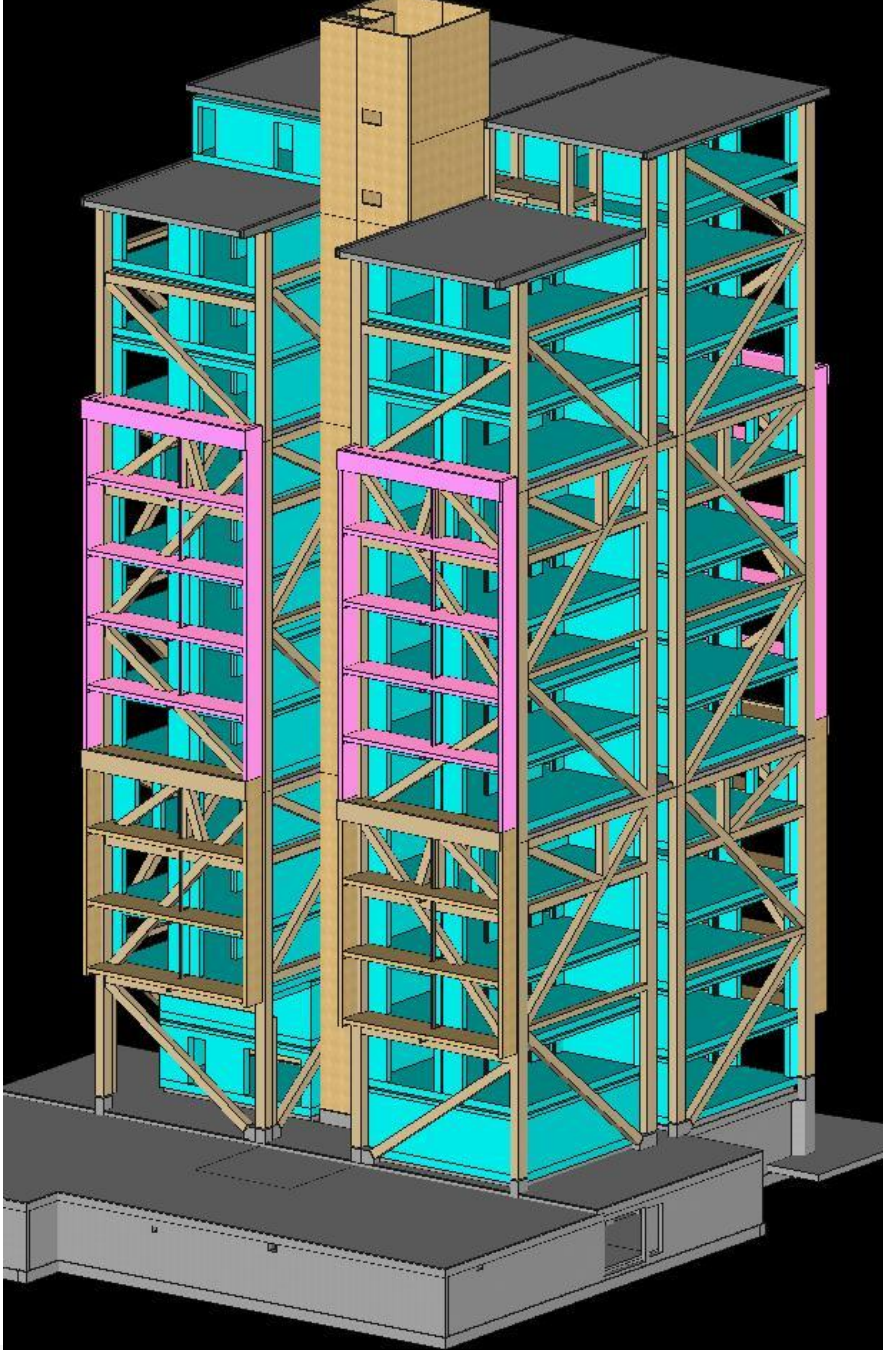




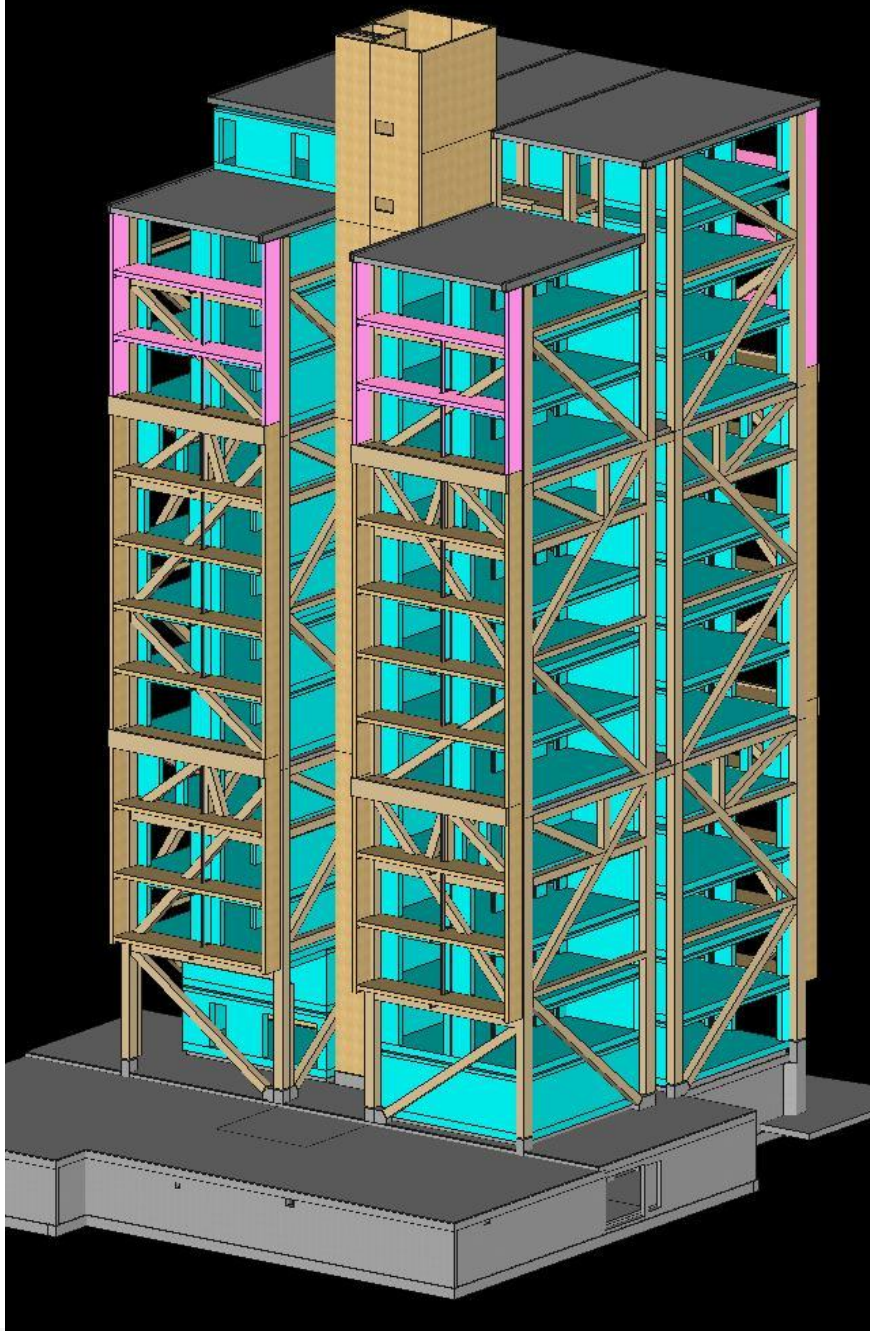














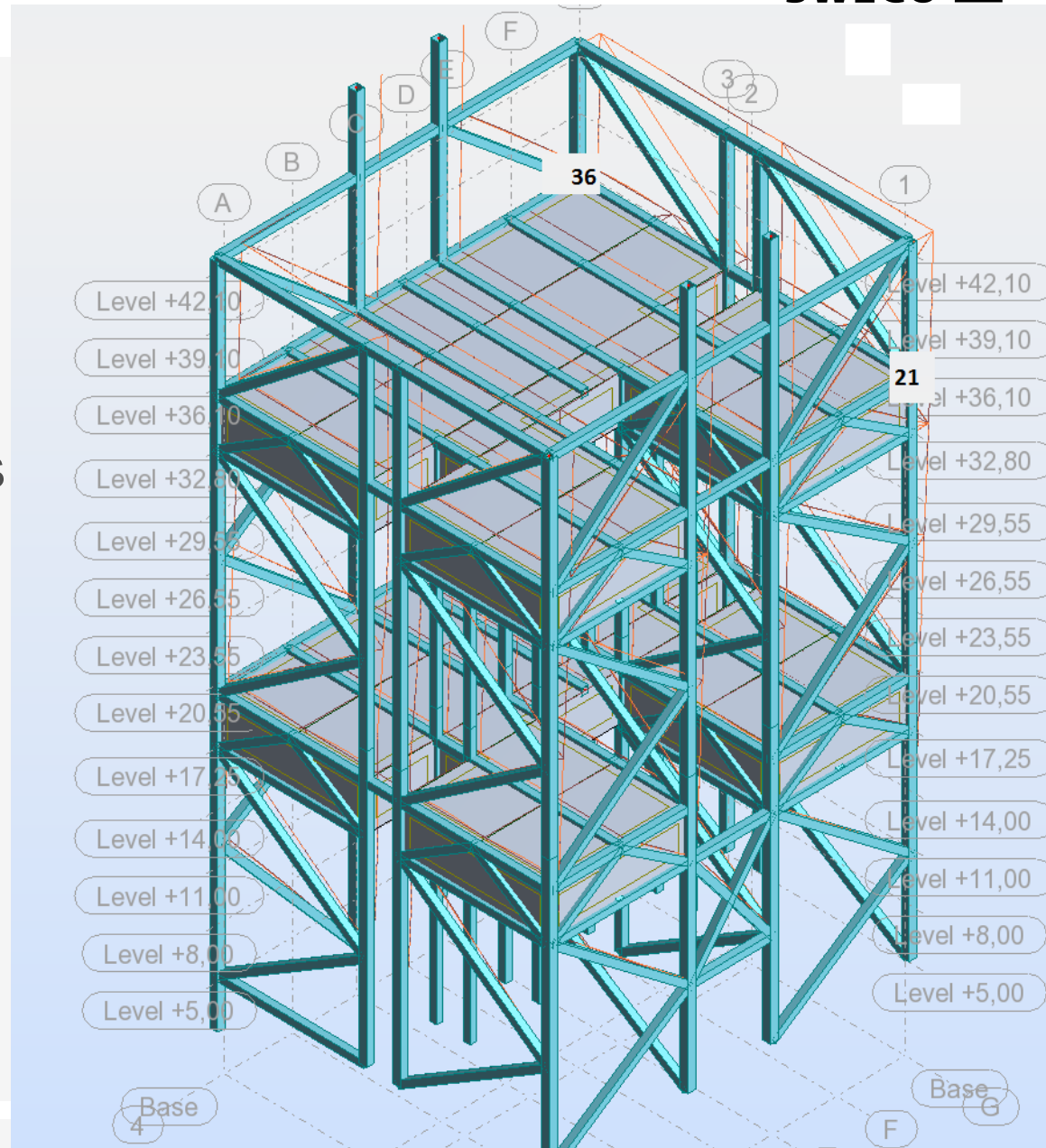
# Facts

- 550 m<sup>3</sup> glulam
- 385 m<sup>3</sup> 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



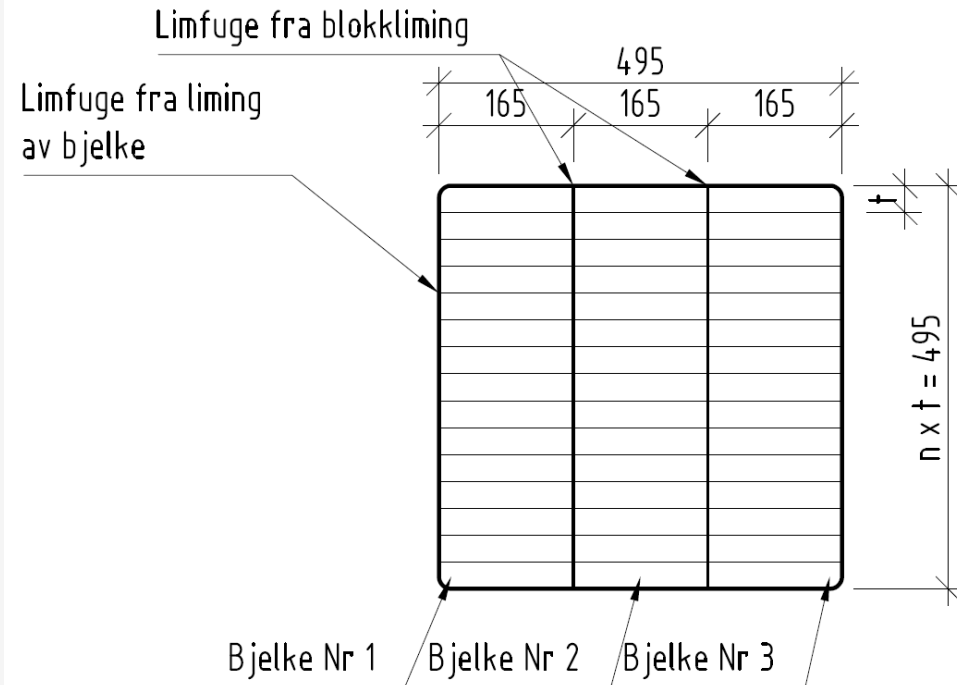
# More facts

- 70 mm max deflection
- Glulam carries all vertical load
- Concrete decks serves as extra weight, and platform for modules
- New expression: **powerstorey**
- Max acceleration in the top about 0,05 m/s<sup>2</sup>



# Even more facts

- The building will be monitored
- 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.



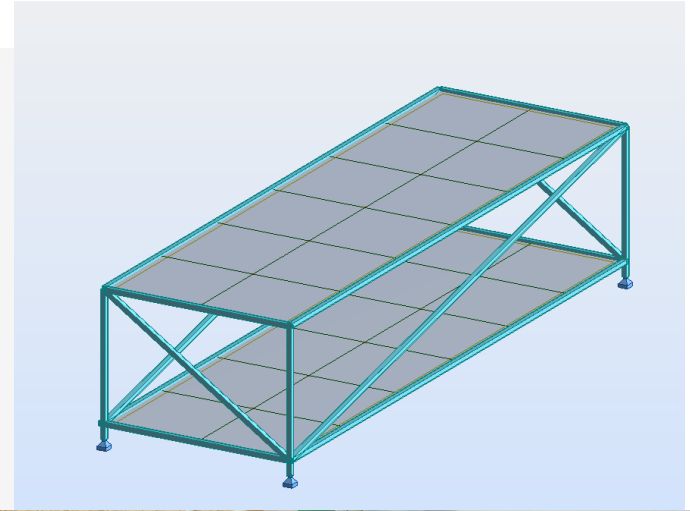


# Finding damping of modules

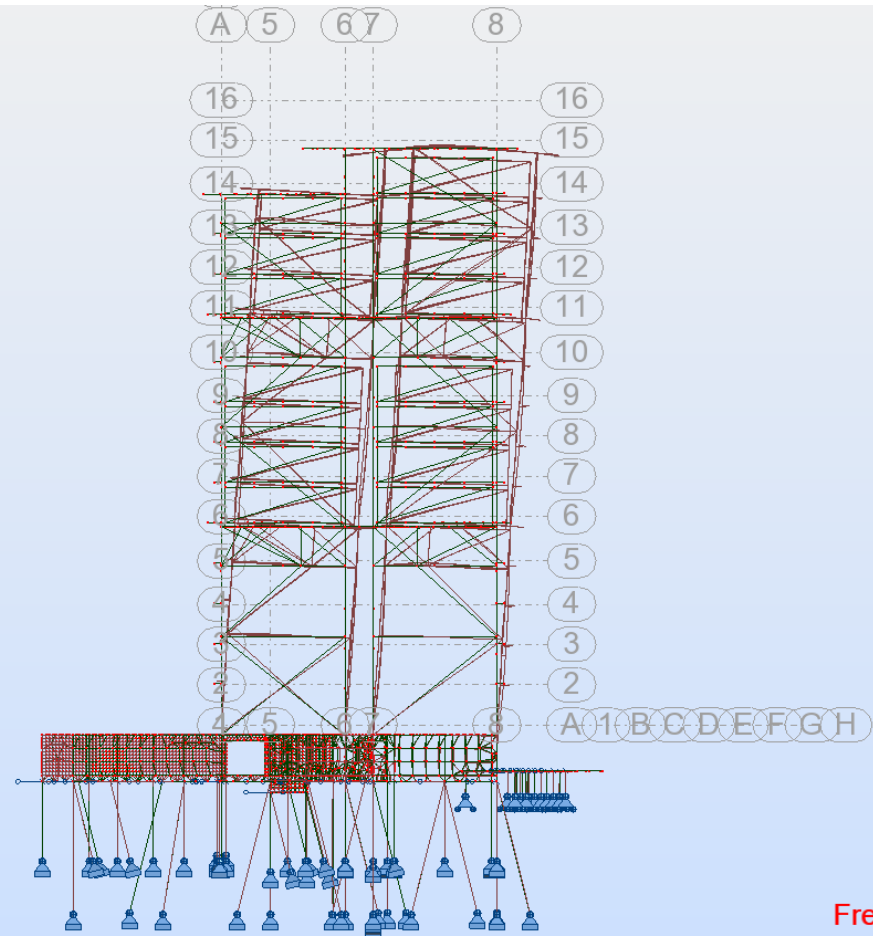
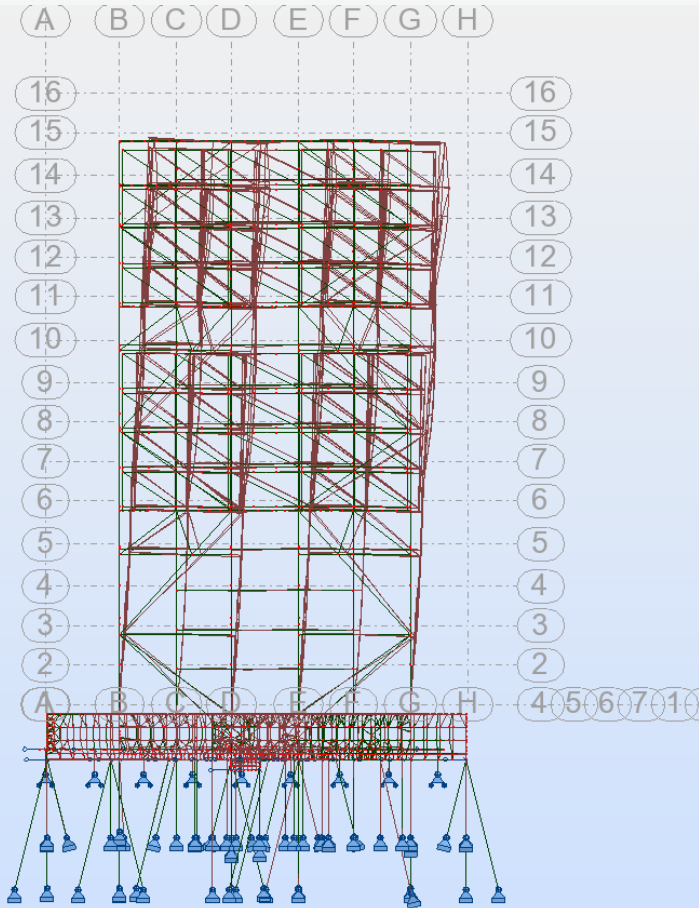


# Modelling of modules

- 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%



# Structural model



Frequency: 0,75 (Hz)  
Cases: 15 (Modal )

Frequency: 0,89 (Hz)  
Cases: 15 (Modal )



- 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.

26 of the 62 apartments are sold as of Dec 5<sup>th</sup> 2013

An additional 8 apartments must be sold before construction work can start

Buy **your** apartment here: [www.treetsameie.no](http://www.treetsameie.no)

# Vielen Dank für die Aufmerksamkeit!

