Bjergsted Financial Park, an innovative timber framed office building in Stavanger

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Abstract

Finansparken Bjergsted is an office building recently built in Stavanger, Norway, for Spare-Bank 1. The structural system above ground level uses timber as the principal load bearing elements (a natural, renewable and readily available local material). Floors are cross-laminated timber (CLT) panels supported by glued laminated timber beams and columns. For strength and complex geometrical requirements, laminated veneer lumber (LVL) made of beech is also used. The three basement levels and the four communications and services cores are of reinforced concrete. Mass timber structural elements are engineered for strength and are prefabricated with strict tolerances for a rapid construction process using mainly direct contact timber connections, without metal fasteners. The beams are shaped and fabricated with openings to suit both the architectural aesthetics and services requirements by means of a fully integrated BIM system.

Keywords: Direct timber connections, Glulam, LVL beech, BIM, double curvature stairs

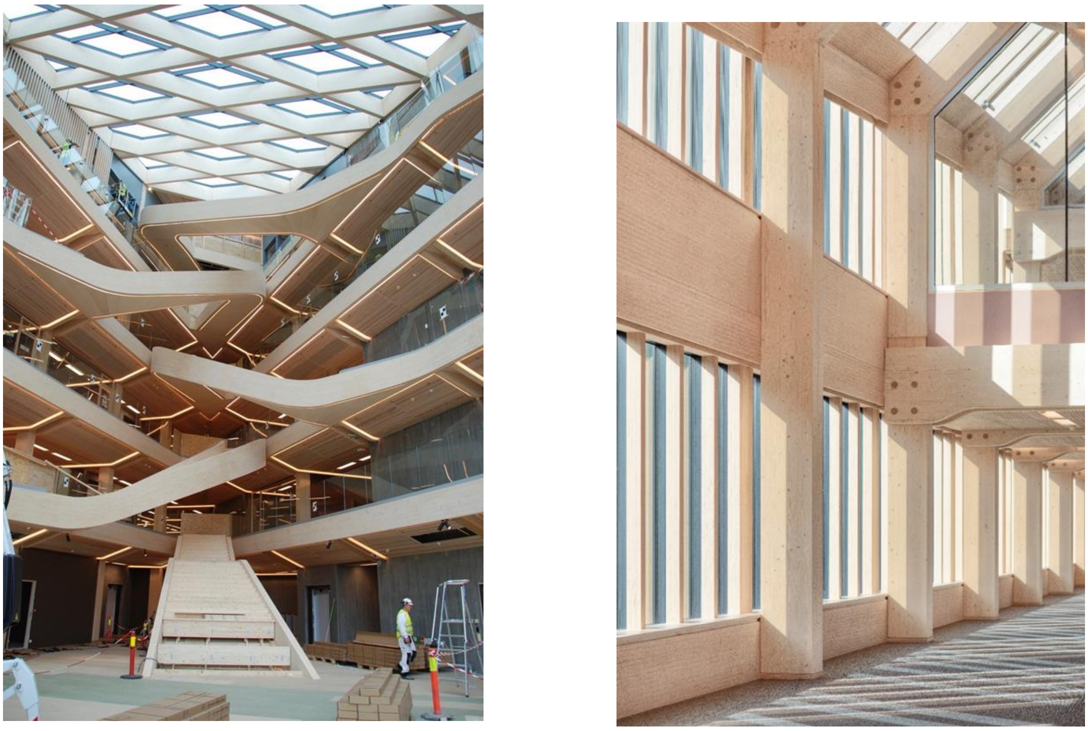

Figure 1: Interior with exposed timber structure (© Helen & Hard)

1. Introduction

This project uses a traditional building material, timber, combined with modern design, detailing and fabrication techniques. Degree of Freedom has been involved, as part of the design team, from concept design through to construction. We have worked in conjunction with the architects Helen & Hard and Saaha during the whole process and during the preliminary design we have had the remarkable technical support from Creation Holz, as timber experts. We have had also a close collaboration with Moelven Limtre AS, who is the main fabricator of the timber elements.

This paper highlights why the timber is taking advantage as a structural element against the typical solutions in concrete or steel. Furthermore, it is explained the key aspects of the design:

1. Choice and use of different mass timber elements to take into account their inherent structural capabilities and to fulfil the architectural vision.
2. Timber connection design and fire protection
3. Use of 3D finite element modelling for timber design.
4. Fully integrated BIM for construction
5. Design of double curvature main stairs

2. Design principles

The geometry, materials and use of the structure have been treated as a whole to define both the inner and outer aspect of the building.

2.1. Architectural concept

The wedge shape, in both plan and elevation, creates a building that changes character and scale to the different surrounding urban landscapes. It is located in a contrasting situation between Bjergstedparken's more monumental buildings in the north, and a cluster of small, old houses in a more urban situation in the south.

The architecture is based on the game of contrasts between a clear and taut exterior and a more organic interior.
The use of timber as a natural material has a positive effect on human perceptions and experience of their surroundings and has been shown to reduce stress. It is acoustically beneficial for an open plan office space compared to more conventional construction materials.

A central atrium emphasizes the timber structure and organic feel of the interior spaces, allows natural light into the building and connects with the exterior park.

Figure 2: Exterior views of the building (© Helen & Hard|Saaha)

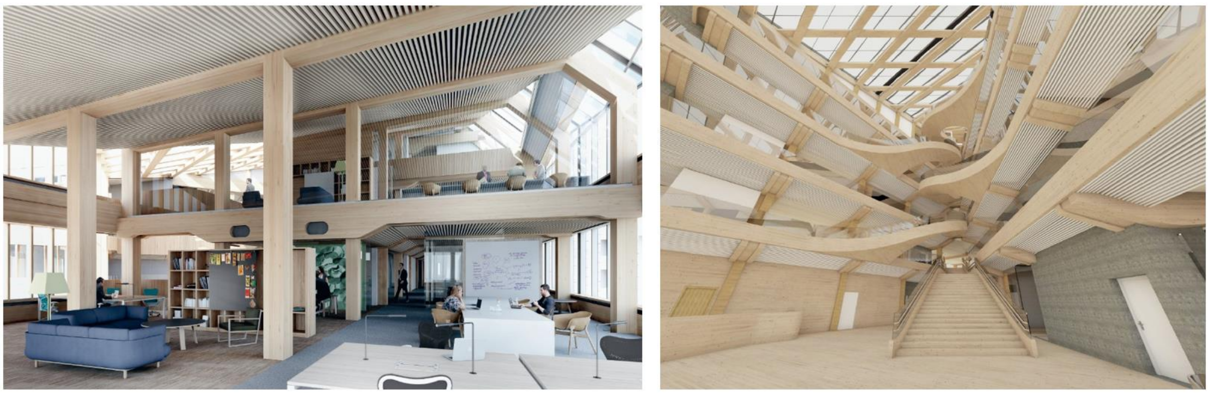

Figure 3: Interior with exposed timber structure (© Helen & Hard|Saaha)

2.2. Material selection

From the beginning, the design team was aware of the concept that timber, as a construction material, has intrinsic healthy and environmental benefits. When harvested responsibly, wood is arguably one of the best tools architects and engineers have for reducing greenhouse gas emissions and storing carbon in buildings.

The following were important aspects for the construction material choice:

- Competitive cost
- Achieve a healthy and clean working environment
- Reduction of CO_2 emissions
- Reduction of construction time and reduction of waste
- Use timber as a symbol for the Bank values
- Obtain BREEAM-NOR excellent certificate
- Aesthetics inner properties of the material

In order to come to a final decision and to convince the future owner, a selected portion of the building was economically analysed during the preliminary design for two possible alternatives: wooden/concrete and steel/concrete structure.

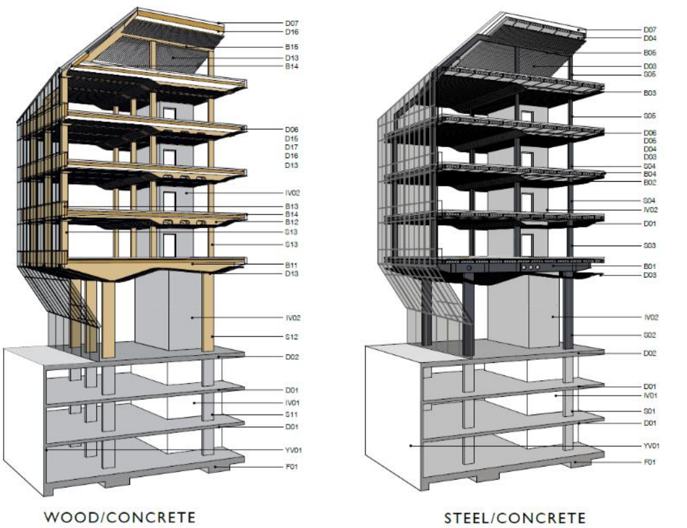

Table 1. Economic comparison

	Item	Steel [kr/m²]	Timber [kr/m²]	Difference
2.1	Foundations	323	323	0%
2.2	Bearing system	1362	1478	+8.5%
2.3	Outer walls	2038	2038	0%
2.4	Inner walls	1201	1201	0%
2.5	Floors	3176	3373	+6.2%
2.5.1	*Slabs*	*1152*	*1489*	*+29.3%*
2.5.2	*Coating*	*764*	*764*	*0%*
2.5.3	*Ceiling*	*1260*	*1120*	*-12.5%*
2.6	Roof	117	187	+59.8%
2	**Total**	**8218**	**8600**	**+4.6%**

Figure 4: Study of alternatives. Cost comparison

When comparing this package of costs to the whole project cost, including general costs, the difference between steel and timber is reduced to 1.4%.
As a conclusion, due to the environmental benefits and the low economic difference, the structure is finally decided to be designed in timber. Following this premise of the project, the building also includes an energy efficient and sustainable sedum roof.

2.3. Structural system

The three basement levels are of reinforced concrete and from ground level four services and communication cores extend up to roof level also in reinforced concrete. These elements provide the overall lateral stability to the structure. Horizontal loads are transferred to these cores via the diaphragm action of 200mm CLT timber floor slabs. The footprint of the timber floor slabs reduces from levels 2 to 7 to follow the wedge shaped elevation. The roof construction is also a continuous 200mm CLT inclined slab.

The vertical load bearing system comprises of the CLT slabs spanning between the main floor beams located on a 5.4m structural grid. The CLT is supported by glulam beams (GL30c). At each grid two glulam beams are continuous across the width of the building bearing directly on to the notched glulam columns (GL30c). Columns are continuous from level 3 to roof level. The floor beams are divided into two, at both sides of the columns, to provide continuity and to facilitate erection. Each beam is made up of two 380mm wide beams glued together – an inner beam of constant depth formed by a LVL beech section and an outer glulam beam of variable depth to suit the architectural requirements. Continuity of the CLT slabs over the main beams is provided by LVL spruce panels (Kerto Q). Figure 5 shows the slab elements where Kerto Q panels are represented in yellow and position of concrete cores in blue.

Figure 5: Typical plan and typical beam cross section

At level 3 a transfer structure is required to redistribute the column loads to the ground floor columns that are set back from the façade to reduce the building footprint at street level. The ground level at east side has a double height with a reduced number of columns to create a distinctive space at the entrance of the building. The columns and beams at this level are LVL beech (Baubuche S and Baubuche Q) [1].

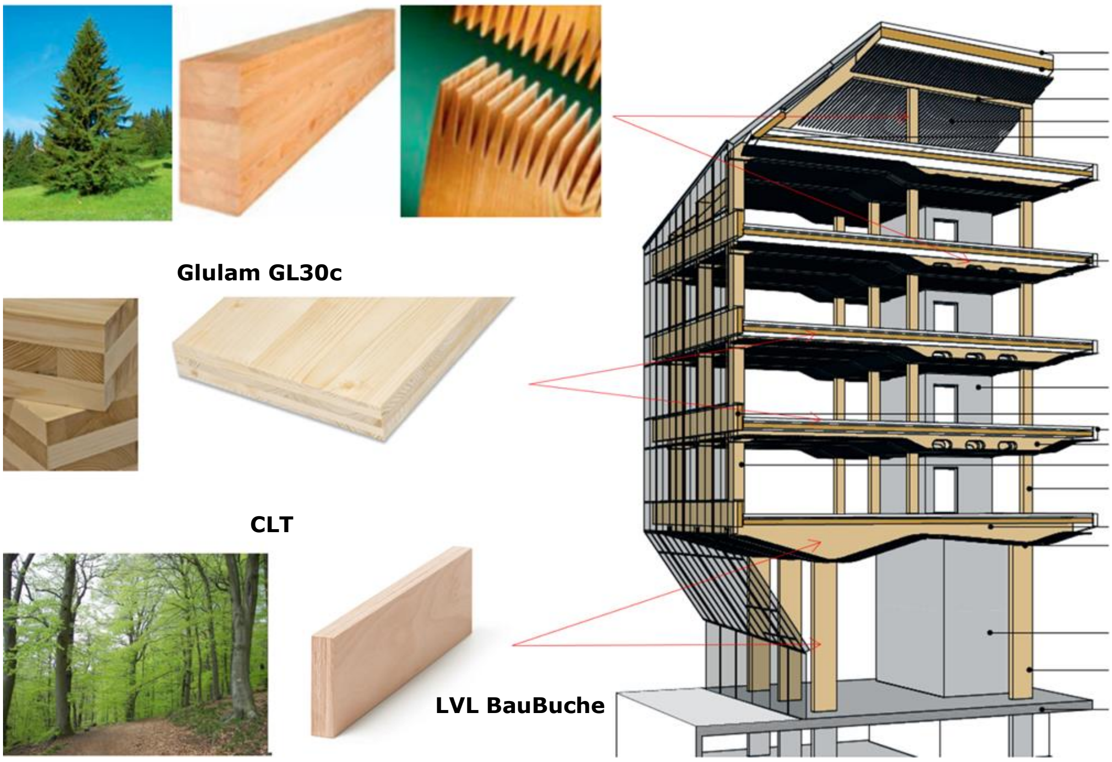

Figure 6: Different types of structural timber

The timber beams at each floor level include openings for the mechanical and electrical services requirements. The design of the structural members is fully integrated with the architectural and services necessities. At preliminary design stage detailed consideration was given to the fabrication and erection of the timber elements.
The façade glazing is supported by a deep timber edge beam (GL70). This beam provides rigidity to the CLT slabs particularly at the cantilevers

2.4. Use of Laminated Veneer lumber made of beech

LVL made of beech is used for the beams and columns in the transfer structure between the ground floor (Level 1) and Level 3. The product used is Baubuche with beech parallel veneers (Baubuche S) or cross-laminated beech veneers (Baubuche Q).
Baubuche Q is used for the beams at level 3 as it has a better performance for service openings due to the crossed laminations.

In addition 60mm or 80mm insertions plates of Baubuche S are also used in the composite glulam floor beams where they bear on to the columns. Glued laminated timber is weak in bearing in compression perpendicular to the grain (2.5MPa) while the beech LVL is much more resistant (14MPa).

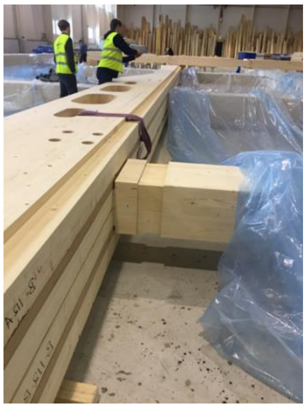

Figure 7: LVL beech beams and columns. LVL insertions.

3. Connections and Fire design

3.1. Connections

Connections are realized in a number of different forms depending on the magnitude and type of forces to be transferred. The project premise is to maximize the use of timber to timber connections without steel. The design philosophy is for connections capable of transferring all the necessary forces by direct pressure between two timber elements where possible.

Timber to timber connection types include:
- Direct bearing between timber elements (beams - columns)
- Glued panel insertions
- LVL timber dowels with Baubuche-Q inserts

Only where necessary, due to structural or erection reasons, the following types have been used (not visible):
- Self-tapping timber screws
- Proprietary timber connectors – Sherpa
- Threaded steel rods – for reinforcement at openings or notches
- Steel dowels with steel plate

Due to the high quality and the strict tolerances in the fabrication of the mass timber components the connections can be executed with a high level of precision and safety.

Figure 8: On site picture. Direct timber connection

Figure 9: LVL beech dowel and timber cut-outs

3.2. Fire design

Well defined and predicable fire behaviour is an intrinsic property of mass timber elements and all the principal structural elements are designed to guarantee a fire bearing resistance of 90 minutes.
Timber columns and beams have been designed using the reduced cross section method from NS EN1995-1-2 [2]. This method defines a charring depth, which for this project is 70mm. This char layer insulates the core of the section preventing it heating up. This reduced section maintains its full strength and can be verified for the critical fire load combination.
All the connections are internal and protected in case of fire.

4. Finite element modelling and structural challenges

The structural model is created from the BIM model exporting the frame elements at the desired position.

4.1. Description of the FE model

The timber is an orthotropic material, therefore modifications of the elastic parameters need to be carried out for both frame and shell elements.
However, the challenge of this project is the full definition of each connection between timber elements in the whole building and to model its behaviour. For this reason, it was decided to implement a detailed hybrid FEM with frames and shell elements at the exact position (figure 10) connected with link elements which are defined with the calculated stiffness for each degree of freedom (k_{ser}) according to the type of connection to be developed.
The slabs work both as plate and membrane to transfer horizontal loads to the concrete cores by direct contact (no tension nor shear forces). For this reason, it has been used non-linear elements which work only in compression (gap type link) around the concrete cores (wrench effect).
The joints between the CLT panels have been represented with up to four different types of links with the desired stiffness.
The portal frames are conceived to carry only the vertical loads and not to resist the lateral actions.

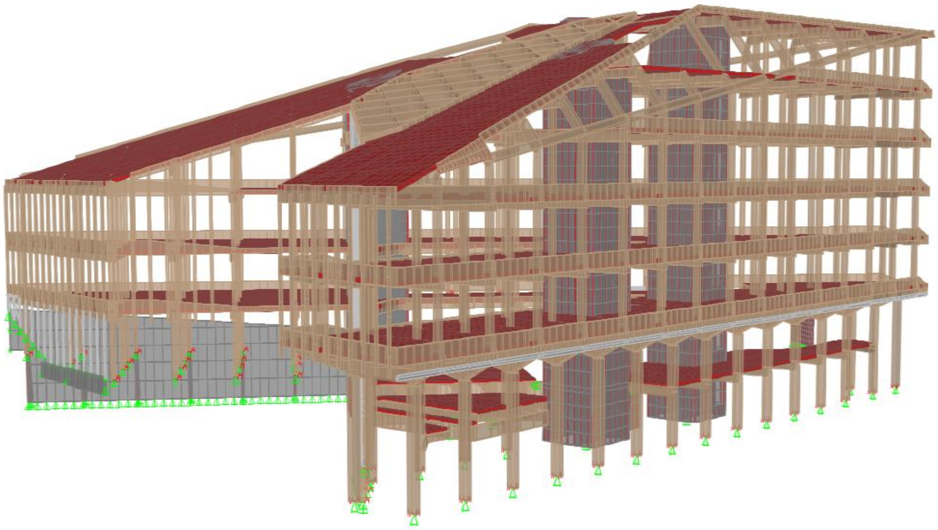

Figure 10: General view of the FE Model

An orthotropic material has been defined to model the layered properties of the CLT panels which have a different behaviour in each direction. The elastic parameters are obtained according to the effective stiffness given by the CLT Handbook [3] which converts the composite section to an homogeneous shell element.

4.2. General results

Timber structures are commonly designed by the Serviceability Limit States (vertical and horizontal deflections and vibrations).
This structure is sensitive to horizontal deflections (figure 11) as some points are located far away from the concrete cores. Satisfactory results were obtained by connecting the west part of the building to the adjacent concrete wall and using the steel elements of the main atrium façade to connect both parts of the building.

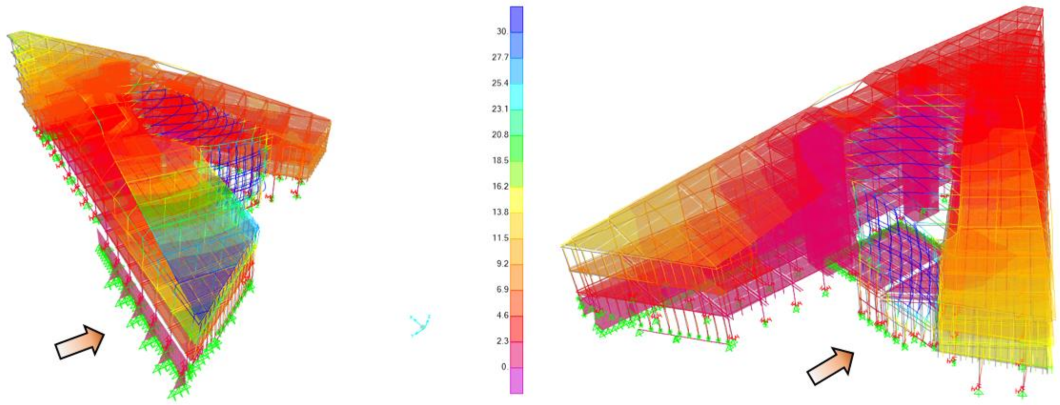

Figure 11: Horizontal deflections

The critical area of the building in terms of vibrations is the south-east cantilever.

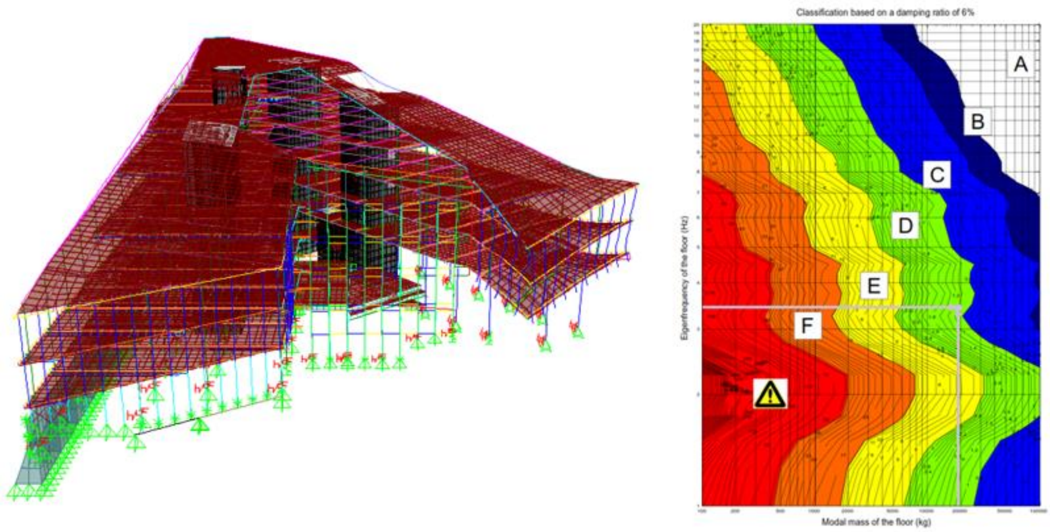

Figure 12: Vibrations

Connecting the three levels with vertical stiff purlins, the structure vibrates within the recommended values [4].

4.3. Main Atrium stairs

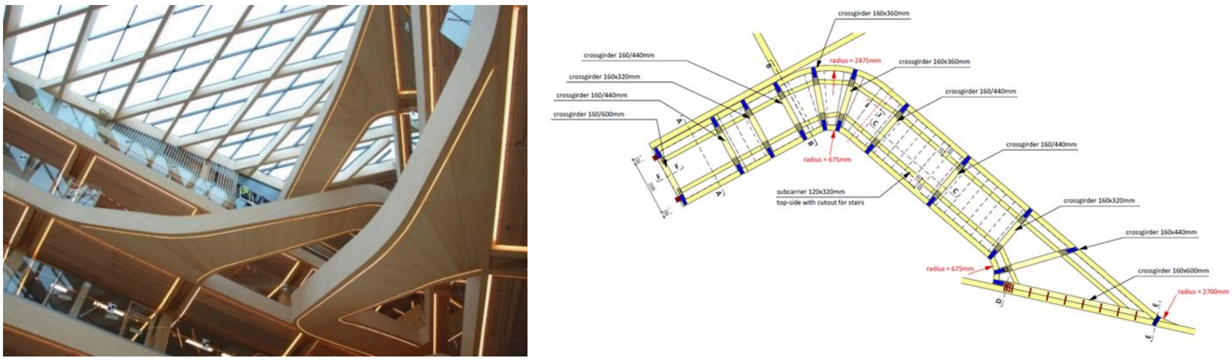

Figure 13. Main atrium stairs. Large span, helicoidal geometry, double curvature beams.

The design of the main atrium stairs, with a geometry that involves double curvature beams with large spans was a challenge to define the geometry, to carry out the structural design and it was required great expertise from the manufacturers for the fabrication and erection.
The main challenges from the structural point of view were to achieve the necessary stiffness in order to avoid excesive deflections and vibration issues, in order to guarantee the comfort for users. It was also difficult to design all the connections between the different elements, that have to transfer large forces and they shall be placed at a location that takes into account limitations related to transportation and erection on site.

The fabrication with great precision of the main lateral beams with double curvature geometry was a remarkable achievement in itself. It is also impressive the smooth geometrical transition between the stairs and the rest of the construction elements.

5. Building information modelling

The use of BIM is increasingly common in Scandinavia for both building and infrastructure projects. Here the client required all disciplines, from the preliminary design stage onward, to share information via a global BIM model. Each discipline, working with their chosen 3D drawing software, exports into the IFC format. The IFC files are then combined into the global model, in SMC format. The combined model is used by the BIM manager to perform clash tests and for interdisciplinary coordination.

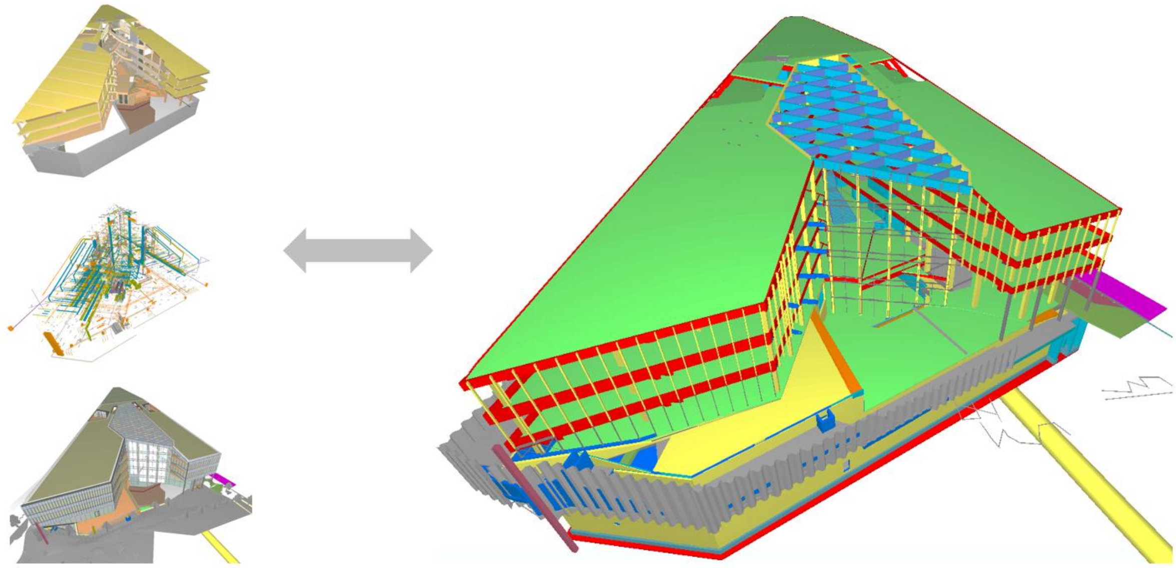

Figure 14: BIM models of different disciplines

It is very important to highlight that the BIM model from designers is used directly by the Timber fabricator, translated into their own software, and later use for the CNC machine at the factory There is no additionally form/shop drawings, as everything is detailed in 3D.

6. Conclusions

The design of Finansparken Bjergsted is innovative in its use of a traditional building material, timber, as the load bearing structure in a modern office building. It takes advantage of advanced prefabricated timber elements that are engineered for strength and can be prefabricated with strict tolerances for a rapid construction process. Connections are also designed, where possible, to transfer forces directly between timber members with minimal steel parts. Self-tapping timber screws and steel threaded rods are used as local reinforcement in accordance with the latest technology.
The inherent advantages of BIM have been used from preliminary design through to fabrication.

7. Acknowledgments

The realisation of this project is thanks to a dedicated design team including the architects, Helen & Hard (www.helenhard.no) and Saaha (www.saaha.no).

Specialist advice on timber design has been provided by Creation Holz (www.creation-holz.ch/en/dienst.php) and on timber fabrication by Moelven, Norway (www.moelven.com/no/).

Throughout all stages the final client and building user, Sparebank 1, has provided constant support as well as the Contractor during construction process, Veidekke AS (http://veidekke.no; http://www.finansparken.no/).

8. References

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