Finansparken Bjergsted, Stavanger: An Innovative Timber-Framed Office Building

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ABSTRACT

Finansparken Bjergsted is an innovative timber-framed office building currently under construction in Stavanger, Norway.The structural system above ground level uses mass 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 (glulam) timber beams and columns. For strength and complex geometrical requirements laminated veneer lumber (LVL) made of beech is also used for some elements. The project is a fully integrated BIM project, including the full definition of the geometry of the timber elements in the 3D model for fabrication.

KEYWORDS: BIM, Timber connections, Glulam, LVL beech timber, CLT slab

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. From competition phase through to the preliminary design phase Degree Freedom have worked in conjunction with the architects Helen & Hard and Saaha on behalf of the client/future building owner, Sparebank1. Specialist technical support for timber design and constructability has been provided by Creation Holz. For the construction phase the BIM model is being prepared by for the contractor, Block Berge Bygg Asworking with Moelven as main supplier of the prefabricated timber elements.

This paper highlights key aspects of the design:

- Choice and use of different mass timber elements to take into account their inherent structural capabilities and to fulfill the architectural vision.
- Fire design.

- Fully integrated BIM for construction.
- Use of 3D finite element modelling for timber design.
- Timber connection design.

The detailed design is currently being finalized to be incorporated into the BIM model for fabrication and construction.

Figure 1. Finansparken Bjergsted (© Helen & Hard|Saaha).

2. Description

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. 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.

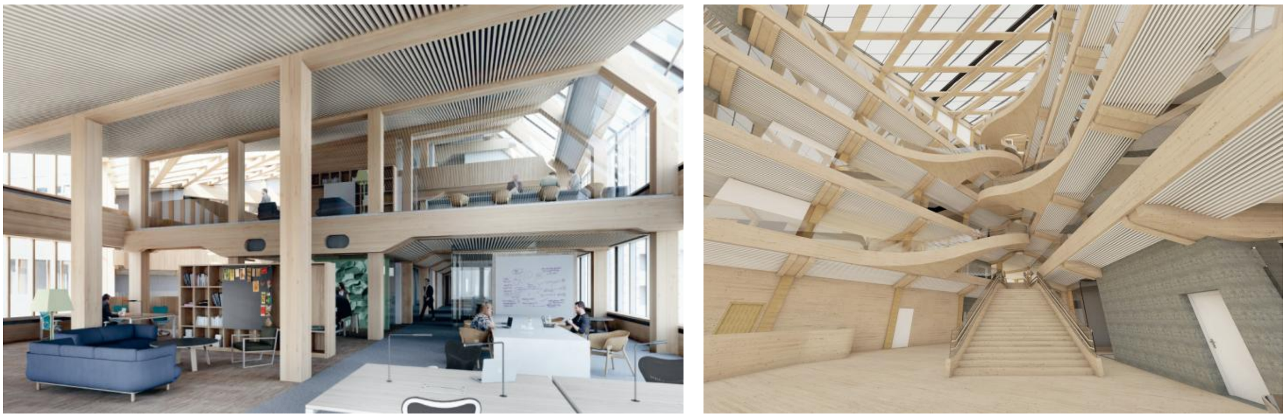

Figure 2. Interior with exposed timber structure.

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

Timber as a construction material has intrinsic environmental benefits. The building also includes an energy efficient and sustainable sedum roof.

2.2. 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 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 glulam section and 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 a LVL insert (Kerto Q).

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 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 4 shows a typical section of the timber structural frame.

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 requirements. At preliminary design stage detailed consideration was given to the fabrication and erection of the timber elements. A full scale mockup, shown in Fig.3, was carried out of a typical frame.

The façade glazing is supported by a deep timber edge beam (GL70). This beam provides rigidity to the CLT slabs particularly at the cantilevers.

Figure 3. Full size mock-up.

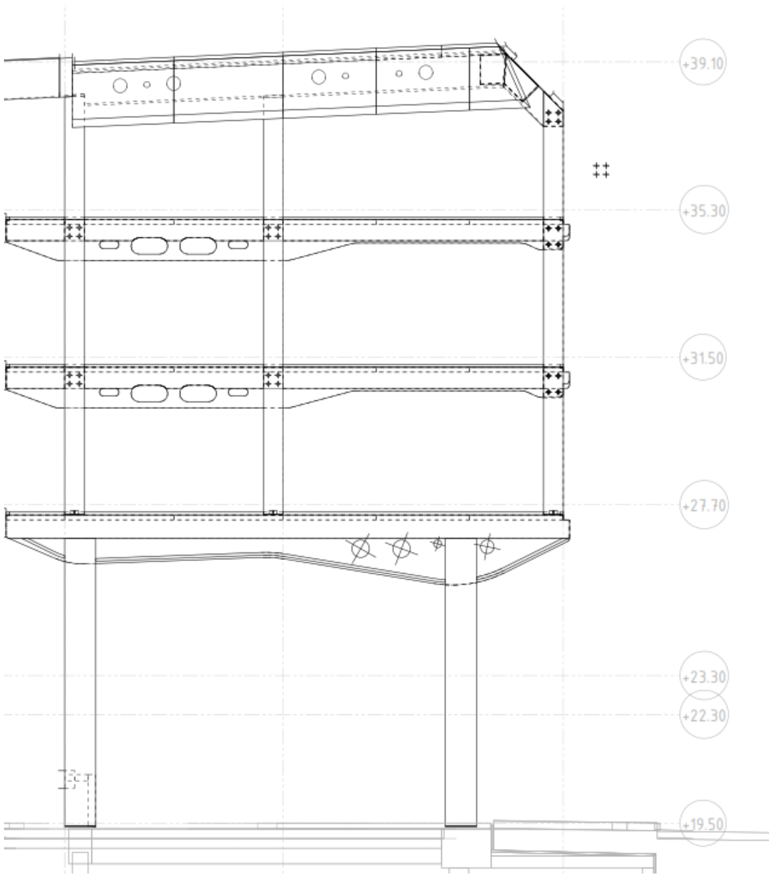

Figure 4. Typical structural timber frame.

3. Types of structural timber

A principle feature of this project is the use of different types of laminated timber elements best suited to the structural requirements. Characteristics of these prefabricated timber elements are governed by both the type of timber used and the direction of the laminations. The different laminations and their direction is also an important architectural feature.

3.1. Glued laminated timber

Glued laminated timber, or glulam, in grade GL30c is used for beams and columns above level 3. This grade is commonly used and column and beam widths have been chosen to suit the standard available sizes. The variable depth beams and service openings are then cut in the factory from a rectangular section. GL30c is fabricated from spruce the most widely available softwood.

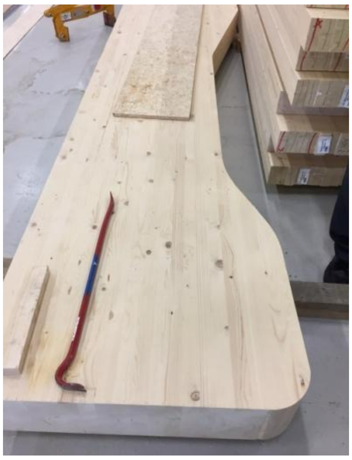

Figure 5. Glulam timber.

Where increased strength is needed GL70 is used, for example in the façade edge beams. This is fabricated from beech, a hardwood.

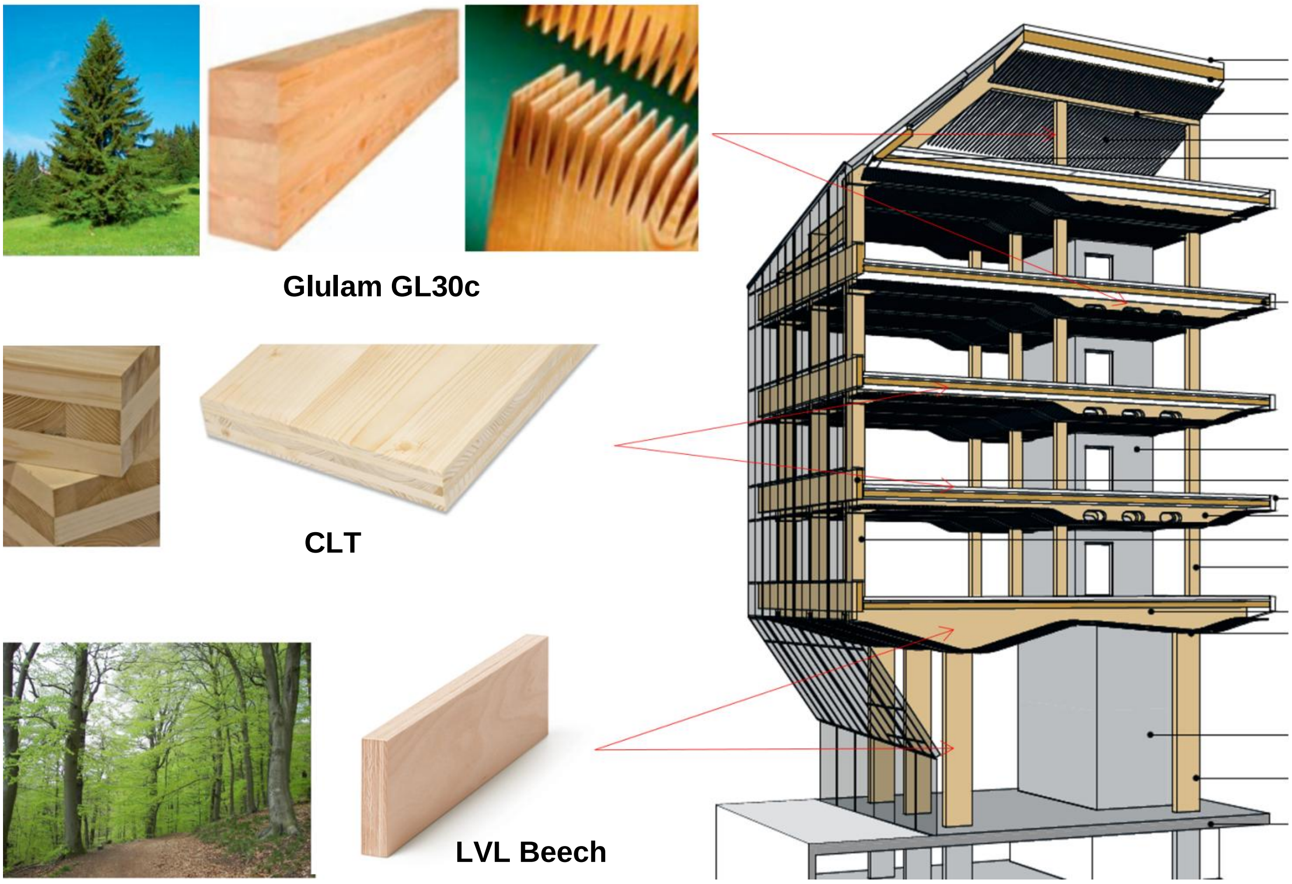

Figure 6. Different types of structural timber used.

3.2. Laminated veneer lumber

Laminated veneer lumber or LVL 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 3mm thicknesses of 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 cross laminations.

Figure 7. LVL Baubuche S showing distinctive 3mm laminations

A 60mm inset of Baubuche S is also used in the glulam floor beams where they bear on to the columns. Timber is weak in bearing in compression perpendicular to the grain and the beech LVL has a resistance of 14MPa compared to 2.5MPa for the rest of the GL30c beam.

3.3. Cross laminated timber

Cross laminated timber or CLT is used for the floor slabs. Slabs are 200mm thick made up of 5 cross layers of grade C24 solid timber.

4. 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.

5. BIM

The use of BIM is increasingly common in Scandinavia for both building and infrastructure projects. Here the client has 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.

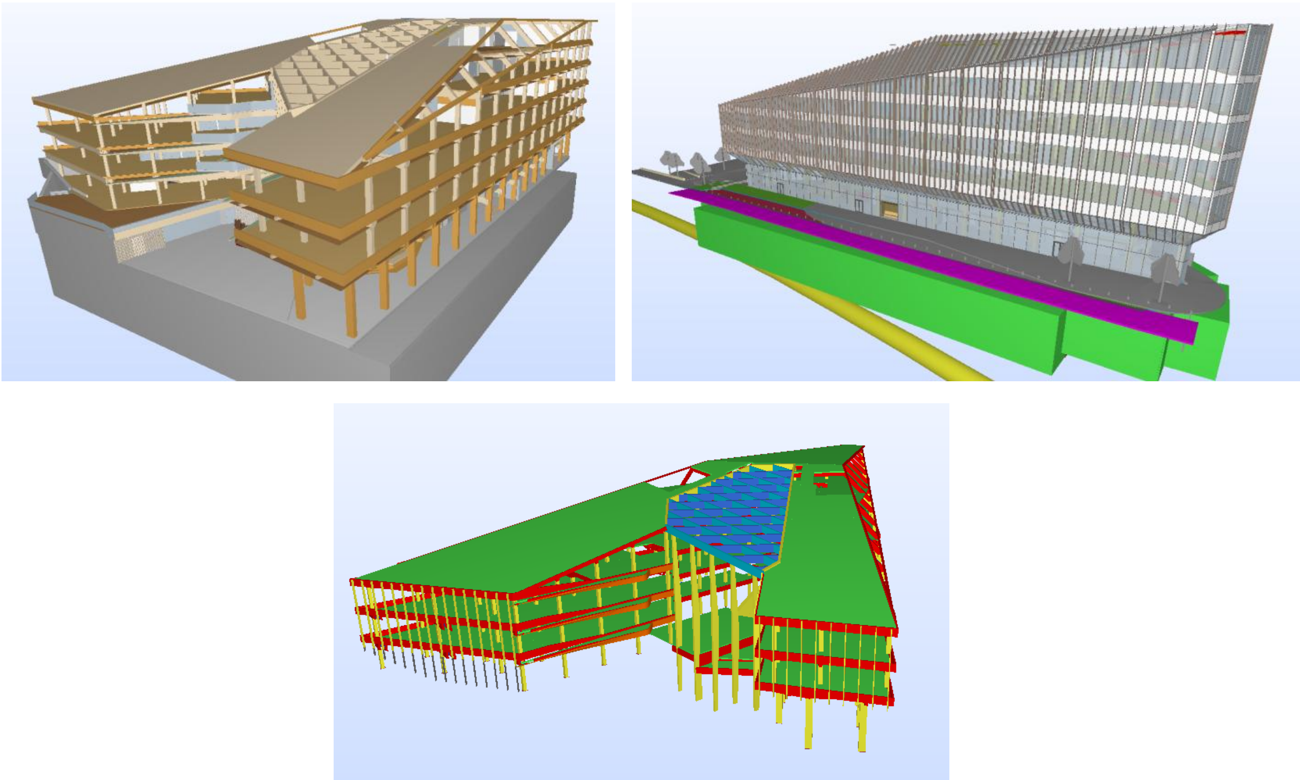

Figure 8. BIM models – Architects IFC (top left), Multidisciplinary SMC (top right), Structural timber IFC (bottom).

6. Finite element modeling

The structural 3D model has been created using Tekla. All geometrical and material specification for the timber structure is included in this model. All 2D drawings, floor plans etc. are taken directly from the 3D model. 2D drawings of the connection details are to be produced in Tekla using the 3D model as a base. The timber elements to be connected are exported directly from the 3D model with their correct geometry. To be added in the 2D drawings are the timber screws, threaded rods or bolts as required.

As well as improved coordination between the design team the BIM model also provides accurate quantities information for the contractor. In this project the timber structural model will be used directly by the contractor for the fabrication and cutting of the timber beams, columns and slabs.

6.1. Description of the FE model

The challenge of this project is the full definition of each connection between timber elements in the whole building. For this reason, it was decided to produce a detailed hybrid FEM with frames and shell elements at the exact position connected with link elements which are defined with the desired stiffness for each degree of freedom 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. Elements in tension are difficult to connect in timber structures. For this reason, it has been used non-linear elements which work only in compression (gap type link) around the concrete cores (wrench effect).

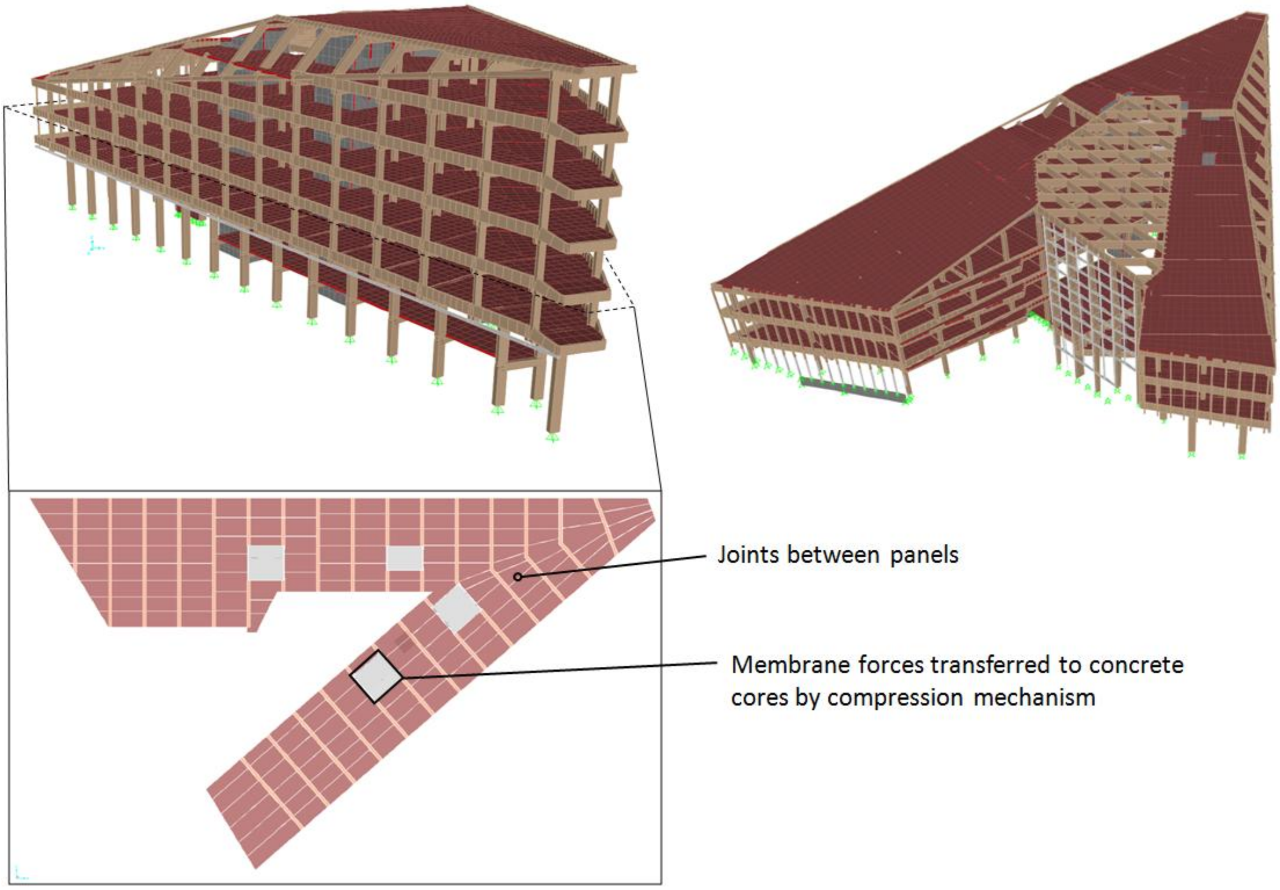

Figure 9. Finite Element Model.

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.

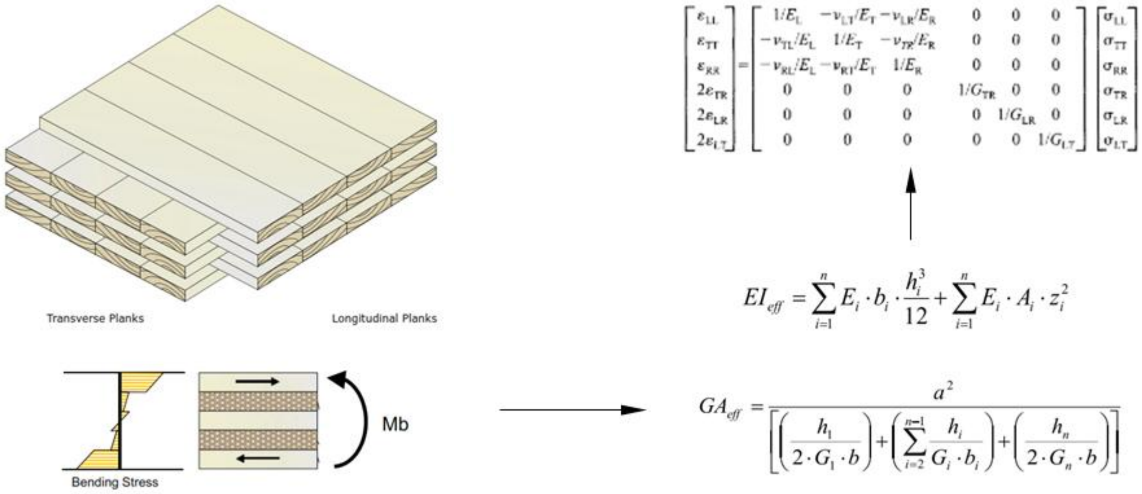

Figure 10. CLT panels properties [3].

6.2. General results

Structure post-processing showed that one key element of the overall structure behaviour is the roof system which mainly consists of the skylight, the edge beams and the membrane effect of the CLT panels passing over the top of the concrete cores needed to reduce the horizontal displacements.

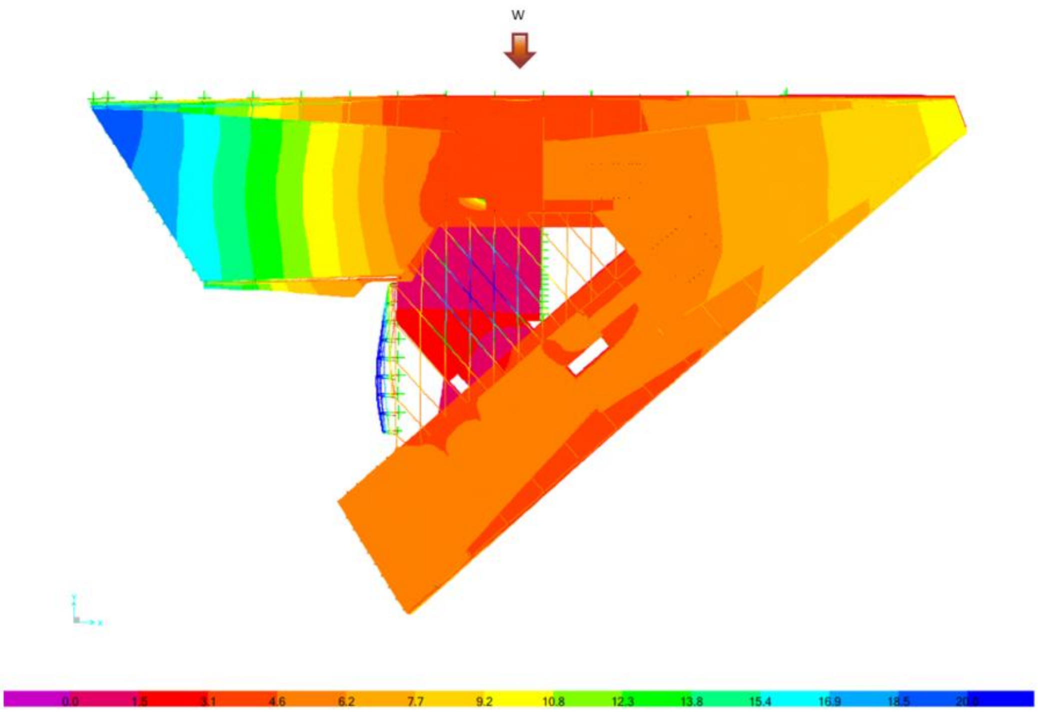

Figure 11. Plan view of the deformed shape for wind loads.

The edge beams are used to stiffen the whole building, especially at cantilevers. At the south-east cantilever it has been verified that the mode of vibration is within the range of frequencies that do not cause discomfort to the users [4].

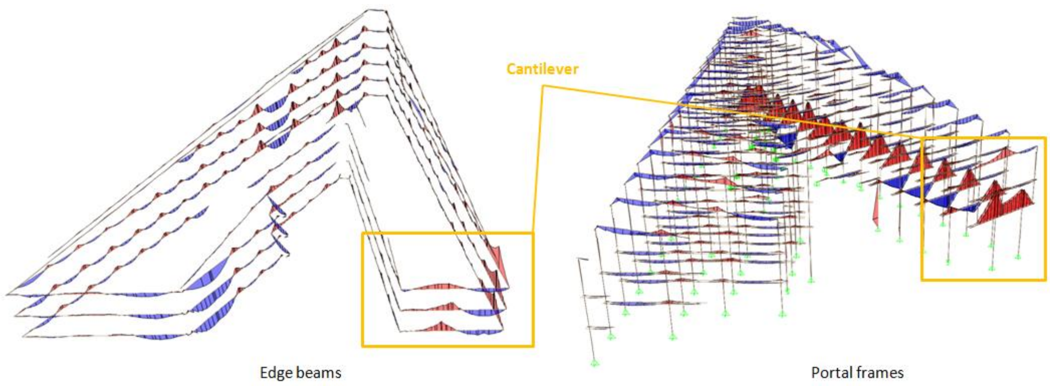

Figure 12. Bending moments for dead loads.

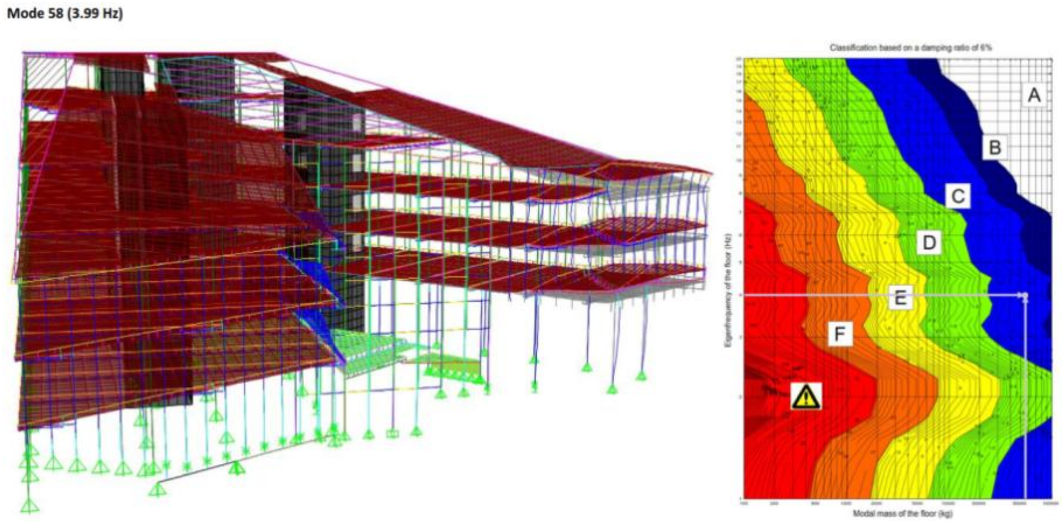

Figure 13. Vertical mode of vibration of the South-East cantilever [4].

7. Connections

One of the main challenges of this type of structure is the connections. Connections are realized in a number of different forms depending on the magnitude and type of forces to be passed. 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
- 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.

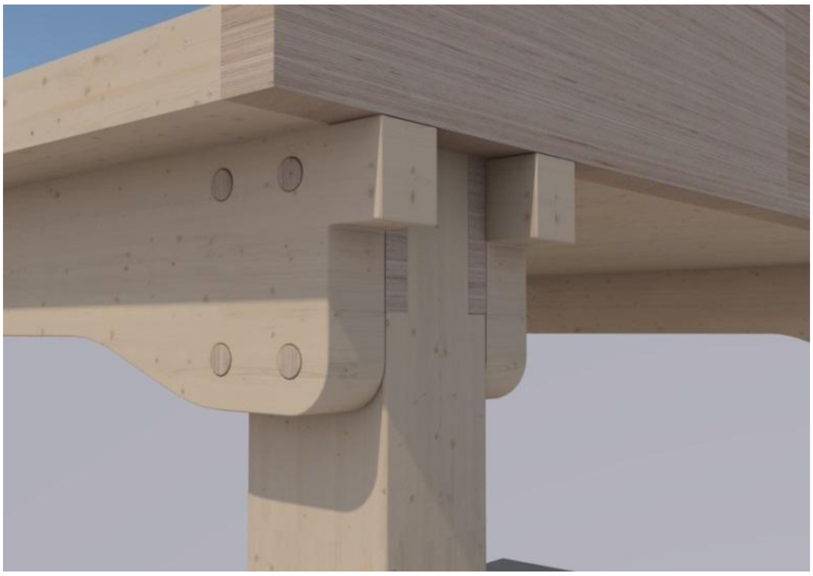

Figure 14. Example of direct bearing timber to timber connection.

8. 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 modern 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.

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 which continues with the client during detailed design, Block Berge Bygg AS (www.blockberge.no/prosjekter/).

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