Report
: Timber Construction Development Finland
YMP_19_0005
→ Petri Heino
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design to production

we master complexity

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1 Process

As our experience shows, key to a successful project is the introduction of a workflow related to practice early in the project. Depending on the project at hand, a suitable prefabricated system in wood is chosen for developed, respecting fabrication and assembly constraints as well as design intentions. Integrating practical aspects early also helps finding capable contractors that match the requirements, or identifying them among the bidders.

Diagram 01 shows the state-of-the-art design and building process, as it is commonly employed: step-by-step from one to the next process phase. This process is only working if the planners can rely on their experience to cover all practical constraints in early phases. Otherwise the project workflow is going to be turbulent as soon as fabrication or assembly constraints are introduced by the contractor, and the result will probably not reach the level of quality expected at the beginning. Another disadvantage of such a workflow is that the latest most detailed model, replaces the less detailed model of the previous stage and concrete information can get lost.

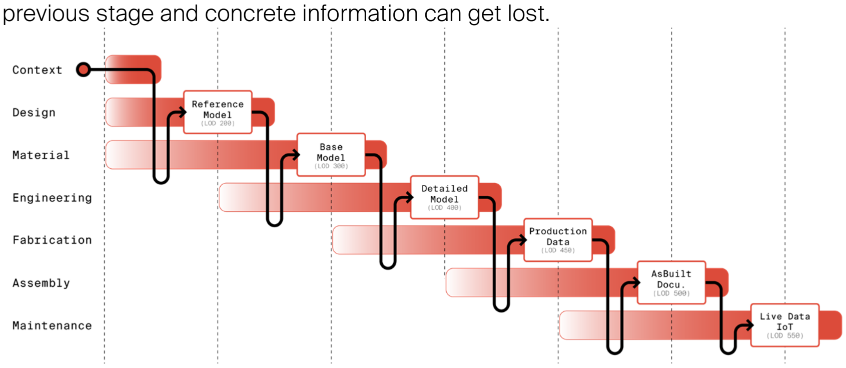

Diagram 01 – Common conventional design process

Diagram 02 shows the “D2P way” of developing projects. The biggest difference to the common process is a shift of effort towards early phases, involving a broader team to cover all relevant topics down to on-site assembly already in the Concept-phase. Time and cost budgets can be used to steer further design decisions as well as technical development. Within each of the displayed project phases and topics, a comprehensive list of questions (input) and tasks (output) exists to make sure nothing is overlooked. Each of these models should contain as little information as necessary, in order to avoid redundancies and inconsistencies.

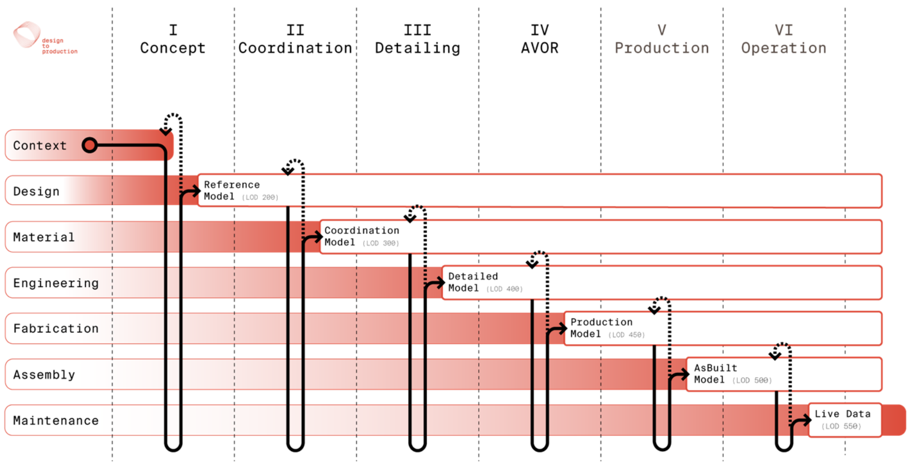

Diagram 02 – Agile Design-to-Production design process

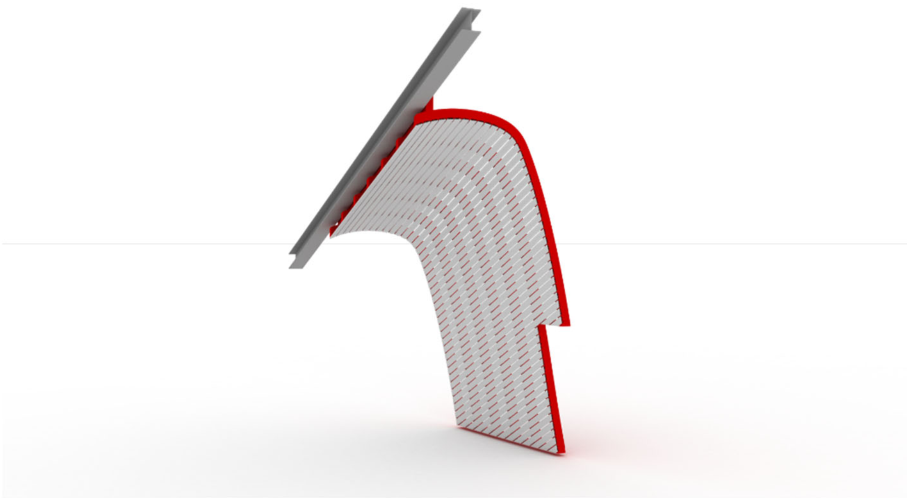

Figure 01 – Mock-up model

Mock-up: In addition to the process diagrams, it is also significate to illustrate the importance of Mock-ups in the design and decision process. Typical types of Mock-ups are:

- Feasibility mock-up: Proof concepts for the first time, both technically and process-wise
- Pre-tender mock-up: Get a clear picture of contractor’s capabilities and quality
- Design mock-up: Make decisions on real components before going into fabrication

2 Objective Ylivieskan Kirkko

The Finnish Ministry of the Environment represented by Petri Heino asked for a concept development to “integrate more timber” in Finnish building projects. The focus should lay on structure, envelope and façade of individual architectural building projects. Considering the longer-term perspective, the result should be a general information for architects, structural Engineers and clients.
The given design proposal was based on common conventional local design methods and constructional systems; our aim was to introduce a more timber related system into the intended design. The proposed design of the project team showcased an intensive pile foundation, massive masonry and concrete walls, and a roof structure with main girders out of glulam and panels in CLT.

Figure 02 – Ylivieskan Kirkko visualisation

2.1. Initial concept philosophy

The following aspects were retrieved from the architectural intent and taken as the initial concept philosophy:

- Following the architectural design intent
- Back to basics
- Less layers in the roof
- No steel or as less as possible (fire protection)
- Respecting the process of prefabrication
- As much pre-fabrication as possible (time reduction on site)
- Local procurement
- Clear and efficient system in timber
- Benefits for foundation
- Innovation

2.2. Proposal intention

The aim of the collaboration was a knowledge transfer in the fields: project- and process management, structural and constructional design in pre-tender phases. Based on our experience in development and consultation of many international "wooden" projects, we as Design-to-Production GmbH covered the fields of CAD modelling, project- and process management.
We collaborated in the following aspects:

- Setting up the right team
- Proceeding from the concept phase to tender
- Organizing and setting up 3D BIM models in early stages
- Bill of Quantity values in early stages
- Handling of constructional interfaces

Additionally, we involved our partner company Création Holz AG. They contributed with their deep knowledge and experience in terms of structural, constructional and building physic topics in the development of wooden projects worldwide.

2.3. Workshop

Together with Création Holz AG, the project team structural engineer office Rakennuskonsultointi T. Kekki, K2S-architects, and Petri Heino on the client side, we organized a workshop in January 2019. The key of the workshop was to brainstorm and actively work on the understanding and raising awareness for the focus on the process of prefabricated timber structures and building envelopes, by introducing the reverse procedure of on-site installation and ending up at the design.

Based on project key points the following requests must be taken into consideration (cf. chapter 2.9):

1. from and to the realisation process
2. from an to building parts
3. from and to details
4. from and to contractors
5. from and to design, coordination and tender

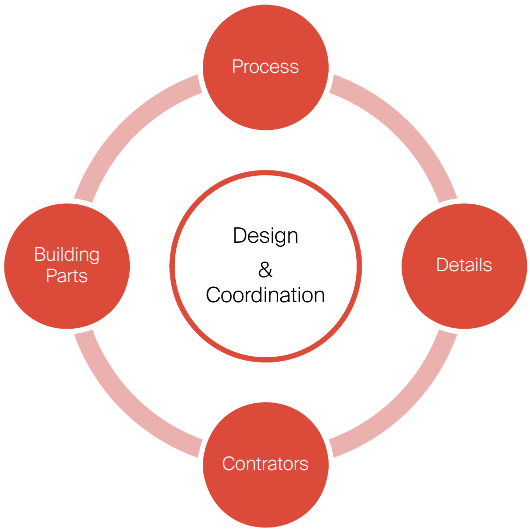

Diagram 03 – Overview of the different trades

All these requests and inputs require the secureness of having a smooth interface between different trades that is continuously updated and solved (i.e. structure – wood – concrete, envelop – timber elements – facades – roofing, timber elements – MEP installations). When interfaces are settled and rules for all participants, working in different disciplines, are defined, the goal to find efficient solutions in all trades can start, i.e. from timber construction to building parts and details, to project building component systems.
The ultimate goal therefore is to find solutions that are working in a more general matter, and where the used approach could be transferred to other projects, rather than being optimal for only one trade.
Another important aspect, which is underestimated nowadays, is the level of systematics. If one focuses on a clearer systematic in details and building parts, the efficiency of projects will rise, especially in prefabricated buildings.

2.4. Alternative design

The outcome of the workshop was the proposal of an alternative design, which answered to the initial philosophy (cf. paragraph 2.1). The proposal is a component based system for both walls and roof. These basis components are measured 1m20 by 60cm, and use CLT 3 layer 30/15/30 in Spruce. These basis components are combined with an edge beam that brings the wall, floor and roof components together. This edge beam is a glulam LVL beam.

The structure has a clear and simple systematic and has the possibility to work with a component grid. The structural typology goes back to basic, and uses less component variation. These simple modules have the advantage to be very stiff, use air as an insulation and have space for MEP. Besides the connections, the structural system doesn't use any steel. If steel is used, it is embedded in wood (fire protection). Due to the module-based design, a high level of pre-fabrication can be introduced locally. The assemble sequence is an open variable that can be decided in a later phase, which can apply a time reduction on site. The components itself are light and small, which reduces the necessity for heavy and costly equipment on site. Due to the simplicity of the system there is a possibility of linear connections, homogeneous load reactions to the connections and foundation. In general, the resulting solution is a clever system and is in that way innovative, so main key aspects are achieved.

Benefits of the proposed structural system:

1. High systematic level (adjustable within one systematic)
2. High level of prefabrication (fast on site – parallel off- and on-site work)
3. Light and rigid (foundation less intensive)
4. Simple and multi-functional (architectural, structural, and building physics)
5. Robust and durable (engineered, massive and homogeneous)
6. Form stable for the planned stone façade (expansion and shrinkage)

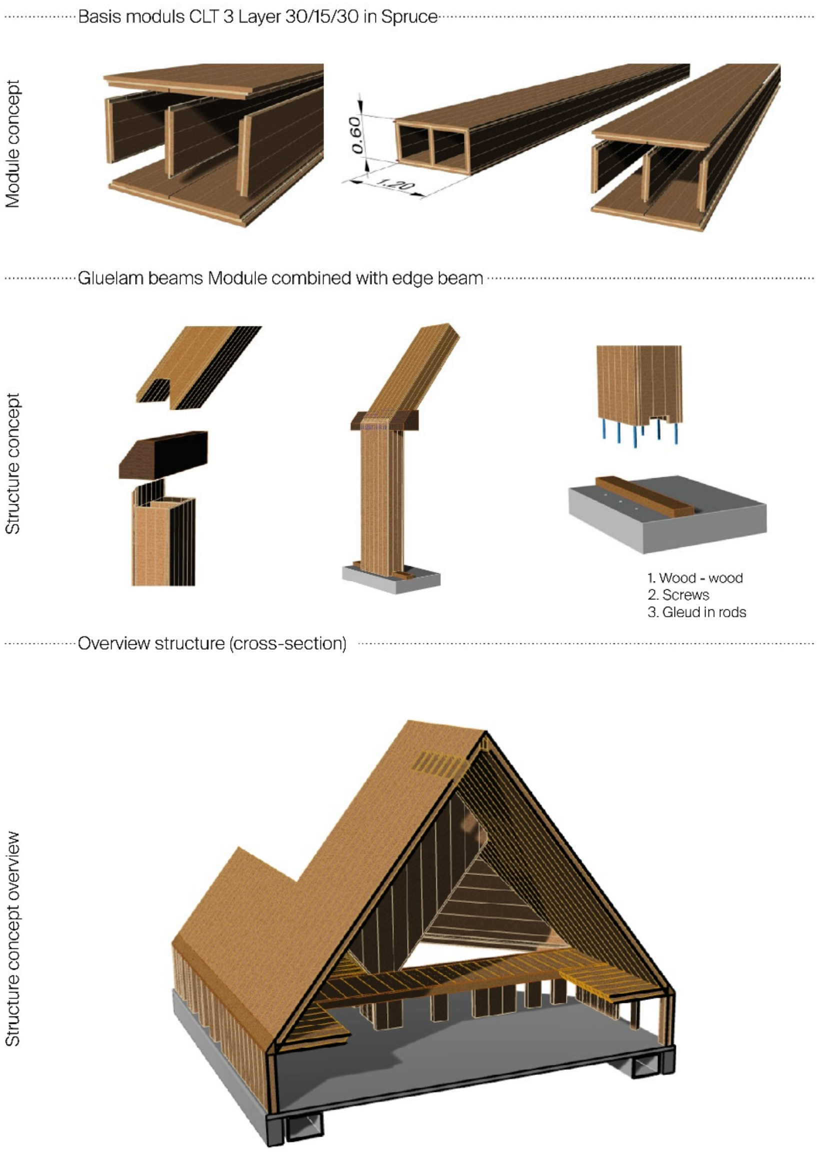

Figure 03 – Structural system proposal

2.5. Details

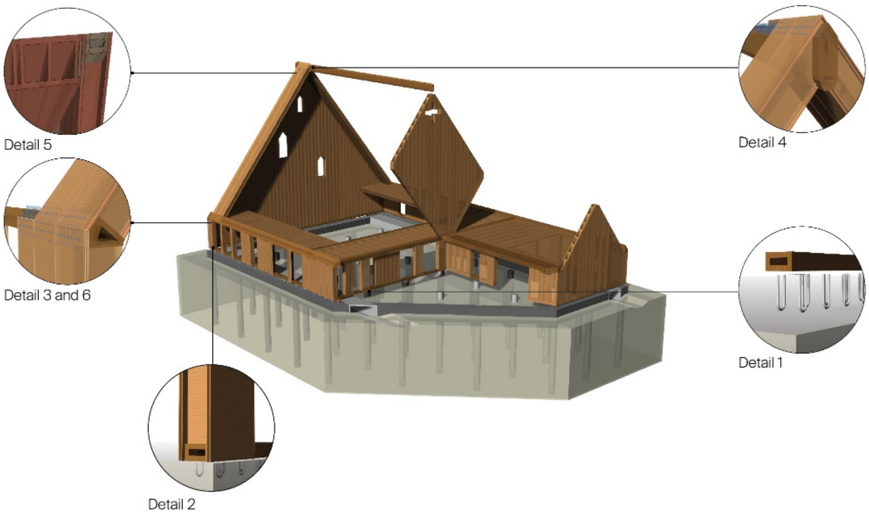

Figure 04– Overview details in the structural system

2.5.1. Detail 1

Detail 1 is the connection to the concrete slab. A threshold with integrated concrete anchors is assembled out of Kerto® LVL Q-panels of 75mm thickness. Creating a robust interface between the on-site concrete work and the prefabricated timber construction. Defined in XY-direction and able to cover tolerances in Z direction.

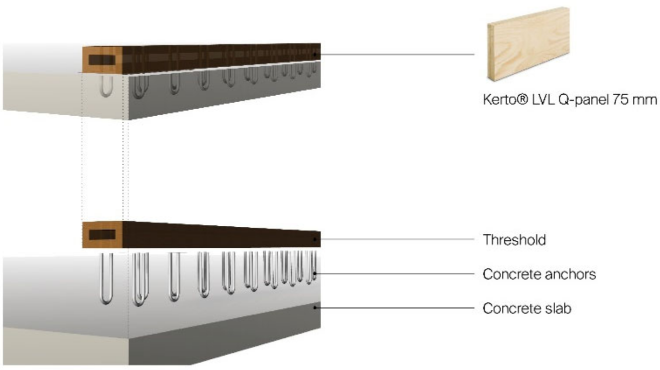

Figure 05– Detail 1

2.5.2. Detail 2

Detail 2 is the connection of the wall-module to the threshold. The flanges of the module are longer and enable an easy vertical engagement that works in every case where the detail is used. The module is connected to the threshold (on the tensile zone part) by using fully threaded screws diagonally through the module and the threshold to assure a fixed connection. The connection can easily be inserted on site, before tightening the detail against water. The tensile zone is located on the outside flange of the module, and the compression zone on the inside flange accordingly.

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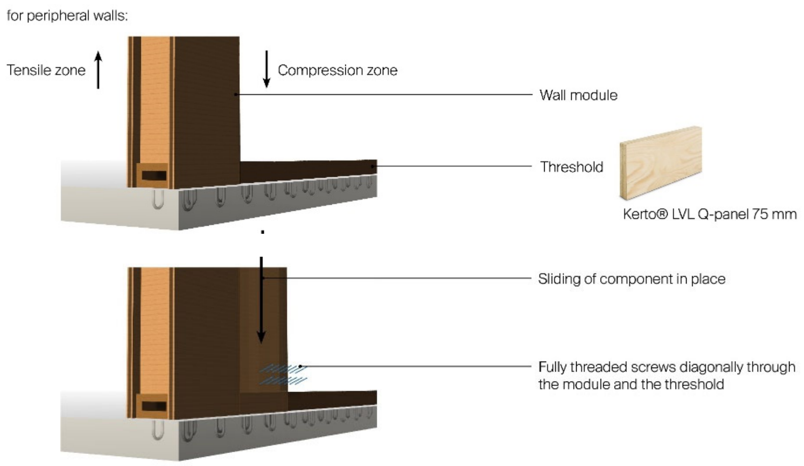

Figure 06– Detail 2

2.5.3. Detail 3

Detail 3 shows the connection between the roof component and the wall component by using an edge beam. Just like the threshold, the edge beam is composed out of Kerto® LVL Q-panels of 75mm thickness. Both roof and wall module are connected to the edge beam (on the tensile zone part) by means of fully threaded screws diagonally through the module and the beam.
The production of the modules, respecting the detail typology, isn't problematic and can be done easily with standard CNC-machines. The shown side-way-engagement direction requests a bit of sensitivity by hoisting them into the final position.

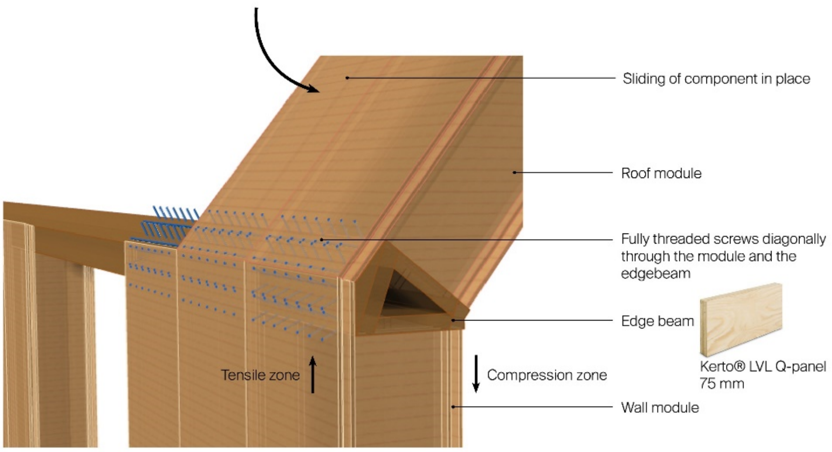

Figure 07– Detail 3

2.5.4. Detail 4

Detail 4 is the connection between two roof modules in the ridge of the roof by connecting it to a ridge purlin. Just like the edge beam and the threshold, the ridge purlin is made out of Kerto® LVL Q-panels of 75mm thickness. The outer flange of the roof modules is longer and embeds the ridge purlin, which are then connected by fully threated screws.

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From the production and installation side, the ridge detail is important as it constructs the two halves of the building. The geometry of the ridge purlin is aligned with the edge beam detail (cf. Detail 3), the angle of the cuts defines a successful engagement.

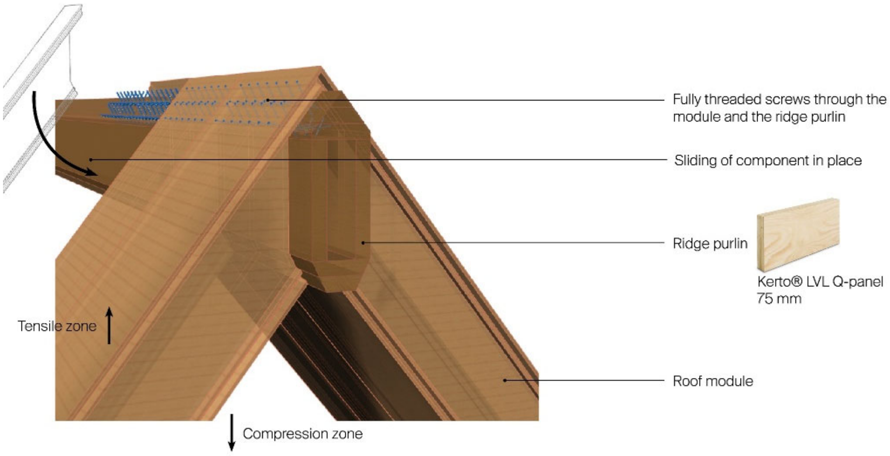

Figure 08– Detail 4

2.5.5. Detail 5

Detail 5 is the connection between the roof module and the wall module of the altar wall. A connection beam, made out of Kerto® LVL Q-panels with 75mm thickness, is fitted between the flanges of the wall module. The roof module is located perpendicular to the wall module and enclosed with an extra plank to ensure full contact between both modules.

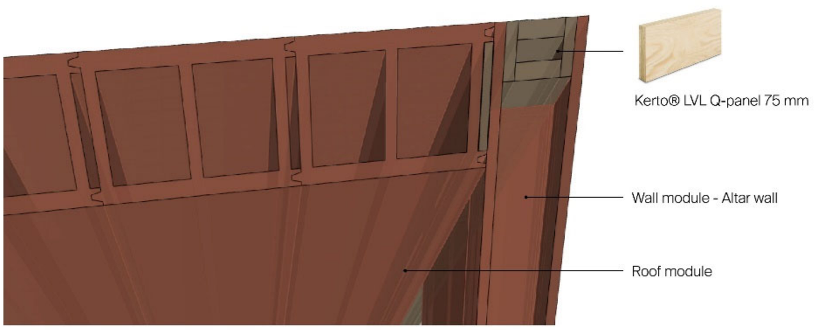

Figure 09– Detail 5

2.5.6. Detail 6

Detail 6 is the connection of the floor modules to wall and roof modules. The modules are resting on top of the edge beam and span the desired length by means of this support. The ending of the flanges of the floor modules are inclined and fitted to the inclination of the roof modules.

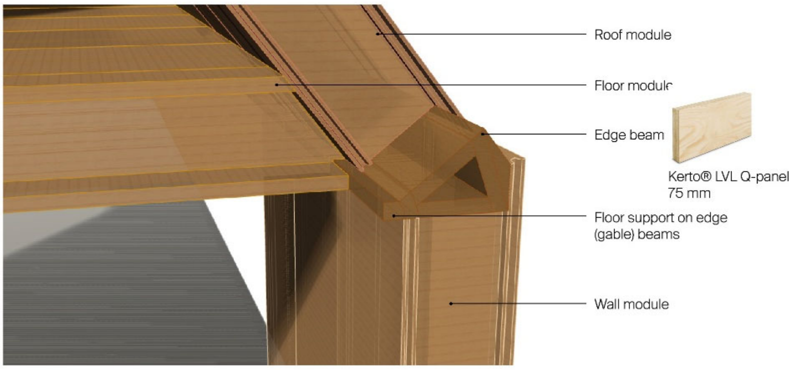

Figure 10– Detail 6

2.6. Assembly sequence

The construction sequence of the main structure has two different possibilities, with both their advantages and disadvantages. They can be studied further during the design phase and while awarding the contractor.

2.6.1. Construction sequence from left to right

1. Pile foundations
2. Frost bars and channels
3. Concrete floor plate
4. Placing of the thresholds by means of concrete anchors (cf. Detail 1)
5. Placing the wall modules of the altar wall (cf. Detail 2)
6. Placing of the side wall modules of the main roof area
7. Mounting of the edge beams (cf. Detail 3)
8. Mounting of the ridge purlin, supported by temporary logs
9. Mounting of the floor modules (cf. Detail 6)
10. Placing of the mid-wall and floor modules
11. Mounting of roof modules by sliding them in place (cf. Detail 4)
12. Finishing of the main roof by connecting roof and wall modules to the edge beam (cf. Detail 3)
13. Mountain of the walls of the annex part
14. Placing of the side walls
15. Finishing of wall and floor modules
16. Placing of the ridge purlin of the annex roofs
17. Finishing roof modules of the annex roofs

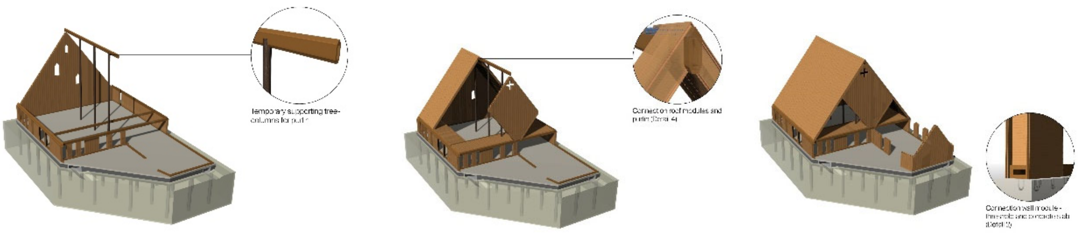

Figure 11– Construction sequence 'Left to right' step 8, 11 and 14

2.6.2. Construction sequence down – upwards

1. Pile foundations
2. Frost bars and channels
3. Concrete floor plate
4. Placing of the thresholds by means of concrete anchors (cf. Detail 1)
5. Placing the wall modules of the altar wall (cf. Detail 2)
6. Placing of the side wall modules of the main roof area
7. Placing of the longitudinal walls and end wall modules
8. Mounting of the edge beams (cf. Detail 3)
9. Placing of the in-between wall modules
10. Placing of the ridge purlin for the main roof
11. Placing of the floor modules and annex ridge purlins
12. Mounting of roof modules by sliding them in place (cf. Detail 4)
13. Finishing of the main roof by connecting roof and wall modules to the edge beam (cf. Detail 3)
14. Finishing of annex roofs

Figure 12– Construction sequence 'Down – upwards': step 7, 10 and 12

2.7. Durability

Durability assessment of the timber module structure.

1. The timber structure is fully covered by a facade or roofing and thus not exposed to weather.
2. The modules are made out of massive 75mm CLT or others in LVL – sections are massive but in a very normal dimension range of components. Therefore, damages in case of shrinking and expansion are not an issue.
3. The structure, which works also as a continuously main building envelop, is breathable and creates a very homogenous, stable and robust layer, focuses on structural and building physic performance.
4. Building physics capability of modules can easily be changed – by implementing insulation – if requested at all or in particular situations
5. The connections can be done in every point mechanical. They are not requesting much maintenance during live time.
6. If the outer water tightening layers are working fine, the structure will stay more than 200 years.

2.8. Next Steps

As next steps we recommend the following topics, to make sure that a continuity of the workflow is guaranteed, one needs essential questions to be answered and the main points clarified. Guaranteeing this enables a good basis to present to the client to gain decisions for the next planning phases.

1) Detailed concept for production and installation
2) component type catalogue and detail catalogue
3) Reference model for BoQ
4) Cost and time estimation
5) Digital mock-up
6) Coordination and adjustments towards a compatible timber construction system
7) Selection, prequalification and introduction of potential contractors

2.9. List of "Request" – Project development – Process related

2.9.1. Realisation process

1) On-site
   i) Installation sequence
   ii) Occupational safety
   iii) Weather protection
   iv) Jigs/ temporary bracings
   v) Hoisting concept
   vi) Quality management system

2) Off-site
   i) Procurement of raw material
   ii) Production of engineered blanks
   iii) Production of CNC-fabricated project components
   iv) Preassembly of parts, elements, and modules – ready for installation
   v) Logistics – storage – transportation
   vi) Quality management system

2.9.2. Building Part Types

1) Availability
2) Environmental properties
3) Durability
4) Visible quality
5) Structural performance
6) Building physic performance
7) Flexibility for implementation of other trades
8) Certifications
9) Level of systematics

2.9.3. Details

1) Engagement of building parts and fasteners
2) Machinability
3) Positioning and orientation
4) Covering of tolerances
5) Structural capacity
6) Visible impact
7) Durability
8) Level of systematics

2.9.4. Contractors

1) Capability – Reference projects – Mock-up
2) Locality
3) Insurances and guaranties
4) Quality management system
5) Project management
6) Model based shop drawing workflow
7) Production facilities
8) Installation services
9) Subcontractor management

2.9.5. Design – Coordination – Tender

1) Basic rules and information for design of a prefabricated system
2) Defined workflow – design – coordination - approval
3) Defined planning interfaces, model stages
4) Defined benefits of a model-based planning process
5) Project cost estimation – coordination – approval
6) Project schedule planning – coordination and approval
7) Concept for decisions making process
8) Strategy to involve and award contractors
9) Method statements of trades focussing on interfaces to others