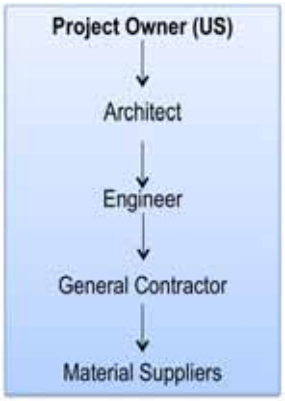
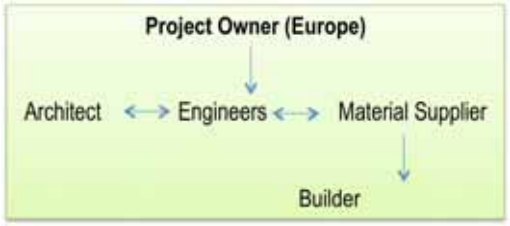
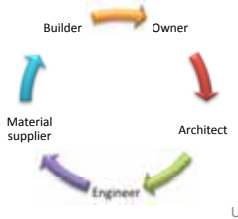
Case Study – CLT and the Integrated Design Process







Advantages

- Timing of incorporation of material suppliers – earlier the better
- Fix cost estimates early
- Material Suppliers (Timber producer) sell projects not just material
- Early integration of all disciplines allows for a higher level of optimization for design, details and delivery schedules
- Iterative process
- Optimization of design results in construction efficiency and reduced costs.
- 3D BIM model imperative to integrate and foresee any future construction issues

Hotel Aqualux, Bardolino Italy

- 4-Star Luxury Hotel, Spa & Wellness Center
- Certified Clima Haus A
- 180,000 sqft of floor space
- 113 rooms and 33 suites
- 11,000 sq ft wellness center and 8 pools
- 2 bars and 1 restaurant
- Professional Conference center
- 195,000 sq ft CLT, 253 mBF of glulam beams and LVL
- 120 tons of custom steel connectors

Problems with the traditional approach

- Estimated construction time in traditonal concrete - 2 years!
- Pour soil conditions coupled with large weight of the concrete structure increased foundation costs
- High thermal standards result in a wall package 2“ thicker with concrete over CLT – by building out of CLT, material volume and therefore costs are reduced.
- Reduced energy efficiency due to thermal Bridging with concrete

- Although eventually Clima Haus certified the original motivation to explore timber options was not due to a desire to build green, but purely due to cost and timeline.

Exploration of building with CLT

- Original cost estimates in CLT were appr. 20% more expensive than concrete (ca. $ 3,0 mil. for the timber structure)
- BUT:
- Estimate of erection time for CLT structure was 3 months (vs. 2 yrs)
- Prefabrication could run simultaneously to construction of the foundation and basement story
- Lower weight of the CLT/Timber option resulted in smaller foundation and therefore reduced costs
- Concrete = 150 lb/CuFt - SPF = 30 lb/CuFt – Wood is 1/5th of the weight of the concrete
- The resulting lighter foundation reduced seismic weight and therefore lateral loads used for design
- The thinner wall package still had a better u-value
- Reduced problems with thermal bridging
- Fast construction time drastically minimized the structures exposure to moisture during construction

Architect & client decide to build in CLT

Our approach

Issues:

- Existing architectural plans were based on the concrete design
- All structural calculations, construction details were for concrete

Next Steps:

1. Produce preliminary construction documents and shop drawings based in CLT
2. Perform Structual Engineering calculations for timber structure
3. Determine fixed unit prices for CLT and other products from the contractor (Finnforest – Merk)



Our approach

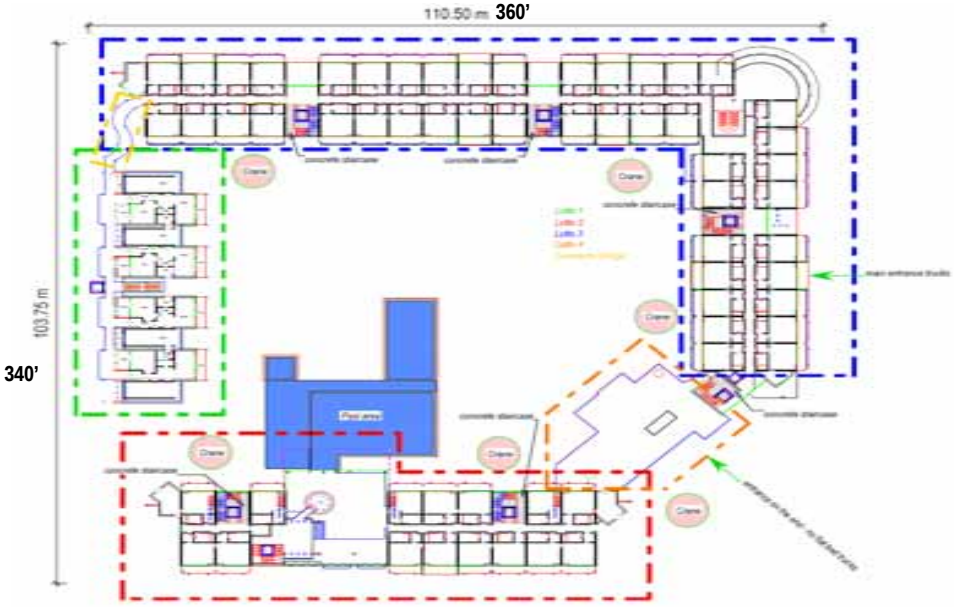
At the beginning of the planning process we divided the building into five phases of construction, in Italian called Lotto.
Phase 1: Ground Floor & 1st floor
Phase 2: 1st and 2nd Floor & swimming hall post & beam construction similar to Lotto 3 but regarding the fact that a lot of the posts are standing in the often in the pools so we selected concrete posts, 1st & 2nd floor CLT construction
Phase 3: Restaurants and Kitchen Area - post and beam construction and 1st & 2nd floor CLT construction
Phase 4: Reception area on ground floor
Phase 5: Connector bridge: connects Phase 1 & Phase 3


Phase 5: Connector Bridge


Phase 3: Restaurant


Phase 2: Indoor Swimming Pool

Project overview



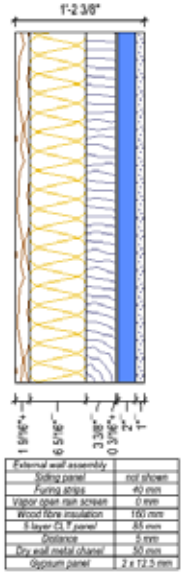
Our approach

We split the design work between the two engineers Dr. Arno Gadner & Dr. Andreas Berger and me in the following way:

- Arno divided the complete construction into individual parts; posts, beams, floor and wall panels and engineered the sections. At each iteration we discussed the design with the architect, If he saw any problems we looked for a solution or started over
- I designed the structure in Dietrichs(3D modeling BIM software) and made proposals for connections. The 3d modeling included also all the necessary steel parts for the timber construction. This helped to avoid interface problems with the steel producer.
- Andreas calculated / designed the connections
- I designed the connections in the 3d model and gave them a feedback including prefabrication options on the available CNC machines (1 PBA, 1 Hundegger K1 and 2 Hundegger K3).
- During the design process we also included the mechanical, electrical, and plumbing subcontractors to determine the most efficient MEP layout.
- We also started also to think about the erection concept and involved the general contractor, Ingo Schmitz and his company Baucon. He overviewed the design process and his input was priceless for us.

This was a continually iterative process where we involved all aspects of the project to incorporate everyone's feedback. Creating one 3D model that included everything from concrete, to CLT, to mechanical and electrical allowed us to troubleshoot potential issues that could occur during construction and address them in the design phase as opposed to in the field.

Wall & Floor assemblies – External Walls

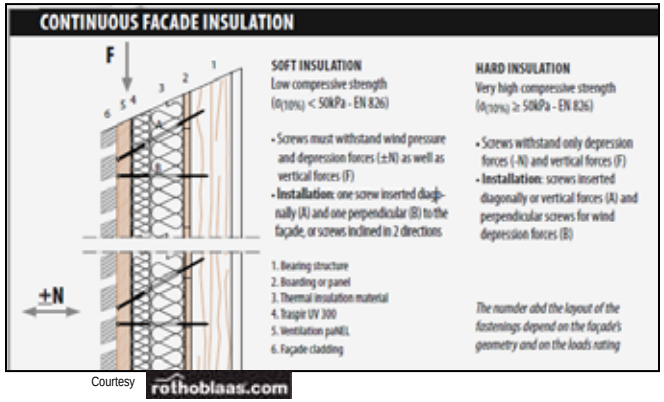


External wall assembly	
Siding panel	not shown
Furring strips	40 mm
Vapor open rain screen	0 mm
Wood fibre insulation	160 mm
5 layer CLT panel	85 mm
Distance	0 mm
Dry wall metal chanel	50 mm
Gypsum panel	2 x 12.5 mm

- 5-layer panel is air tight and works as a vapor retarder = vapor open wall assembly
- Up to 6" thick, the wood fiber panels and the furring strips can be fixed with staples = fast to build
- Transfer of the vertical loads from the siding with special screws

General advantage of CLT construction:

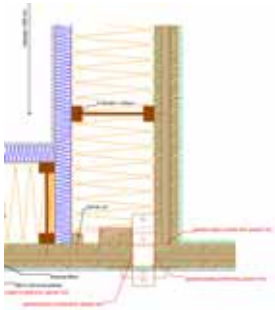
Dividing structural and insulation layer makes it easy to avoid thermal bridging and the insulation thickness is scalable.



Wall & Floor assemblies – External Walls

Rigid wood fiber available here in max. thickness of 1 ½" (Steico has a supplier in Canada)

- Mineral based ridged insulation boards are available up to 6" thickness and with compressive strength up to 58.5 kPA / 1220 psf
- Working with two crosswise layers of furring strips. Lower density insulation material can be used.
- For highly insulated structures:
  vertically attached I-joist with a 1 ½" rigid insulation panel attached on the CLT and blown in cellulose insulation (often used for Passivhaus)



Wall & Floor assemblies – Partition walls

Partition walls:

- Partition walls were initially planned as double walls (two CLT panels with a gap) to satisfy the desired acoustic and fire protection.
- To reduce costs we considered a single panel solution

Challenges to a single panel system:

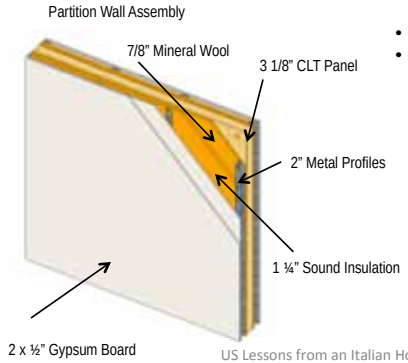
- 90 min fire rating
- 58 dB STC rating

Our solution:

- Uncouple the structural panel from the gypsum structure
- Protect the structural panel directly with a non combustible 1.5" mineral insulation (solution we worked out with the local fire department)

Simpler solutions here:

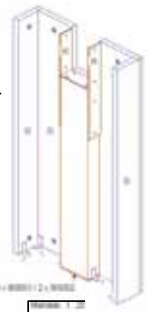
- Gypsum panel directly on the CLT panel for high fire protection
- 2x2 furring strips for nailed on the gypsum to create an installation gap (this is faster than metal profiles) and only one gypsum board
- Or 2x2 furring strips with double gypsum board
- Mechanical space only on one side of the panel and the gypsum board attached direct on the panel on the other side



Wall & Floor assemblies – Integration of plumbing & electrical

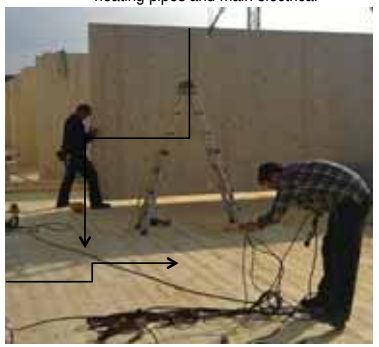
Integration of the vertical MEP distribution systems in the walls for Phase 2 & 3

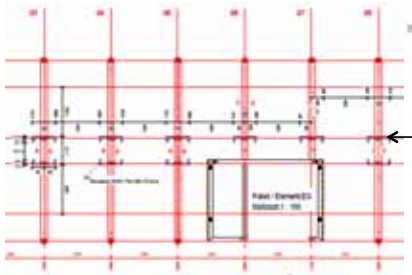
- In the 1st & 2nd floor the architect provided regularly spaced niches to integrate all the pipes and wires but we had no walls in the ground floor in Phase 2 & 3



The pipes and wiring for the rooms upstairs was integrated into a box around the posts for the frame structure. At each gridline we had two of these posts.

Cut out for air conditioning ducts heating pipes and main electrical





Predrilling for tubes in the upper floor panel

Wall & Floor assemblies – Integration of plumbing & electrical

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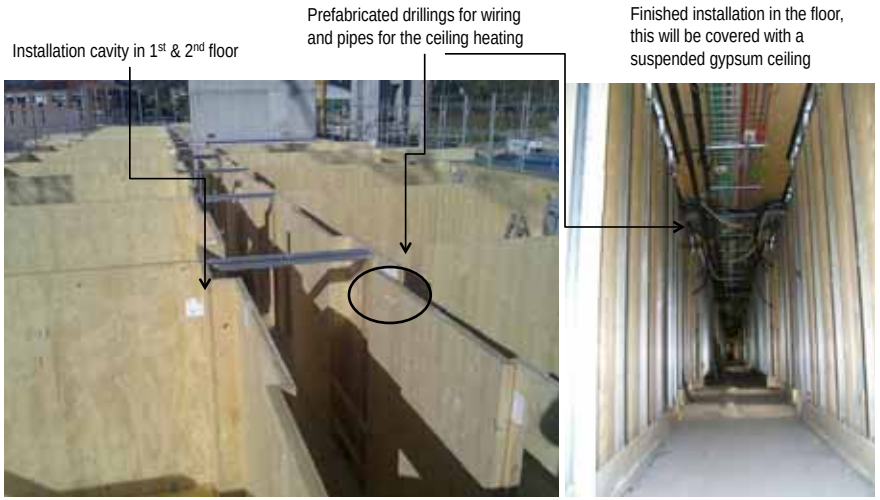
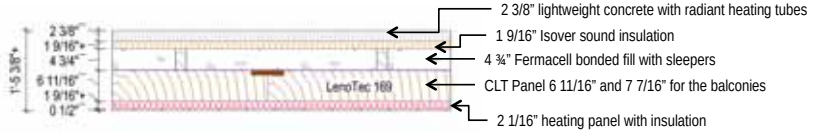


Wall & Floor assemblies – Floor assembly

Horizontal distribution of the MEP systems in the floor and ceilings

- The requirement for the floor package on top was approximately 9" to integrate an air duct outlet channel under all windows in the rooms.
- In the first details the architect had a lightweight concrete on top of the panel to create space. The higher weight was requiring bigger panel thicknesses with more layers (drives the price up)
- The bonded fill weights approximately ¼ of the lightweight concrete this allowed us to reduce the panel thickness



Wall & Floor assemblies – Floor assembly

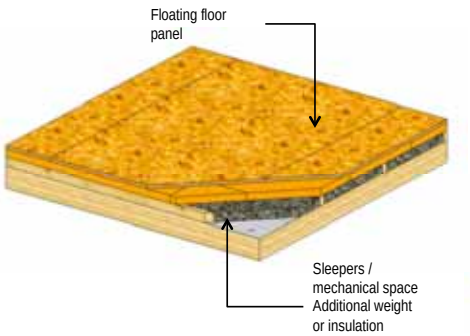
Typical floor assemblies here:

- I-joist or trusses – the installation is running in the space of the box construction
- Requirements for acoustic protection are lower

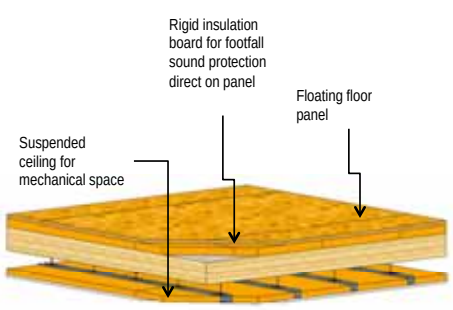
What could be a solution for CLT floors?

- Apply Rigid insulation panels directly to bottom of the CLT floor panel and install floating floor panels on top (OSB / Plywood / Gypsum Fiber Board)
- If ducts have to run on top of the floor 2x6 sleepers can provide enough space for rectangular ducts
- The space between the sleepers can be filled with additional weight for higher acoustic protection
- Use suspended ceiling systems to create space if the floor panels are not visible
- Radiant heating build ups can made as shown below with Warmboard instead of OSB or with a floating lightweight concrete / gypsum grid

Sample ceiling with CLT visible and mechanical space



Sample ceiling with CLT visible and mechanical space



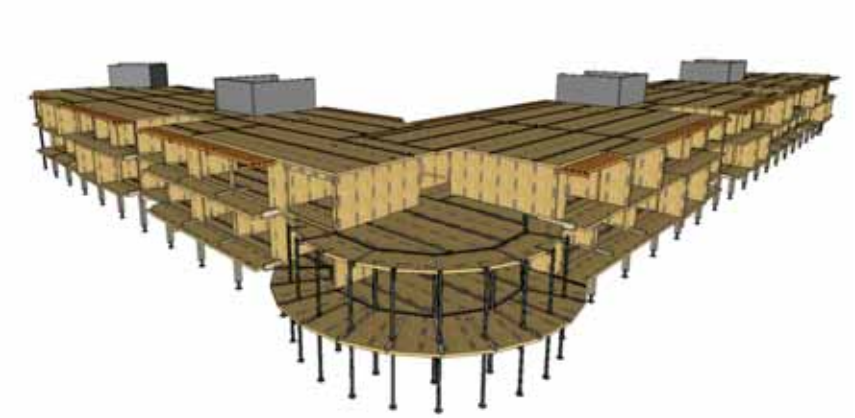
Wall & Floor assemblies – general notes

- The CLT handbook provides additional wall and floor assemblies
- The Website www.dataholz.com is a great source for typical assemblies in Europe and can provide good input. Not all of the materials used in Europe are available in North America or the pricing is different. But it can be a good starting point and source for ideas and details.
- Think early about the mechanical spacing and get the experts involved.
- Contractors might be not be easy to convince to work with new materials

Mechanical room in the basement

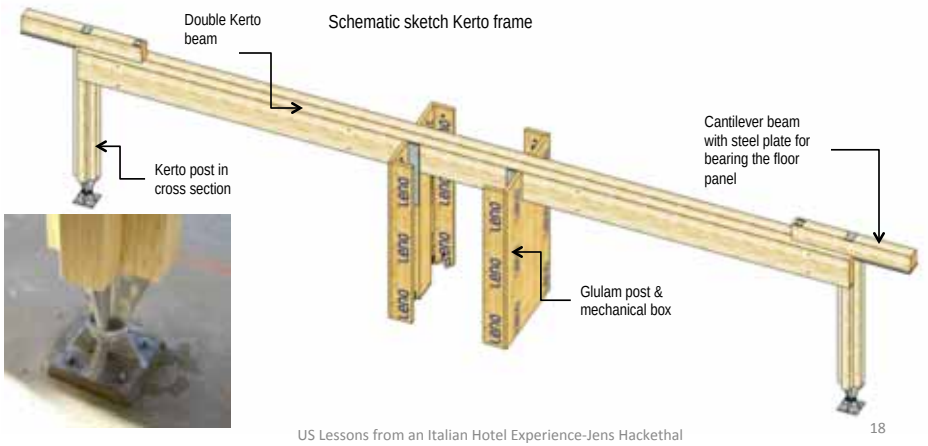
Phase 3

- The ground floor area houses a restaurant, 2 bars & kitchen. The two upper floors include hotel rooms and in the outside corner of the L-shape another bar is located
- The two upper floors in CLT standing in the ground floor on Kerto (special LVL) posts. Only in the L – corner are some CLT walls continuous from the ground floor to the roof. We could use two of these walls for the building bracing.
- The Kerto posts with the beam on top are repeating in each gridline of 17'
- The horizontal loads for the building are transferred to the four concrete stairways



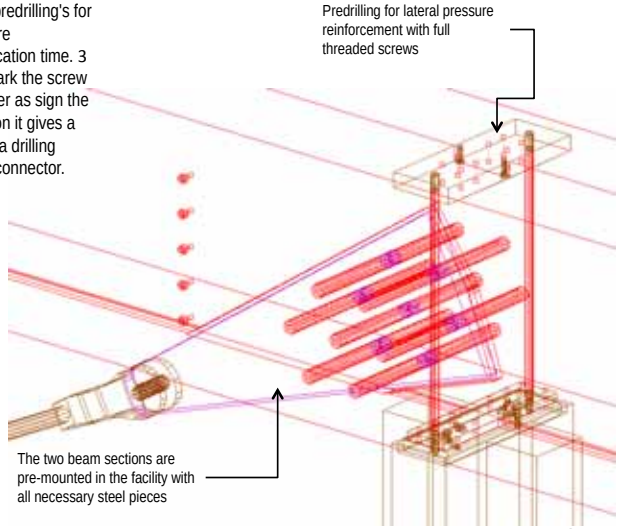
Phase 3

- Originally the post and beam structure was conceived in concrete however the concrete contractors could not meet tolerances so another option was required.
- We researched steel and timber. At first steel posts and beams were attractive but to achieve the required fire protection we would have to cover all steel parts with panels resulting in twice the cost.
- Ultimately a Kerto LVL and Glulam structures was chose. To meet fire standards the size of the members could be increased and however the higher strength of the Kerto LVL in comparison to glulam allowed us to keep the beam sections shallow enough to provide enough floor height.



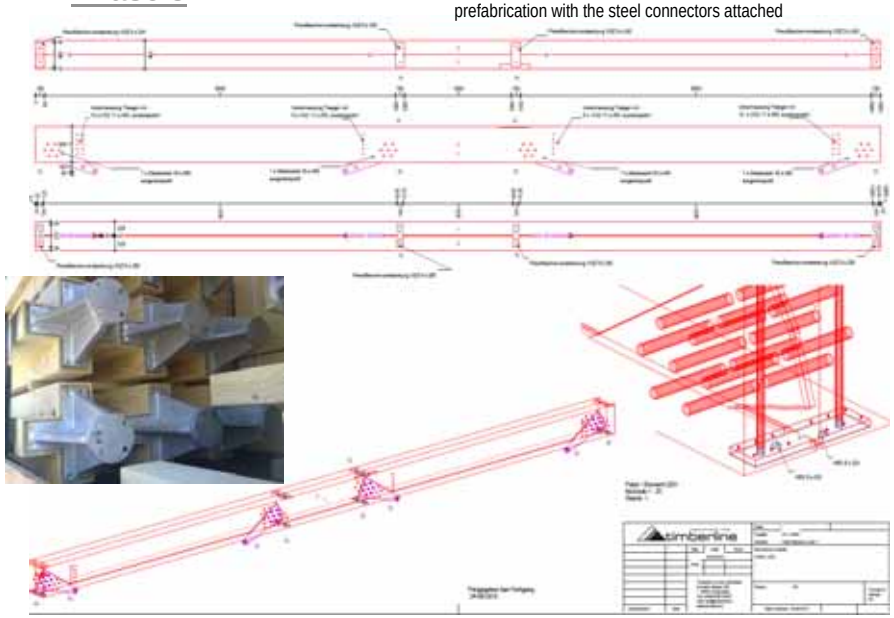
Phase 3

- We tried to prefabricate as much as possible in the facility to avoid too much handling on site
- All connections and drillings are included in the 3d model. For example the little predrilling's for the beam connection and pressure reinforcement speed up the fabrication time. 3 The drilling depth is only ¼" to mark the screw positions in this way is much faster as sign the for each beam by hand. In addition it gives a good control for the fabrication – a drilling without screw means we miss a connector.

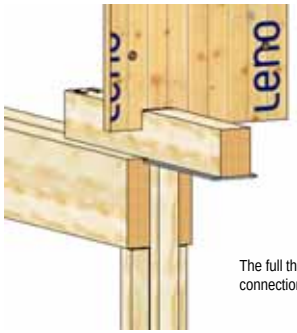


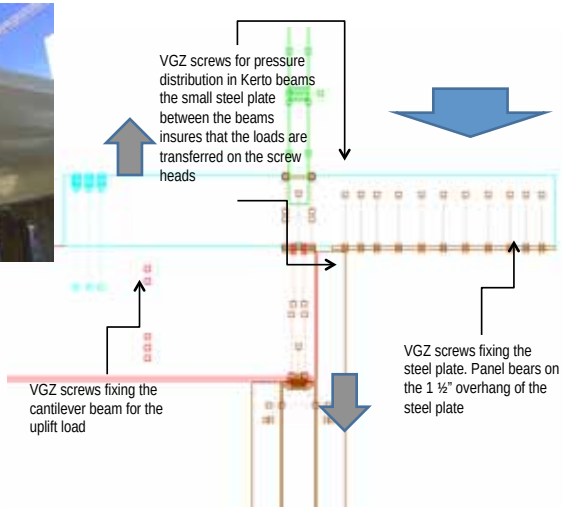
Phase 3

Sample shop drawing for the Kerto beams prefabrication with the steel connectors attached



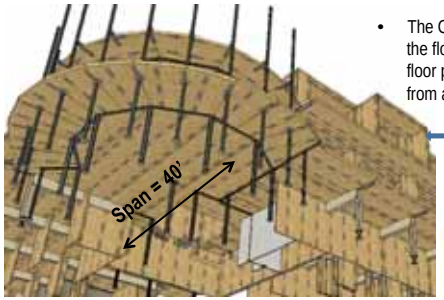
Phase 3 – Detail bearing CLT panels for balconys



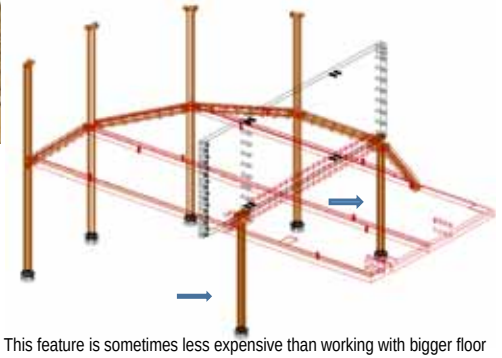


The full threaded screws provide a lot new possibilities for connections and reinforcements. Steel connections can be sized smaller. This can help to make the structure more cost efficient.

Phase 3 – CLT walls act as a deep beam



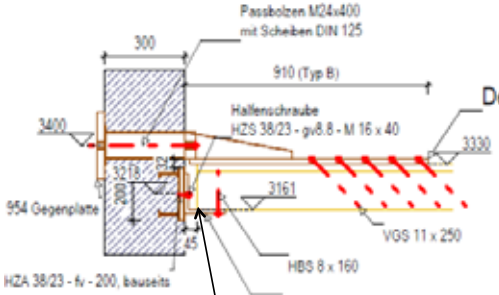
- The CLT wall panel spans between 2 ground floor posts. The edge joint on the floor panel is 'hung' from the bottom of the wall panels above. The long floor panels are connected to the wall with full threaded screws screwed from above.
- The same system is used with some of the panels from the balconies. They are hanging on the cantilevered partition walls.



This feature is sometimes less expensive than working with bigger floor panels. Creative structure like this can also allow the architect more freedom in design. See the photo to the left. The 30 deg rotated upper story is bearing in the wall in the middle of the building. This made it possible to work without a corner post for the windows.

Phase 3 CLT, concrete and building tolerances

All the timber parts and pieces are prefabricated on CNC machines and arrive on site with tight tolerances. The cast-place-concrete does not have as tight tolerances therefore, adjustable details are needed to account for this.



Halfen cast in channels for vertical tolerances

Long hole in the steel L-profile for horizontal tolerances

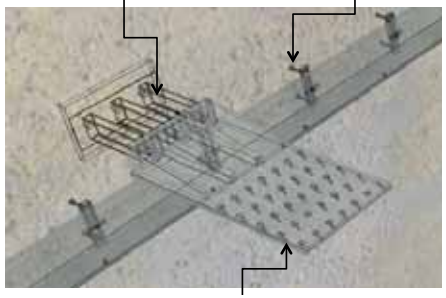
CLT panels have 1 ½" tolerance to the wall. To transfer the horizontal loads (earthquake) the gap is filled with a high resistant non shrinking grout

Detail A

The rendering below shows the connection concept. The template in the concrete was also delivered form us.

Build in template for bolt trough connection

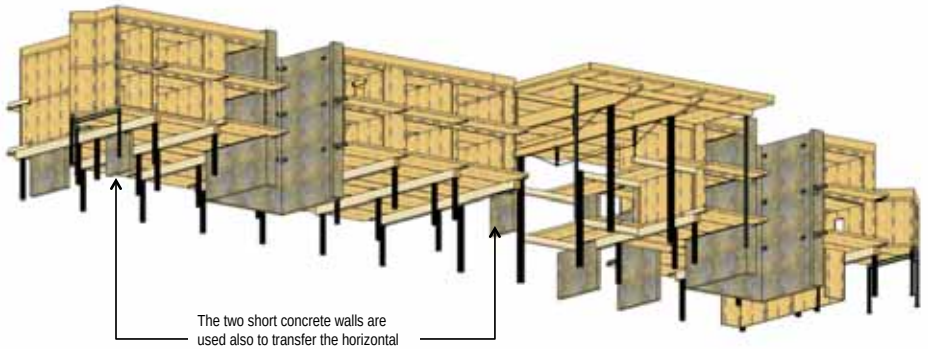
Halfen channel & steel profile with long hole



Steel connector for horizontal connection of the floors to the concrete

Phase 2 CLT and concrete and the building tolerances

- The ground floor area houses the swimming pool and spa area with a 3 story ceiling height.
- The roof structure in the swimming area was supported by 4-3-story high posts. The swimming pool was built around these posts, therefore they were made out of concrete.
- Except for the two concrete stair cases there are no continuous walls from the ground floor up to the roof. There are only two short concrete walls on the end of the building to transfer the horizontal loads and the two concrete stair cases.

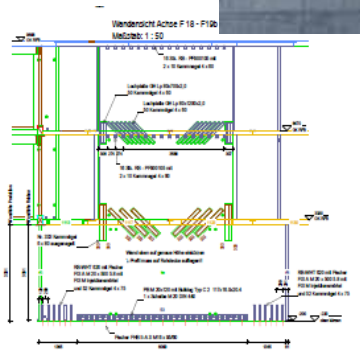


The two short concrete walls are used also to transfer the horizontal loads

Phase 2 CLT and concrete and the building tolerances



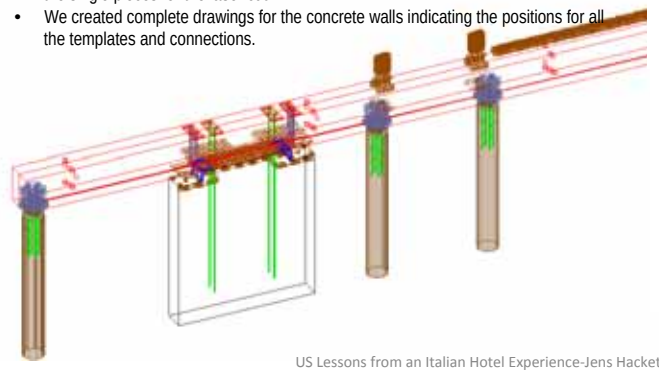
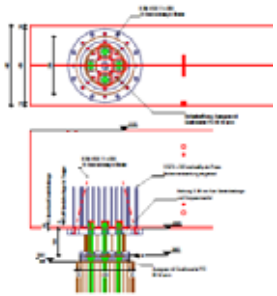


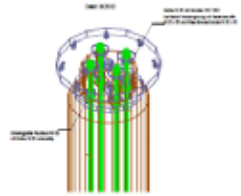


Phase 2 CLT and concrete and the building tolerances

We can see in the pictures below that the connections to the concrete required high precision. The steps to insure the required tolerances and avoid mistakes were the following:

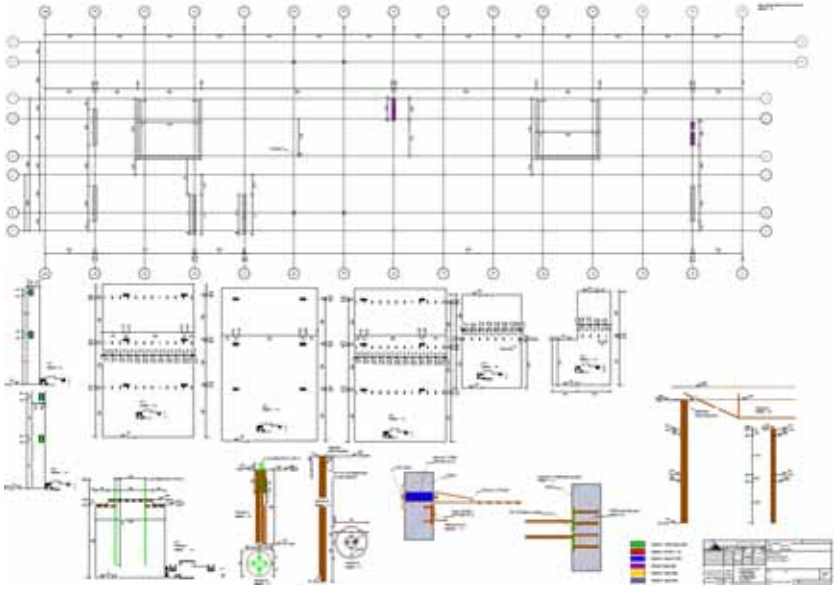
- The connection concepts were developed in cooperation with the engineer who designed the concrete elements and with the general contractor to avoid interface problems with them.
- We included the modeling of all necessary steel connections and parts in our 3d model.
- To make the positioning of the threaded rods easier, we used templates to install them.
- We created all the steel shop drawings out of our model and provided dwg files for the single pieces for the laser cut.
- We created complete drawings for the concrete walls indicating the positions for all the templates and connections.



Phase 2 CLT and concrete

Drawing for the concrete contractor with the connection details and template positions for building phase 2



Phase 2 the roof over the pool

The challenge here was to bridge the 52' clear span with a minimal beam height to not constrain the view from the last floor into the pool area. CLT roof panels are spanning 90 degree rotated in 17' grid over these beams. The best solution here was to create a pre-tensioned beam with steel tension rods. This allowed us to reduce the beam height to 36". The steel tension rods do not constrain the view too much. The beam section was built with two glulam beams. The small gap between the two beams allowed the steel plates to be connected without any complicated cuts.


The erection time for the complete structure was 2 months. This also included the sun protection in Larch and the steel posts on the balconies. The Baucon team was assembled two truck loads of CLT per day with eight carpenters. Three different companies were responsible for the prefabrication of the timber parts which required machine data files for five different machines. The amount of mistakes was minimal. Except for one small design error on one panel, the mistakes were mostly due to truck loading errors and late material orders.

Case Study – Summary

- The early involvement in the design phase helped to find effective and smart solutions. Architects and engineers cannot have the deeper knowledge of all types of construction than a team of construction professionals who do this job every day.
- Typically in Europe, the timber construction companies are responsible for delivery of a complete project from material fabrication to erection. It is their target to be as fast, efficient and accurate as possible. This responsibility lends itself to a more optimized material delivery and erection process. In addition a high prefabrication level helps to meet these goals.
- The inclusive 3d modeling of all timber, steel pieces and interfaces with other trades avoids a lot mistakes. It is easy to imagine that on a project where each material supplier (Glulam, CLT, SIP panels and steel fabricators) creates their own shop drawings, the possibility for supply issues can be higher.
- CNC machining is an industry standard and helps to reach better precision. This helps to speed up also the erection process.
- The prefabrication of additional interior walls and their erection in the same cycle with the CLT panels can save time and money on side too.

We do not sale timber products
We sell complete creative solutions
Thank you for your attention