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Sustainable Public Buildings Designed and Constructed in Wood (Pub-Wood)

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Study on Best Practices in Wooden Public Buildings' Design and Construction

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INTRODUCTION

The Pub-Wood Project is a two-year project that aims to develop a trans-disciplinary and transnational course/ elective element in the EU HEIs on the design, construction and management of sustainable public wooden buildings in order to enhance the quality and relevance of students' knowledge and skills for future labour market needs.

The specific objectives of the project are:

1) To strategically research at which level sustainable design, construction and management of wooden public buildings are to be planned and implemented in the partner countries.
2) To educate all participants (students, teachers, entrepreneurs) in the field of the sustainable wooden construction.
3) To develop and implement the new strategic trans-disciplinary module/elective element, which meets the needs of the HEIs and market representatives, fulfils the future challenges of sustainable public wooden buildings' design, construction and management.
4) To improve competencies of students and teachers in problem solving and team work, innovative thinking, motivation, awareness of cross-professional project input and project management by using real problem-based and blended learning approaches.
5) To ensure open awareness of the project results to local, national, EU level and international target groups.

Study contains analysis of best practices on implemented public wooden buildings' projects.

The content of this reportis related to the Pub-Wood Project and reflects only the author's view. The National Agency and the Commission are not responsible for any use that may be made of the information it contains.

1. CASE STUDY 1: Open-air stage in Krimuna

1.1. General information

1. Location: Krimunas, Krimuna parish, Dobele district
2. Architects: SIA "RBD"
3. Client: Dobele district municipality
4. Year of construction: 2017
5. Duration of construction: 2 months
6. Height: 7 meters
7. Number of floors: 1
8. Cost: EUR 97469.05 plus VAT 21%

Fig. 1. After construction (Gadalabākābūve Latvijā 2017, 2018. The best building of the year in Latvia, 2018)

1.2. Design and structural principles

The aim of the project is to construct the roof structure on the foundations of the existing stage, making high-quality cultural services available to the residents of Krimuna parish of Dobele district.

Fig. 2. Before construction (Gadalabākābūve Latvijā 2017, 2018. The best building of the year in Latvia, 2018)

The construction of the stage ensures a well-maintained and quality environment for cultural events promotes a variety of public life activities and makes recreational services available.

The stage is designed to partially preserve the platform of the previously built stage. The arched form and wooden architecture are adapted to the environment and artistic events.

1.3. Materials and finishes

The load bearing structures of the stage are made using curved glue-laminated wood beams manufactured in Latvia.

The arches are made using variable geometry to obtain the architectonical features of the structure. The load bearing structure consists of curved glue-laminated wood arches with a span of 13.72 m and a total building height of 7.20 m.

Fig. 3. Curved glue-laminated wood arches(Gadalabākābūve Latvijā 2017, 2018. The best building of the year in Latvia, 2018)

Fig. 4. Construction phase (GadalabākābūveLatvijā 2017, 2018; The best building of the year in Latvia, 2018)

The load bearing structures are made of 21.62 m^3 of glue-laminated timber.

Fig. 5. Latvian Forests (Latvian State Forests, 2018)

In Latvian forests, 0.95 m^3 grows in 1 second (Latvian State Forests, 2018). The amount of wood used in load bearing structures grows in 22.76 seconds in Latvian forests.

1.4. Resources consumption in the use stage (water, energy, etc.)

Within the framework of the project, the construction of the roof structure ensures the possibility of placing the sound and lighting equipment under the roof covering, thus protecting the equipment available to the community centre from rain and other unfavourable factors.

In addition, rainwater drainage system has been built in the construction of the roof, promoting rainwater drainage from the foundations of the stage, which will ensure the sustainability of the stage.

1.5. Additional information

The object serves not only as a venue for local cultural events, but also as tourist attraction.

2. CASE STUDY 2: Rebuilding the barn of Aluksne station

2.1. General information

1. Location: Jankalna Street 52, Aluksne, Aluksnedistrict
2. Architects: SIA "Arhitektes Ināras Caunītes birojs"
3. Client: Aluksnedistrict Municipality
4. Year of construction: 2018
5. Duration of construction: 2 years
6. Height:
7. Number of floors: 1
8. Cost: N/A

Fig. 6. Outside view (Gadalabākābūve Latvijā 2018, 2019. The best building of the year in Latvia, 2019)

Fig. 7. Inside view (Gadalabākābūve Latvijā 2018, 2019. The best building of the year in Latvia, 2019)

2.2. Design and structural principles

National cultural monument preserves rich history and is unique on the Baltic and European scale.

The goal is to preserve the 1902 luggage barn for future generations, to ensure accessibility, and to diversify tourism offerings.

Fig. 8. Before rebuilding (outside) (Gadalabākābūve Latvijā 2018, 2019. The best building of the year in Latvia, 2019)

Constructive solutions:

Soil characteristics: *Simple*,

Foundation: *Shallow (ribbon and pile foundation),*

Object constructive scheme: *Frame,*

Inter-floor covering type: *Wood beam,*

Type of roof covering: *Rafter, bundle and brace structure,*

Non-load bearing exterior wall material: *Wooden stands, planking,*

Partitions: *Wood frame, planking,*

Stair construction: *Wooden staircase on concrete foundation,*

Bearing external wall material: *Wood frame, planking.*

Fig. 9. Before rebuilding (inside) (Gadalabākābūve Latvijā 2018, 2019. The best building of the year in Latvia, 2019)

The main challenges in the design process: by making the most of the existing structure to construct an insulated building that would still create an impression of the luggage barn inside and outside.

To restore the foundations, the structure of the building was made as easy as possible: the roof covering and planking were removed.

The building frame was lifted and based outside the foundation area.

Boulder foundations were built, the crown beam and the damaged wood structures were replaced.

2.3. Materials and finishes

Non-load bearing exterior wall material: *Wooden stands, planking,*

Partitions: *Wood frame, planking,*

Stair construction: *Wooden staircase on concrete foundation,*

Bearing external wall material: *Wood frame, planking.*

The paths surrounding the building are covered with ELASTOPAVE cover – it is visually closest to the historical gravel road surface. ELASTOPAVE cover is natural stone (granite) chips interconnected (bonded) with polyurethane binder.

The cover withstands temperature fluctuations, maintains physical properties, and withstands frost/thaw actions.

Fig. 10. Wooden stands, planking before rebuilding (Gadalabākābūve Latvijā 2018, 2019. The best building of the year in Latvia, 2019)

Thanks to the porous structure, water does not accumulate in the pavement and at the same time it has a free space where water can expand by changing the physical state. In winter, such cover is not slippery.

2.4. Resources consumption in the use stage (water, energy, etc.)

Use of energy-efficient solutions:

Double-skin walls and roof structures filled with eco-wool ensure the thermal stability of the building – heating costs account for EUR 90 per month.

The heating system of the building is connected to the district heating networks.

The heating unit is located above the cashier’s desk covering and hidden behind the exposition.

To achieve the impression of unheated space, the heating elements are integrated into the floor.

2.5. Additional information

Conservation of cultural heritage and ensuring its accessibility.

A multimedia exposition has been created that allows visitors to get acquainted with the creation and history of narrow-gauge railway.

Renewed infrastructure is an important resource for popularizing the industrial heritage of Latvia and promoting tourism development.

High quality cultural environment has been created.

3. CASE STUDY 3: Construction of covered roof of open public skating rink on Pasta island of Jelgava

3.1. General information

1. Location: Pasta sala 1, Jelgava
2. Architects: SIA “Igate Būve”
3. Client: JelgavaMunicipality
4. Year of construction: 2018
5. Duration of construction: 1 year
6. Height:
7. Number of floors: 1
8. Cost: EUR305 482.02 plus VAT 21%

Fig. 11. Outside view (construction phase) (Gadalabākābūve Latvijā 2018, 2019.The best building of the year in Latvia, 2019)

Fig. 12. Outside view (final view) (Gadalabākābūve Latvijā 2018, 2019. The best building of the year in Latvia, 2019)

Fig. 13. Inside view (final view)(Gadalabākābūve Latvijā 2018, 2019. The best building of the year in Latvia, 2019)

3.2. Design and structural principles

The task of designing a construction project is to protect the existing hockey area from rain and snow.

The greatest challenge is to design the existing communication in "the jungle".

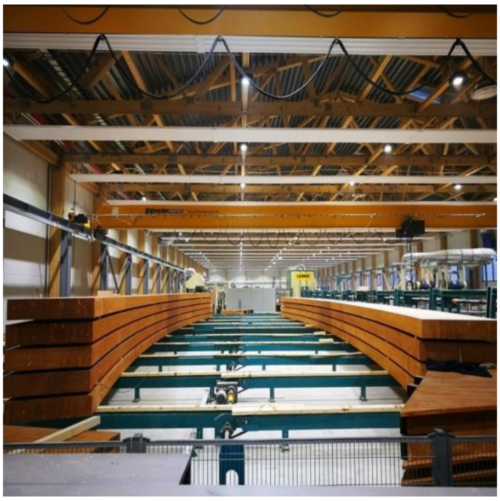


Fig. 14. Wood structure materials (Gadalabākābūve Latvijā 2018, 2019. The best building of the year in Latvia, 2019)

The most important challenges in the construction project are related to the moment node and the design of suitable foundation.

3.3. Materials and finishes

The roof of the skating rink is made up of glue-laminated wood frames covered with membrane-type roofing. Between the columns, mesh structures are secured to prevent rain and wind.

Fig. 15. Three-threaded frame (Gadalabākābūve Latvijā 2018, 2019. The best building of the year in Latvia, 2019)

The structure consists of a three-threaded frame of curved and variable cross-section elements with a common span of 22.60 m.

In addition, different size steel pipe-profile beams have been designed for membrane type roofing reinforcement and additional support.

3.4. Resources consumption in the use stage (water, energy, etc.)

The roof bearing structures are made of 112 m3 of glue-laminated timber. In Latvian forests, 0.95 m^3 grows in 1 second (Latvian State Forests, 2018).

The amount of wood used in load bearing structures grows in 2 minutes in Latvian forests.

3.5. Additional information

The surrounding area is one of the most popular footpaths of residents of Jelgava, as well as the central venue for organising events in Jelgava.

4. CASE STUDY 4: Universal sports complex in Palanga, Lithuania

4.1. General information

1. Location: Sports street 3, Palanga, Lithuania

2. Architects: Matas Jurevičius, Gediminas Jurevičius

3. Client: Palanga city Municipality

4. Year of construction: 2014

5. Duration of construction: 2 years

6. Height: 11.3 m

7. Number of floors: 2

8. Cost: 4.4 million Euros

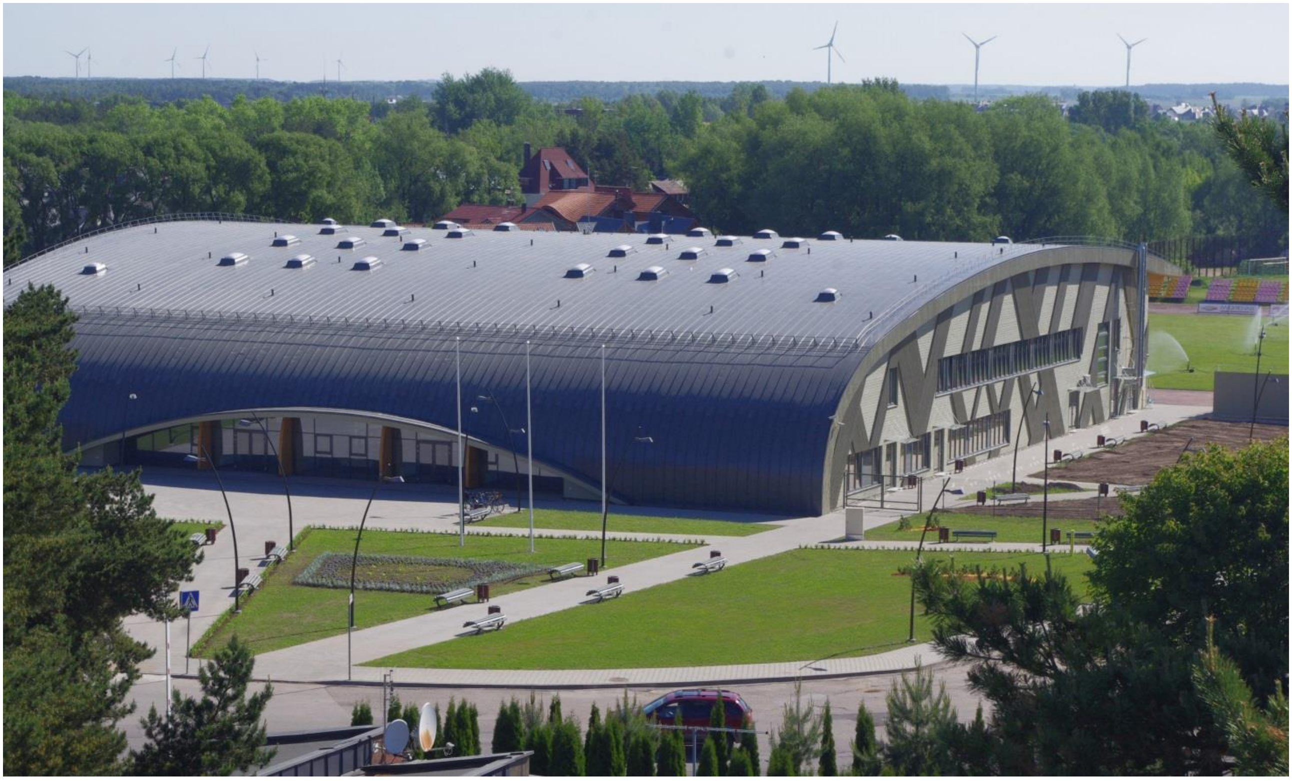


Fig. 16. The outside view of the completed building (www.sporthall.palanga.lt)

Fig. 17. The inside view of the completed building (www.sporthall.palanga.lt)

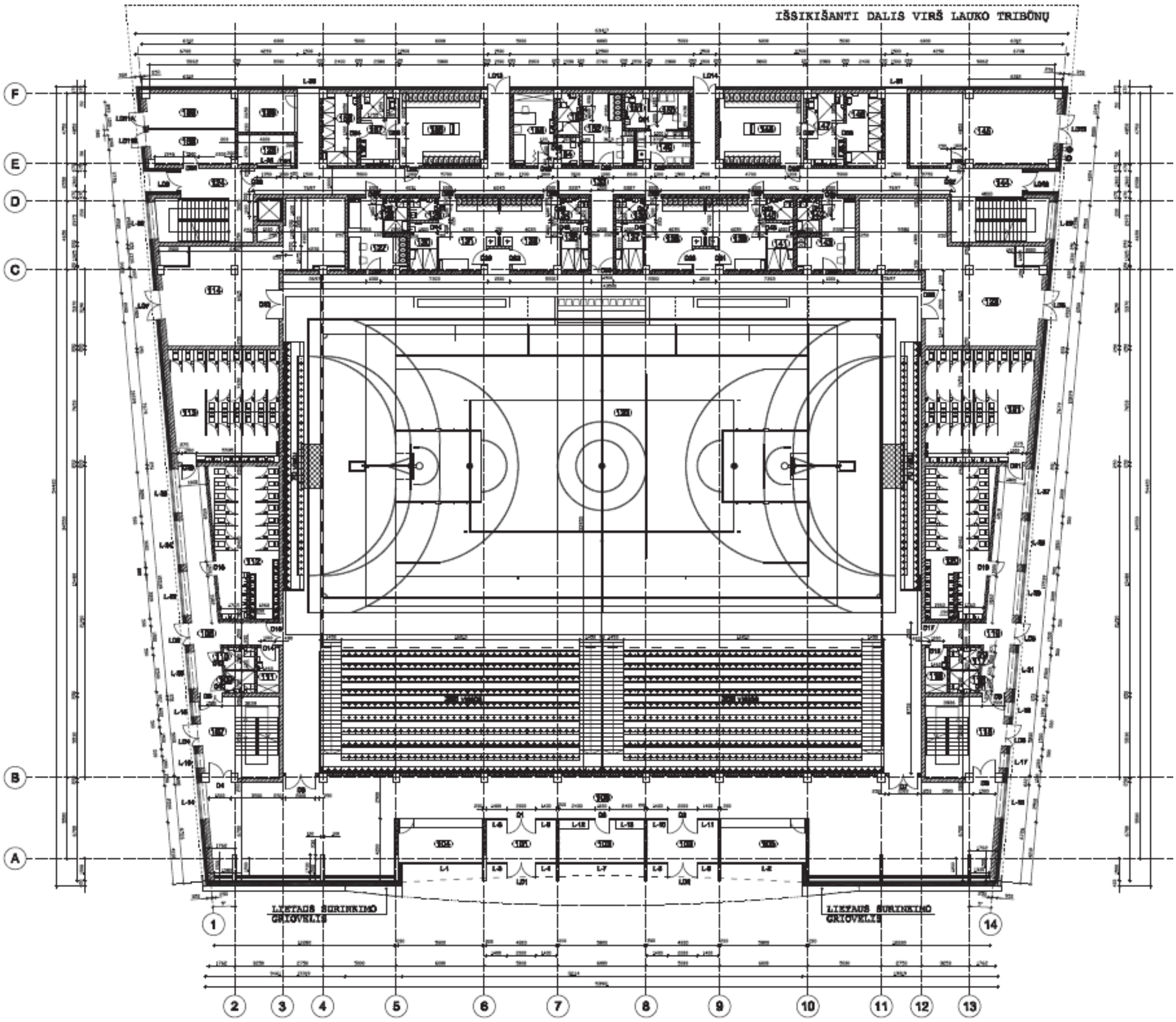


Fig. 18. The plan of multifunctional sports hall

4.2. Design and structural principles

The load bearing structure of the multifunctional sports hall is reinforced concrete columns and curves axis glulam beams and arches. The main cross section of the building is shown in Figure 19, in which all load bearing structures are shown. The rectangular shaped reinforced concrete columns are rigidly connected to the foundation; while curved axis glued laminated timber beams are flexibly supported on the reinforced concrete columns and foundation.

The maximum span (the maximum distance between supports) is 34.55 meters. This span is overlaid using the entire glued laminated timber beam. The transportation of the glued laminated timber beams (36 meters length with width 180 mm; height 1960 mm) to the construction site is shown in Figure 20.

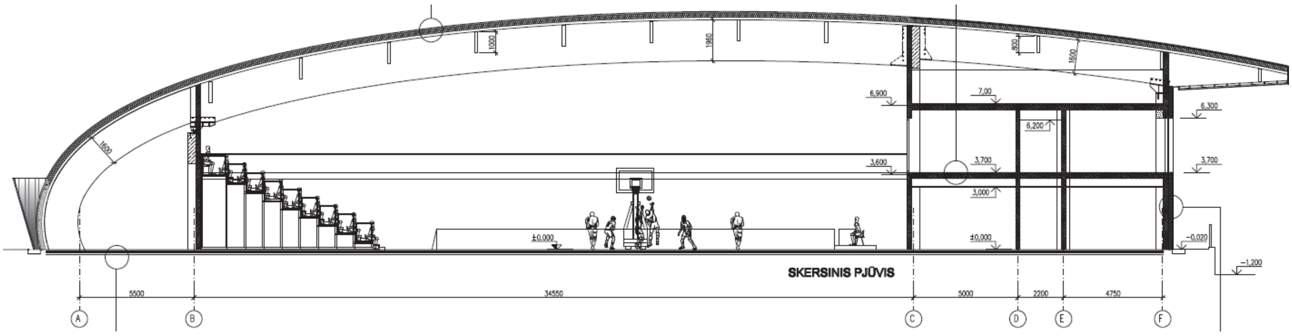


Fig. 19. The cross section of the multifunctional sports hall in Palanga city, Lithuania

Fig. 20. The transportation of 36 m length glulam beams for the multifunctional sports hall in Palanga city, Lithuania (www.veidas.lt)

One glued laminated timber beam with length of 36 meters weighs around 10 tones. The mass is relatively small as timber has very good strength/mass ratio, especially if comparing with heavy materials such as reinforced concrete. Views from the construction process are shown in Figure

21, in which main structural materials are shown, glued laminated timber and reinforced concrete in combination with masonry walls.

Fig. 21. The construction process of sports hall in Palanga city, Lithuania (www.sporthall.palanga.lt)

4.3. Materials and finishes

As the previous figures show, the timber view in the interior is left with is natural appearance, it means covered only with translucent lacquer. Other structural materials (reinforced concrete and masonry walls) were plastered or covered with plasterboards. Some parts of glulam beams are extracted to the outside of the building, so these parts were covered with thin walled steel canopies, for protection from rain, shown and solar.

4.4. Resources consumption in the use stage (water, energy, etc.)

No technical or commercial data could be found in terms of recourses consumption for this multifunctional sports hall.

4.5. Additional information

The multifunctional arena is used for both, commercial and non-commercial purposes. Some TV shows are filmed in this arena. Also, Lithuanian national basketball team usually trains in this arena for the championships.

5. CASE STUDY 5: Lookout restaurant Al Nahham in Banana island Doha, Qatar

5.1. General information

1. Location: Banana Island, Doha, Qatar
2. Architects: Project Management and Supervision Consultants Hill International
3. Client: Private Engineering Office, Doha, Qatar (the current governing manager: Anantara)
4. Year of construction: 2014
5. Duration of construction: 2 years
6. Height: 12.8 m
7. Number of floors: 1
8. Cost: No data

Fig. 22. The outside view of the lookout restaurant in Banana Island, Doha, Qatar

Fig. 23. The inside view of the lookout restaurant in Banana Island, Doha, Qatar (www.anatara.com)

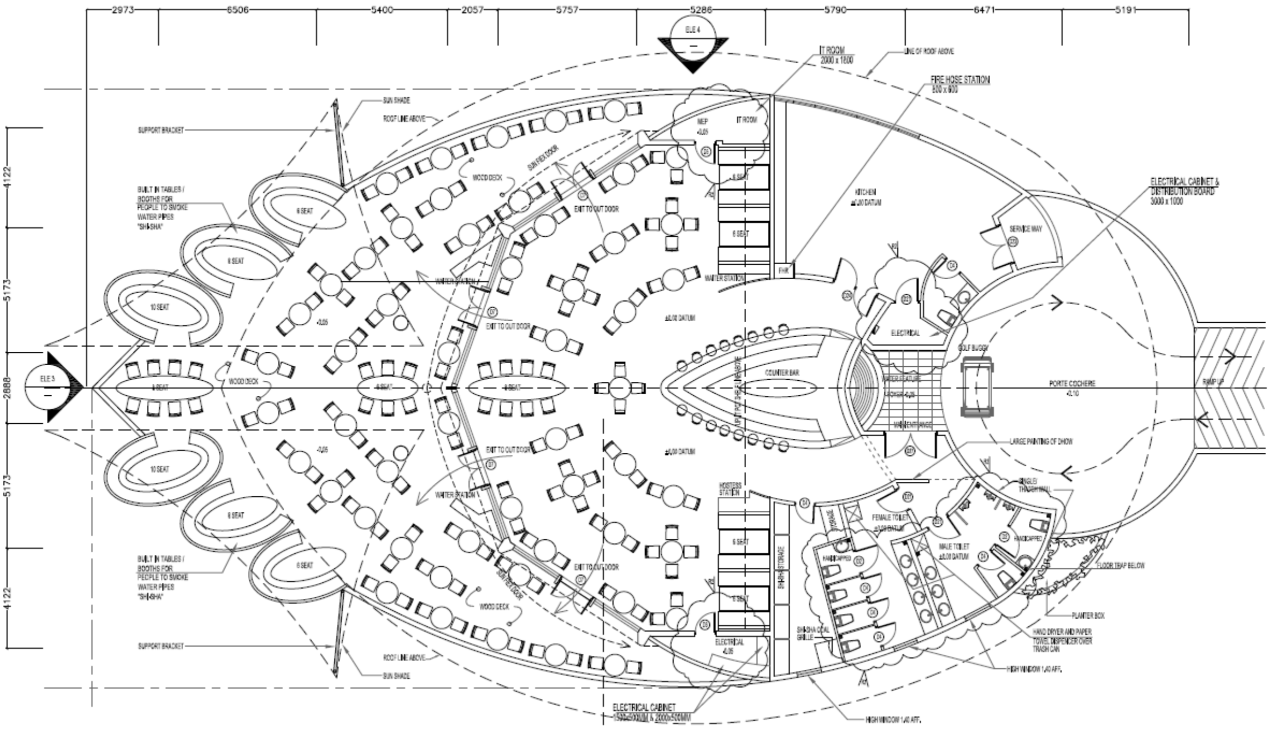


Fig. 24. The plan of the lookout restaurant in Banana Island, Doha, Qatar

5.2. Design and structural principles

The dimensions in plan of the Lookout restaurant are 43 m in length and 25.6 m in width. The three dimensional view of the whole load bearing structures are shown in Figure 10. The load bearing structure consists of: rectangular and circular cross section reinforced concrete columns; circular hollow steel supporting struts and the load bearing curved glued laminated timber arches. The reinforced concrete columns are rigidly supported to the foundation and struts are flexibly connected to the top of reinforced concrete columns. The load bearing glulam arches are supported on the steel struts. The whole roof structure is supported only on 8 reinforced concrete columns. The cantilever of glulam arches are up to 7-8 meters.

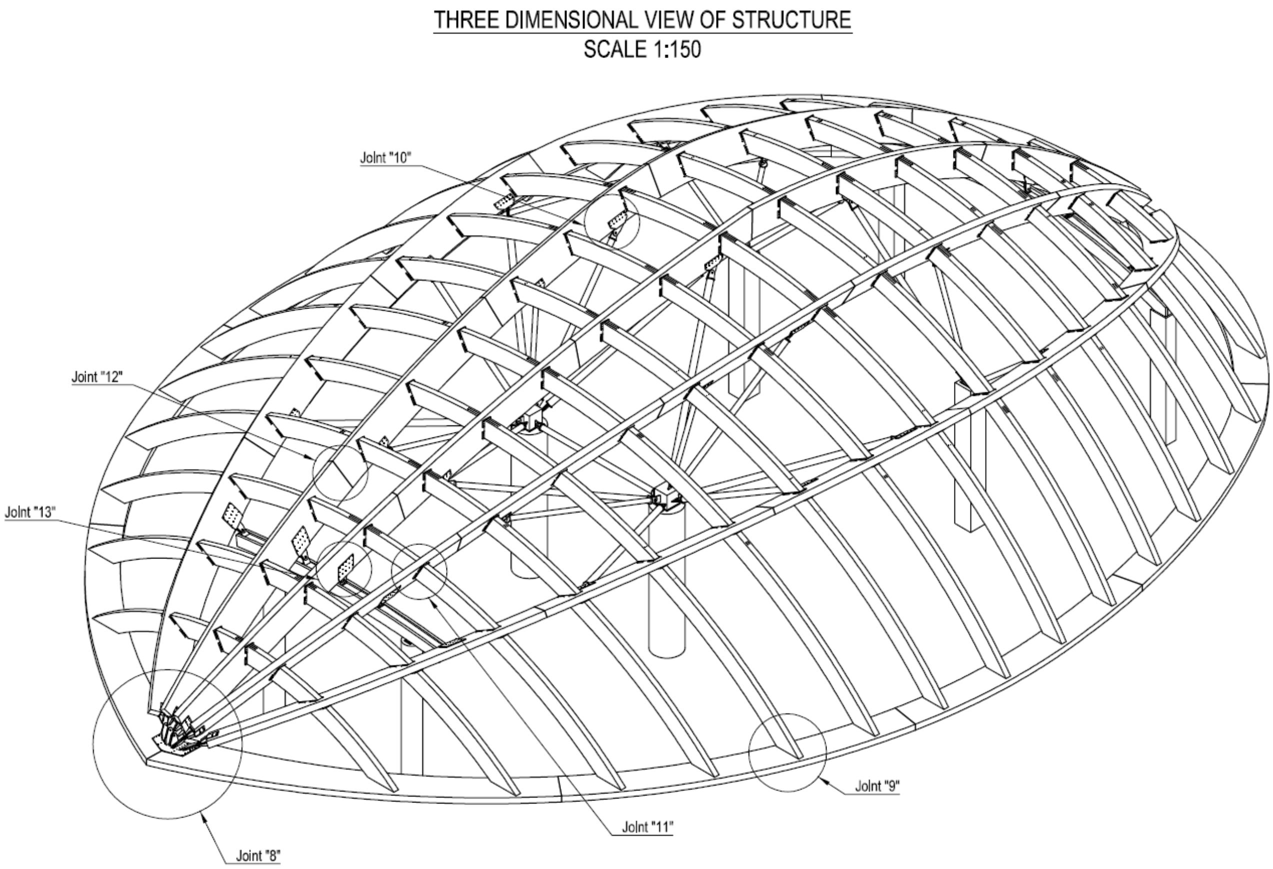


Fig. 25. The 3 dimensional view of the lookout restaurant in Banana Island, Doha, Qatar

The process of construction is shown in Figure 26. Close to the construction site there are no factories which produces glued laminated timber load bearing structural elements. For this reason the main arches with length up to 60 meters were cut into 5 separate elements with maximum dimensions up to 13 meters with an aim to fit these elements in sea containerships. For this purpose special connections with self-tapping screws developed. This type of connection is able to transfer bending moments; axial and shear forces. The main issue with the design of this load bearing structure was very high wind speed, value 42 m/s. As timber structures are relatively light structure, so there should be some special anchoring details to fix the roof structure to the below load bearing structure.

Fig. 26. Construction process of the lookout restaurant in Banana Island, Doha, Qatar

The beam-to-beam connection of main roof arch was installed using the self-tapping crews, shown in Figure 27. This type of self-tapping screws does not require any predrill holes in timber and in steel plates with thickness up to 15 mm. The initial stip of the connection is avoided by using this type of screw.

Fig. 27. Self-tapping screws used for timber beam-to-beam connection of main glulam roof arches (www.rothoblaas.com; www.sfs.biz)

5.3. Materials and finishes

The roofing material was chosen a natural thatch. This roofing represents the traditional architecture in tropical countries.

As it was shown previously, the glued laminated timber elements were left unpainted, only several layer covered with antiseptics and flame retardants. The interior of the building shows the natural view of roof timber elements.

The steel strut elements were painted with fire resistant painting.

5.4. Resources consumption in the use stage (water, energy, etc.)

There was no information provided on recourses consumption in the use stage.

5.5. Additional information

The Al Nahham Restaurant was awarded in 2018, in World Luxury Restaurant Awards. Dine in the comfort of the eye-catching restaurant designed in contemporary Arabic style (source: https://www.luxuryrestaurantawards.com/listings/al-nahham-restaurant).

6. CASE STUDY 6: Rievaulx Abbey Visitor Centre

6.1. General information

1. Location: Helmsley, U.K.
2. Architects: Simpson & Brown
3. Client: English Heritage
4. Year of construction: Completion date July 2016
5. Duration of construction: unknown
6. Height: unknown
7. Number of floors: One
8. Cost: Contract value: £ 1.2m

Fig. 28. External appearance (www.ribaj.com)

Fig. 29. Internal view (*www.architecture.com*)

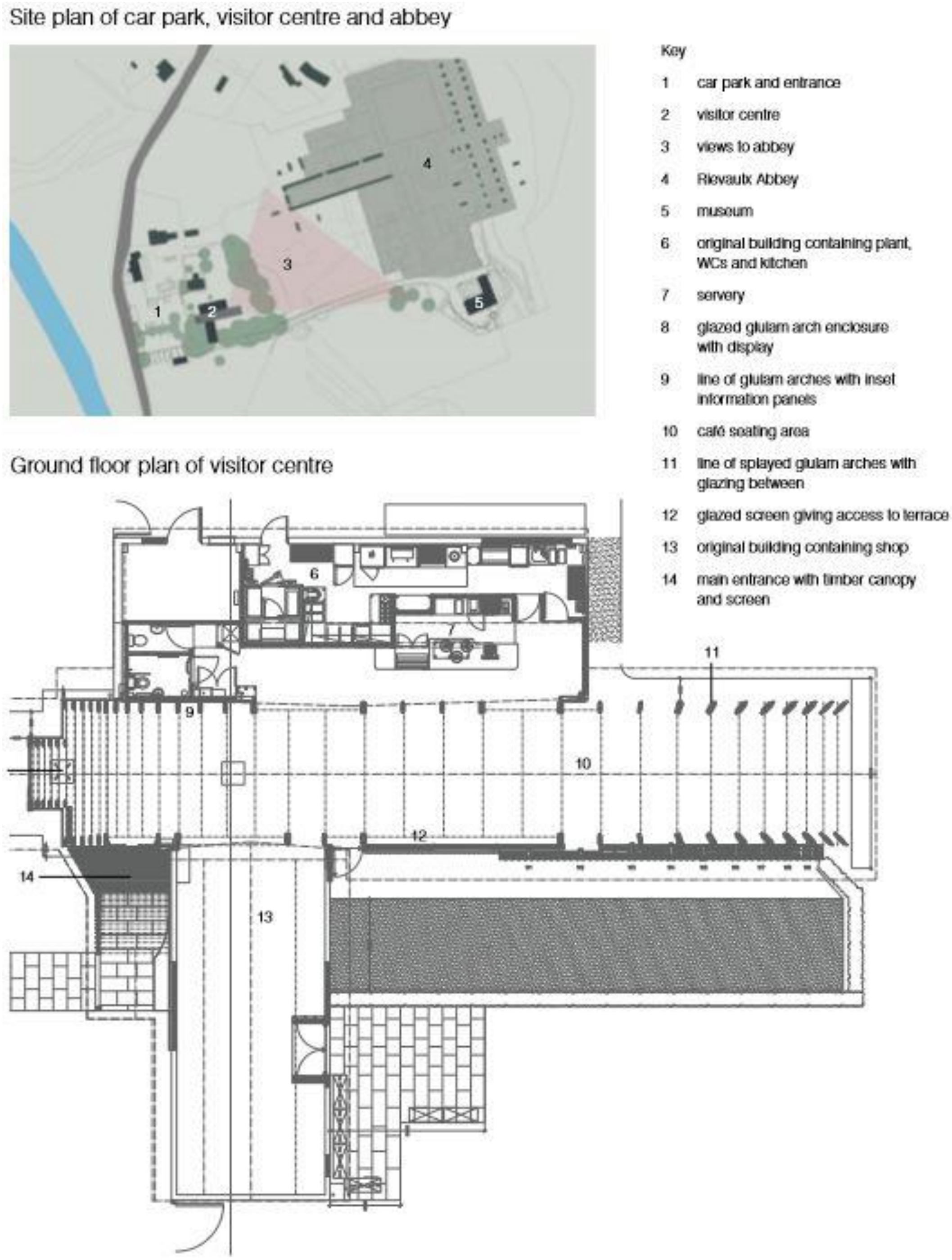


Fig. 30. Site and ground floor plan (TRADA, 2019)

6.2. Design and structural principles

Simpson and Brown Architects were appointed by English Heritage for an improved visitor centre at Rievaulx Abbey. The initial aim of the project was to upgrade the existing visitor facilities, upgrade the museum building, improved staffing facilities and attract more visitors to the Abbey.

The most significant section of the project for this case study is the new central hall within the existing L-shaped building that previously existed.

This new central hall contains a series of engineered glulam timber arches of Scandinavian spruce painted in stunning white gradually splay to reveal site lines to the abbey and presents itself as a modern mirroring and connection of the historic stone columns and arches beyond. These spruce glulam columns and rafters are joined with epoxy bonded-in rods and steel flitch plates conceal the join.

Although only single storey, this double height space provides a sense of height that is flooded by natural light, creating a stunningly beautiful space fitting for a site of historical purpose.

Structurally the engineered glulam frames are joined at roof level with CLT sheeting. Concealed services (including lighting) are within a perimeter edge beam and the panels are visible where feasibly possible.

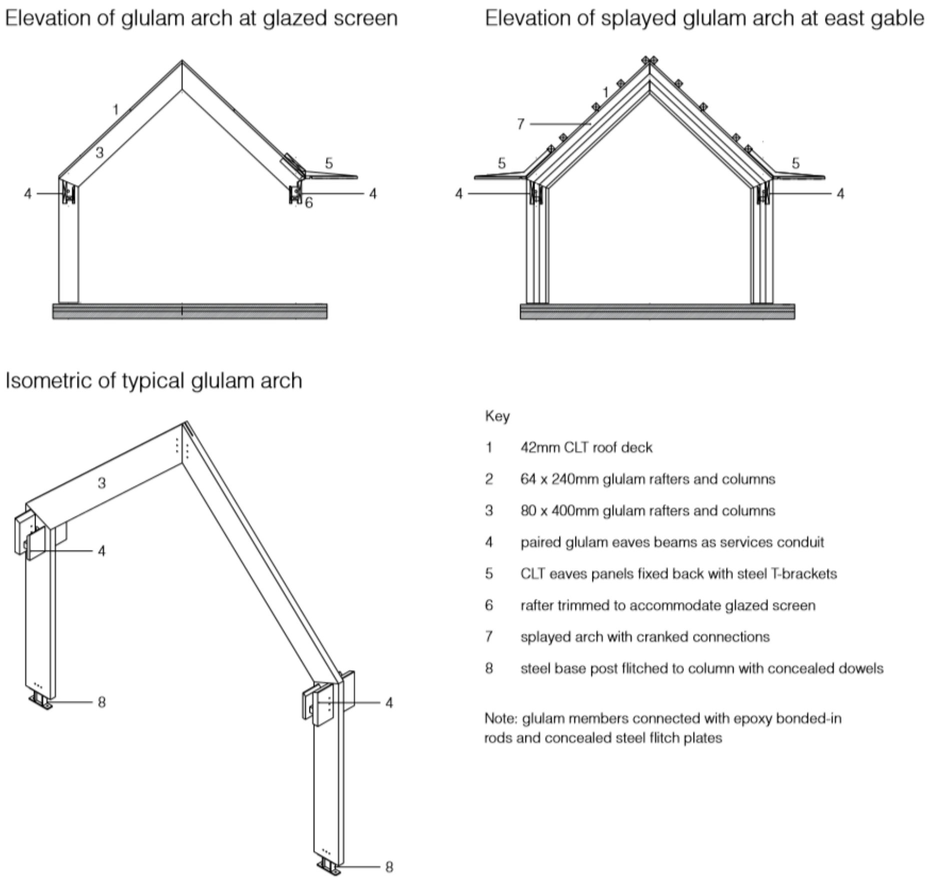


Fig. 31. Structural and detail representation (TRADA, 2019)

Fig. 32. The central hall

(www.e-architect.co.uk)

Fig. 33. 6 Carved stone from the ruin

(www.e-architect.co.uk)

6.3. Materials and finishes

The main materials used for the project include engineered timber, zinc and polished concrete. A ruin from the abbey is also used, exquisitely carved and bears the abbey's name.

Due to the restricted site and tight construction programme off-site fabrication was used. Slot windows were set inside the vertical CLT panels. Both gable ends of the centre are fully glazed, providing the visitor to key views towards the museum and more importantly the ruin itself (as show in Figure 32).

The arches (varying in size but consistent heights and pitch) are connected with 42 mm CLT panels at roof level, these preturde the exterior glazing on the gable ends and fixed with profiled steel T-brackets. These are stained to match the appearance of the arches. The roof is finished in zinc sheet with insulation below.

6.4. Resources consumption in the use stage (water, energy, etc.)

The building has a gross internal area of 469m² and uses as much of the original fabric and timber structure as possible. By using prefabricated components the construction speed was increased, less material waste and the need for materials to be transported to site was reduced. This included the two-stage glulam structure.

The design includes a substantial overhang aiding to direct sunlight overheating in summer and entirely naturally ventilated to all key zones. The latest energy saving devices are used in lighting (LED) and controls.

Simple thoughtful design delivers simple maintenance whilst delivering excellent life cycle costs.

6.5. Additional information

Awards Wood Awards Commercial & Leisure Winner 2017

RIBA Yorkshire Award, Winner 2017

7. CASE STUDY 7: Children Village, boarding school

7.1. General information

1. Location: Formoso do Araguaia, TO, 77470-000, Brazil

2. Architects: Aleph Zero, Rosenbaum. Design Team; Adriana Benguela, Gustavo Utrabo, Pedro Duschenes, Marcelo Rosenbaum

3. Client: Fundação Bradesco

4. Year of construction: 2017

5. Duration of construction: unknown

6. Height: unknown

7. Number of floors: two

8. Cost: confidential

Fig. 33. Exterior appearance (Leonardo Finotti - www.archdaily.com)

Fig. 34. Interior appearance (Leonardo Finotti - www.architecture.com)

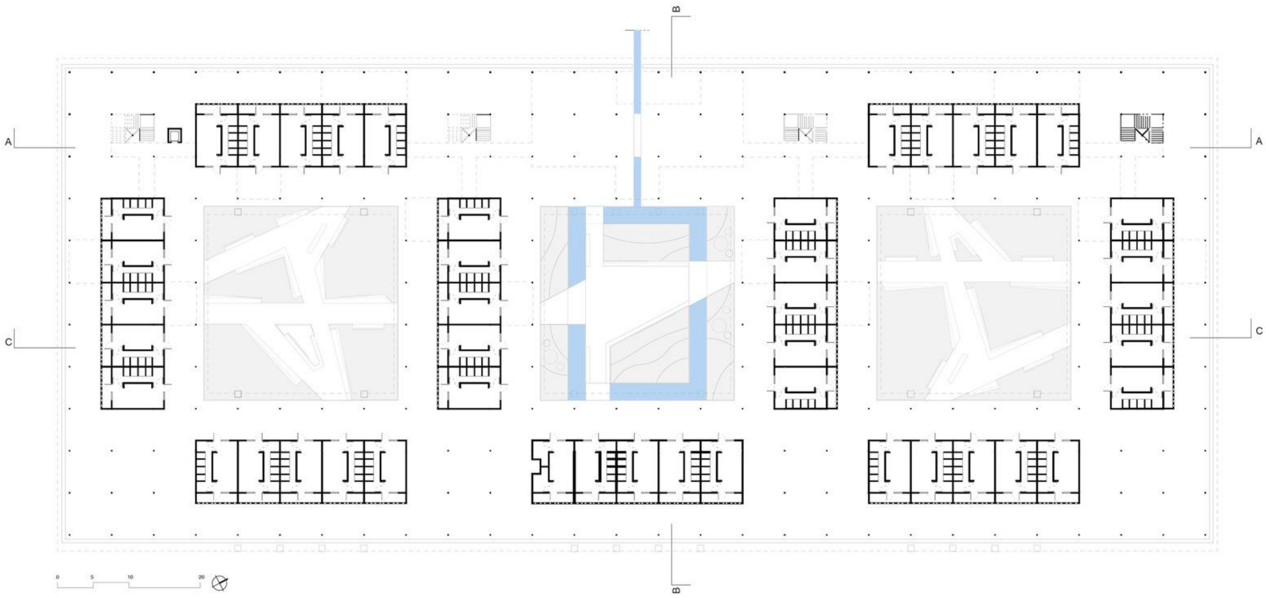


Fig. 35. Ground floor plan (Leonardo Finotti - www.archdaily.com)

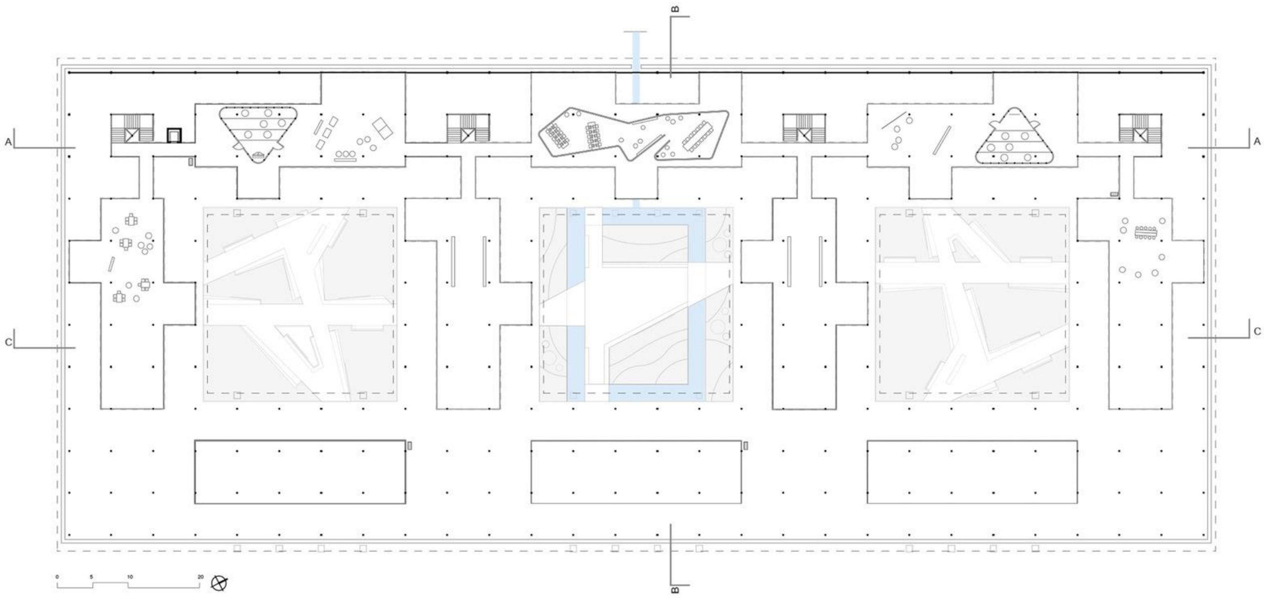


Fig. 36. First floor plan (Leonardo Finotti - www.archdaily.com)

7.2. Design and structural principles

Two identical structures (one for boys and the other for girls) are set each side of the main school buildings. A large timber roof sloping from west to east is supported by glulam columns and beams over sails the main independent timber accommodation units. Sculptural stairs rises above these units to walkways, recreational use space and balconies separated with slatted timber screens.

The natural cross-ventilation throughout the building with breathable walls, expansive shade results in no air conditioning in temperatures well over 40ºC. Control of low temperatures at night is a problem however, with extra blankets needed in the dorms.

Fig. 37. Column with ground detail (Leonardo Finotti - www.archdaily.com)

Fig. 38. Columnsand roof structure (Leonardo Finotti - www.archdaily.com)

7.3. Materials and finishes

The materials used for the project include white metallic roof supported by 5.9m x 5.9m lightweight eucalyptus glulam grid on local eucalyptus glulam structural columns.

The accommodation uses solid form stabilised local earth blocks, to provide natural ventilation, these blocks were perforated for the wash rooms.

7.4. Resources consumption in the use stage (water, energy, etc.)

The main aim is providing a cool environment across the internal area of 23,344m² during uncomfortable daily temperatures, this is well achieved as previously discussed.

Due to the rural location of the school it was important to use as much pre-fabrication as possible. This also accelerated the construction speed which limits the disruption to school activities. Local materials were used with the timber frame elements as well as local earth for the blocks. For other timber elements computer numerical control (CNC) cutting providing highly accurate cutting.

2.5. Additional information

Awards:

RIBA Award for International Excellence 2018

RIBA International Emerging Architect for Aleph Zero

8. CASE STUDY 8: Wadden Sea Centre

8.1. General information

1. Location: Okholmvej 5, Vester Vedsted, 6760 Ribe, Denmark

2. Architects: Dorte Mandrup A/S

3. Client: City of Esbjerg

4. Year of construction: 2017

5. Duration of construction: September 2015- February 2017

6. Height: Unknown

7. Number of floors: 2 Floors, at all 2500m^2

8. Cost: 6.000.000 Euro

Fig. 39. External appearance (Photography Adam Mørk)

Fig. 40. External appearance (Photography Adam Mørk)

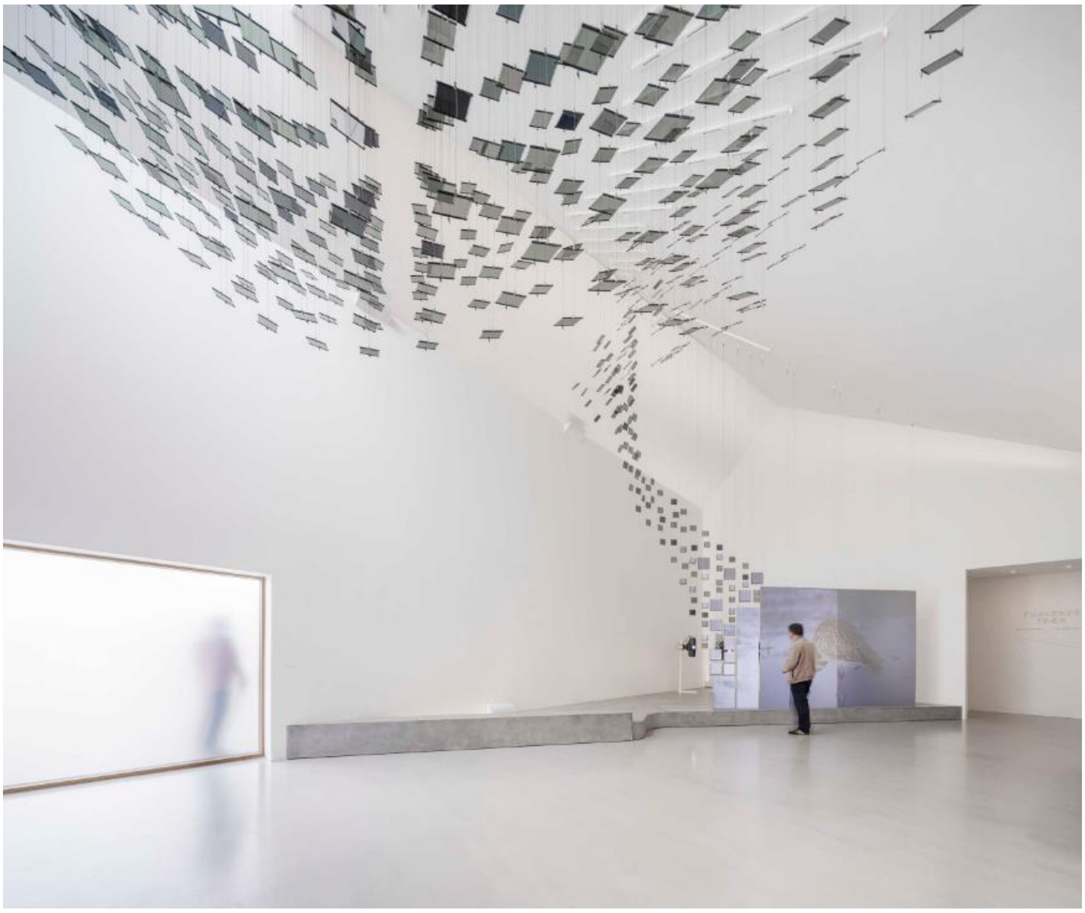


Fig. 41. Internal view (Photography Adam Mørk)

Fig. 42. Internal view (Photography Adam Mørk)

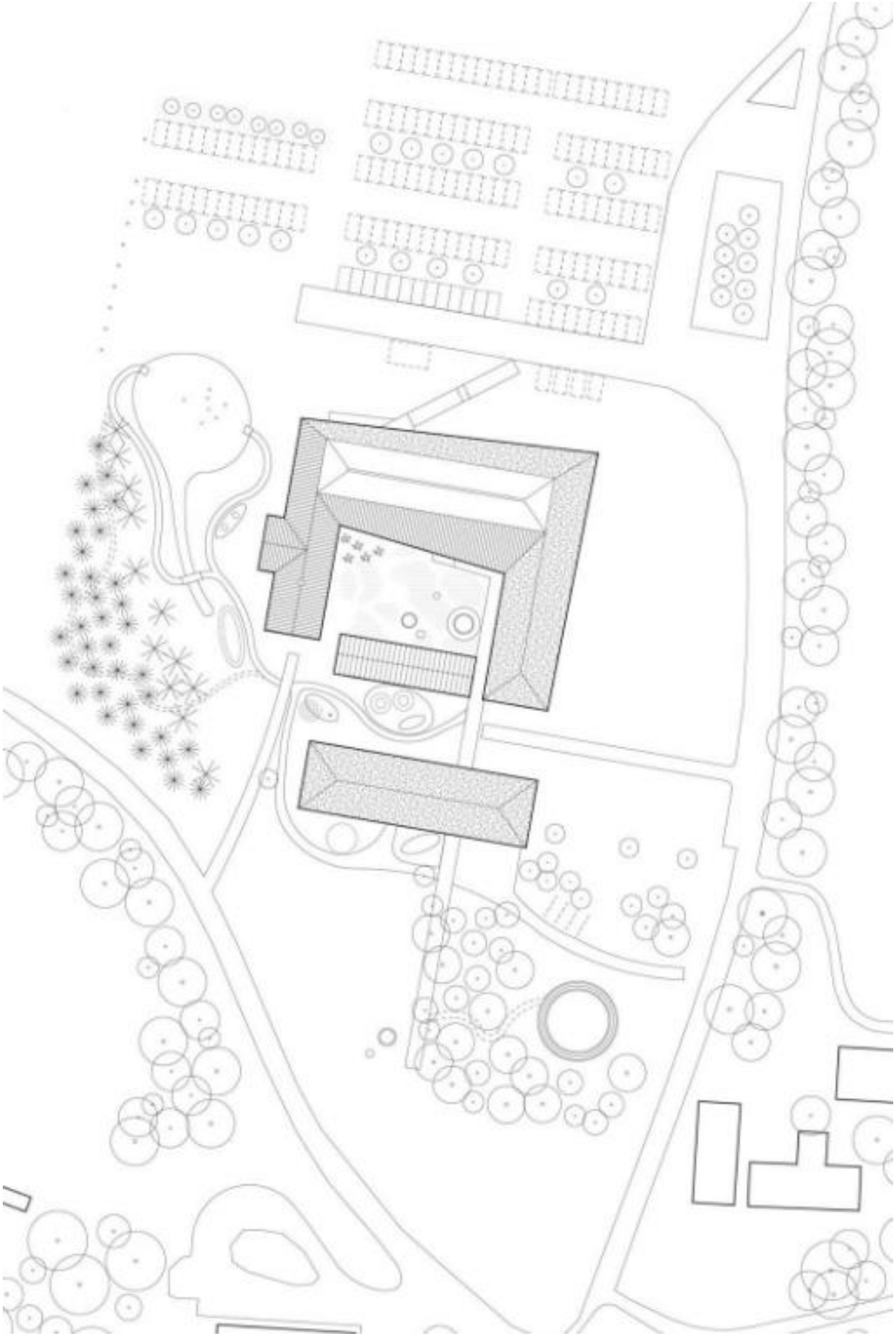


Fig. 43. Site plan (Illustration: Dorte Mandrup)

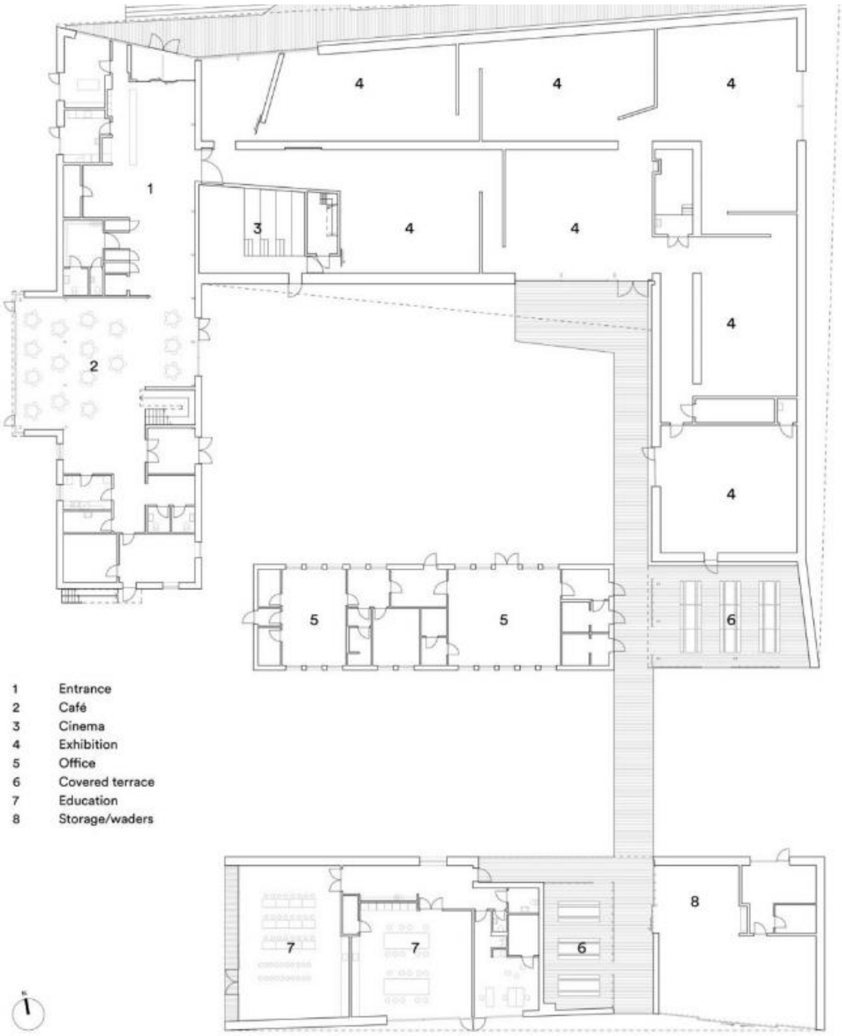


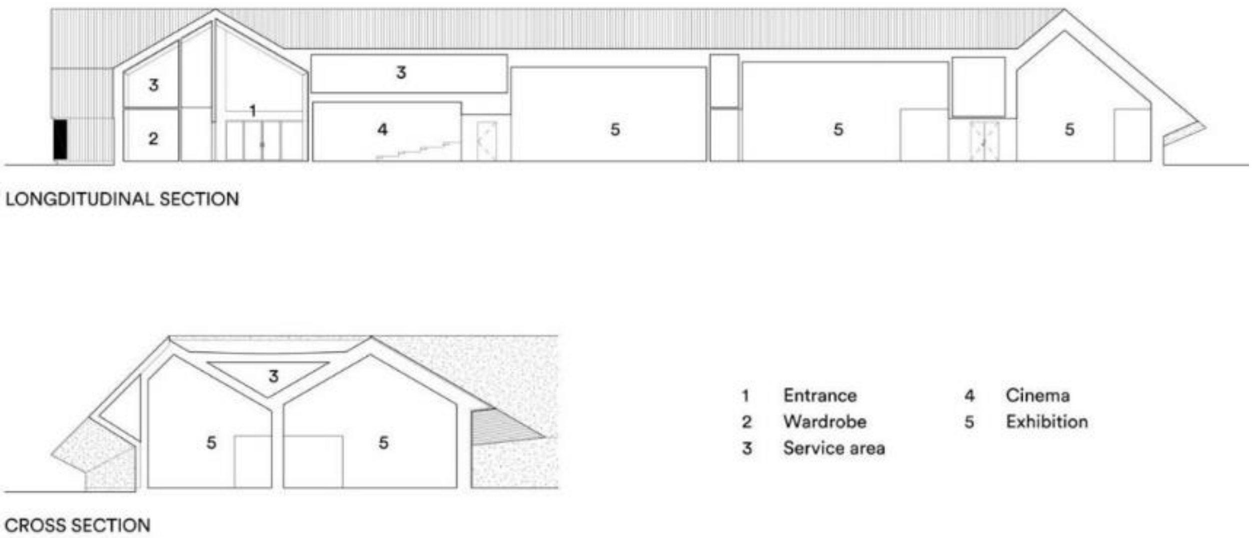
Fig. 44. Site plan (Illustration: Dorte Mandrup)

8.2. Design and structural principles

The building, which was initiated in February 2017, is an interpretation of the local building tradition and the rural farmhouse typology significant in the area.

The centre is erected with pre- paginated robin wood and thatched roofs and facades, hereby underlining the tactile qualities and robustness that can be found in traditional crafts and materials of the region.

The combination that gives a unique experience that gives the impression of a building that falls into nature.



1 Entrance
2 Wardrobe
3 Service area
4 Cinema
5 Exhibition

Fig. 45. Site plan (Illustration: Dorte Mandrup)

Fig. 46. External appearance (Photography Adam Mørk)

8.3. Materials and finishes

A combination of using pre-patinated robin wood and straw for the exterior facades and roofs makes this building coincide well with the surrounding nature found in the area that has been used. Great craftsmanship has been carried out in connection with the construction of the building, which makes the building itself a great experience in itself.

Fig. 47. External appearance (Photography Adam Mørk)

8.4. Resources consumption in the use stage (water, energy, etc.)

The building is heated with geothermal heat, which has buried 3.4 km of pipes in the outside terrain for the actual geothermal heat.

There are solar cells hidden on the roof that live 40% of the annual energy.

The building is illuminated with led light.

The building is equipped with water-saving toilets, showers and taps.

The building is insulated further than is required in accordance with the Danish rules.

9. CASE STUDY 9: ”Næste Skur”

9.1. General information

1. Location: Holbergskolen KBH N
2. Architects: Krydsrum A/S
3. Client: Københavns Komune
4. Year of construction: 2019
5. Duration of construction: 2018–2019
6. Height: 3.2 m
7. Number of floors: 1
8. Cost: 46,900 euro

Fig. 48. External appearance (Photography Jonathan Weimar)

Fig. 49. Internal view (Photography Jonathan Weimar)

9.2. Design and structural principles

The idea is to unite the traditional Danish building custom – timberwork and large roofs with overhangs that protect the facade, with prefabrication and fast assembly.

It is attractive to recycle the large quantities of rafters, laths, floorboards and roof tiles that today are thrown out as building waste during renovations in Denmark. The sheds are durable, functional and should inspire increased resource awareness when building.

Fig. 50. Module facade (Photography Jonathan Weimar)

9.3. Materials and finishes

Beams, rafters, floorboards, newer rafters, roof tiles, smoking tiles, gutters and mirrors.

All recycled from demolitions in the Copenhagen area.

Fig. 51. Internal view (Photography Jonathan Weimar)

9.4. Resources consumption in the use stage (water, energy, etc.)

Recycled lighting fixtures with new LED inserts and motion sensor.

The solar panels are prepared to be installed in the facade so that the shed becomes self-sufficient.

Fig. 52. Module facade (Photography Jonathan Weimar)

9.5. Additional information

The idea is to develop a circular business model that can be scaled and thus have a great impact on the environment. a lot of CO2 can be saved each year if you switch to building with recycled materials.

10. CASE STUDY 10: Mjøstårnet

10.1. General information

1. Location: Brumunddal, Norway
2. Architect: Øystein Elgsaas, Voll Arkitekter
3. Client: Arthur and Anders Buchardt, AB Invest AS
4. Year of construction: 2019
5. Duration of construction: April 2017 – March 2019
6. Height: 85.4 m
7. Number of floors: 18
8. Cost: 52 million euros

Mjøstårnet, also called Mjösa Tower, is the world's tallest timber building at the moment. It is located in Brumunddal, Norway. The building, which provides homes, office spaces and a hotel, is designed by Øystein Elgsaas, who is an architect and partner for Voll Arkitekter. Arthur and Anders Buchardt from AB Invest AS are the customers for this unique project (METSÄ WOOD, 2019). HENT was the contractor for the project. Moelven Limtre was HENT's subcontractor for structural timber components. Sweco did the engineering for HENT and structural timber design for Moelven Limtre. The third party reviewing for the structural and fire design was made by Rambøll (Abrahamsen, 2017, p. 4).

The 85.4 meters high 18-floor building opened on 15 March 2019 (METSÄ WOOD, 2019). The combined floor area is around 11 300 square meters. (Moelven, 2019)The proposal for the project was given in 2016 (CTBUH, 2019). The groundwork started in April 2017 and the first construction was started in September in the same year (Moelven, 2019).

The cost of the project is valued at about NOK 500 million excluding VAT (Moelven, 2019). This is about 52 million euros.

Fig. 52. Mjösa Tower illustration (METSÄ WOOD, 2019)

Fig. 53. Mjösa Tower Roof Terrace illustration (METSÄ WOOD, 2019)

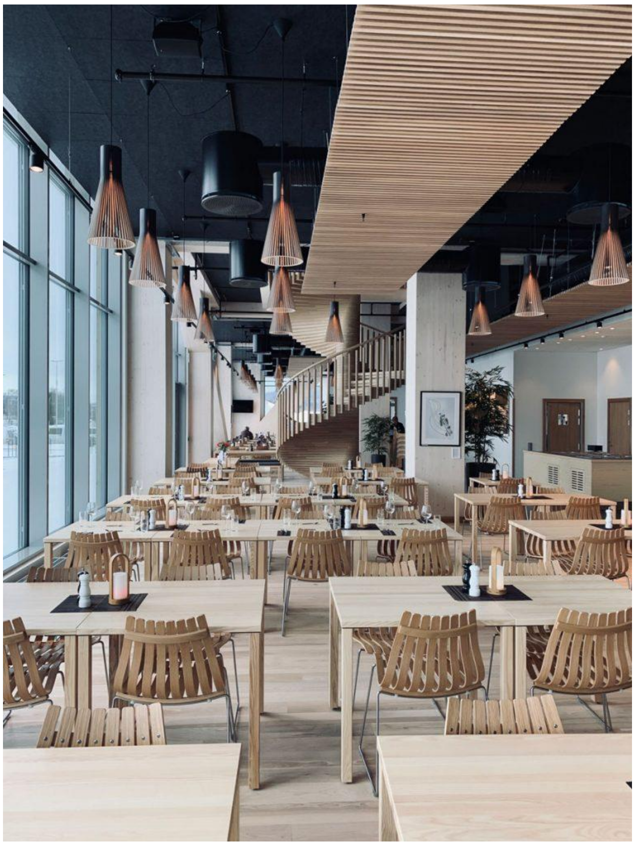


Fig. 54. Voll-Arkitekter Mjøstårnet Interior (Voll Arkitekter AS, n.d.)

Fig. 55. An elevation plan of Mjösa Tower (Abrahamsen, 2017, p. 10)

10.2. Design and structural principles

The design approach for Mjösa Tower comes from the Norwegian tradition to use wood in architecture. The tower was built using this approach to inspire others to build the same way (METSÄ WOOD, 2019).

The load bearing structure is similar to conventional buildings, but itis much larger than usually. For example, the wooden columns were 60 x 60 cm on average and the largest columns were almost 60 x 150 cm. The building is narrow, but wide, which is ideal for hotel rooms (METSÄ WOOD, 2019).

The decks on the upper floors, which have the the apartments, are made of concrete. This is because the weight of the concrete slows down the swaying that is caused by the height of the building and makes it harder to notice (METSÄ WOOD, 2019).

The project did not use external scaffolding, but a large crane and internal scaffolding. The tower was assembled four storeys at a time. First the glulam structures were assembled on the ground and then hoisted up and in their places. Next the floor slabs were set. The façade was installed by Ringsaker Takelementer AS (Moelven, 2019).

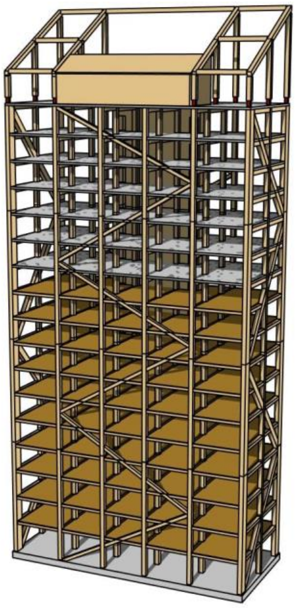


Fig. 56. Mjösa Tower 3D model (METSÄ WOOD, 2019)

10.3. Materials and finishes

Both the structure and façade of Mjösa Tower are made of wood. The structure consists of columns, beams and diagonals, which are all made of glulam. With their large cross-sections they can meet the fire safety requirements. The first ten floors, which have the offices and hotel facilities, are made of prefabricated wooden elements. There Metsäwood's Kerto LVL Q-panels provide the stiffness (METSÄ WOOD, 2019). The LVL is combined with glulam, which was provided by Moelven Limtre. In addition to the beams, columns and diagonals, they also supplied the CLT elevator shafts and stairs and Trä8 floor slabs. The Trä8 is a concept developed by Moelven Töreboda in Sweden (Moelven, 2019). The CLT was produced by Stora Enso and the insulation in the floor elements is Rockwool. Most of the floor elements have a 50 mm concrete screed on top (Abrahamsen, 2017, p. 6).

The Kerto LVL Q-panels wereprefabricated in Moelven Limitre’s factory and some of them were pre-cut and sanded beforehand. The Kerto LVL was a good material for the project because it is very straight, lightweight and has a good strength-to-weight ratio. Because of the lightness of the elements, the tower grew almost by one floor every week (METSÄ WOOD, 2019).

Powder coated S355 steel was used in the connections and it was combined with acid-proof steel dowels (Abrahamsen, 2017, p. 6).

The wooden cladding was supplied by Woodify. It has fire retardant properties (Abrahamsen, 2017, p. 6).

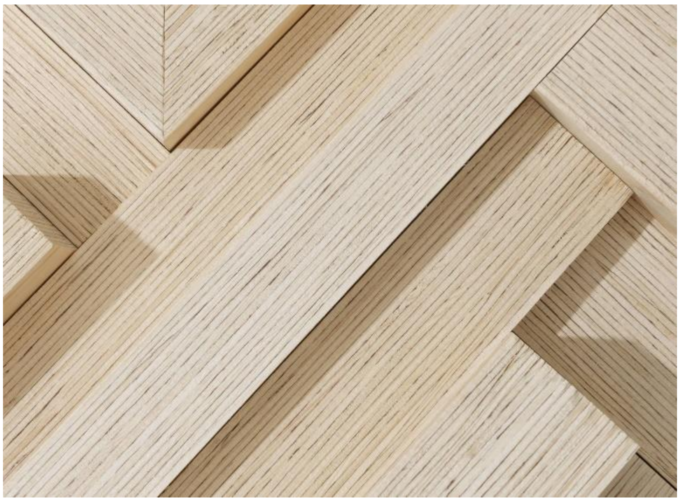


Fig. 56. Wood pattern (METSÄ WOOD, 2019)

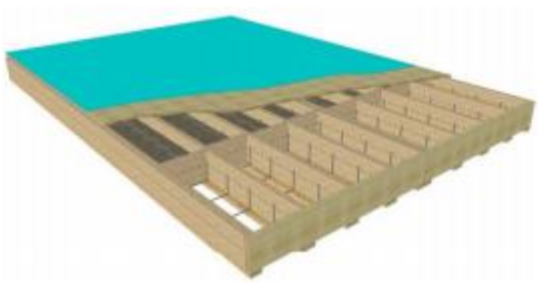


Fig. 57. Trä8 floor element layout (Abrahamsen, 2017, p. 8)

10.4. Resources consumption in the use stage

Mjøstårnet is designed to produce the same amount of energy as it spends using solar thermal energy, solar panelling, and ground and water heat pumps (Innovation Norway, 2019).

10.5. Additional information

The council on Tall Buildings and Urban Habitat (CTBUH) amended the official guidelines upon which tall buildings are measured and added timber as a recognized structural material. The revised criteria states that the main structural elements and the floor spanning system must be constructed from timber, though there can be localized non-timber connections. The change coincided with the verification of the completion of Mjøstårnet. The tower has now the unique title of the "World's Tallest Timber Building" (CTBUH, 2019).

11. CASE STUDY 11: Nature Center Haltia

11.1. General information

1. Location: Nuuksio, Espoo, Finland
2. Architect: Rainer Mahlamäki, Lahdelma & Mahlamäki Architects
3. Client: Timo Kukko, Nuuksiokeksus Oy
4. Year of construction: 2013
5. Duration of construction: fall 2011–spring 2013
6. Number of floors: 2–3
7. Cost: 16.7 million euros

Nature Center Haltia is located on the shore of Lake Pitkäjärvi and right next to Nuuksio National Park in Espoo, Finland. It is an exhibition, restaurant and conference building, with estimated 200 000 visitors per year (Mahlamäki, 2013, p. 10).

Haltia is the first public building made of CLT-elements in Finland (Haltia, 2019).

The total floor area of the building is 3 534 square meters and it was completed in 2013. The client is Timo Kukko who is the manager of Nuuksiokeskus Oy. The project manager was Juha Välikangas from Pöyry CM Oy. The architectural design as made by Professor Rainer Mahlamäki, M.Sc Architect, from Lahdelma & Mahlamäki Architects. The structural design was made by Insinööritoimisto Tanskanen Oy. The main contractor was YIT Rakennus Oy and the wood structures were made by Stora Enso and Eridomic Oy. The costs of the building were 16,7 million euros (Mahlamäki, 2013, p. 13).

Fig. 58. Two pictures of Nature Centre Haltia from outside (Huisman, n.d.)

Fig. 59. Two pictures of Nature Centre Haltia from inside (Huisman, n.d.)

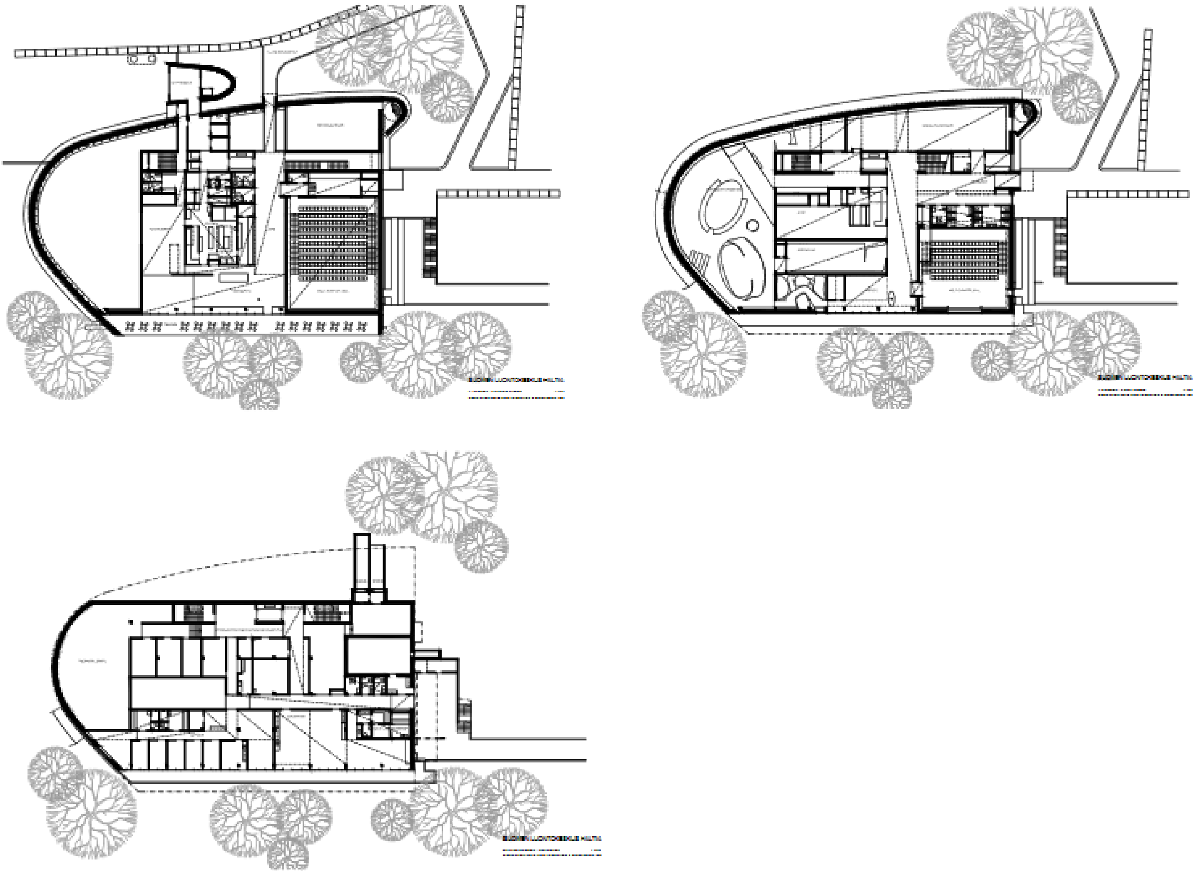


Fig. 60. The floor plans. Starting from the top left: second floor, first floor, and ground floor (Mahlamäki, 2013, p. 11)

11.2. Design and structural principles

The inspiration for the Haltia architecture came from the Kalevala, the national epic of Finland and Karelia (Haltia, 2019) (Asplund & Mettomäki, 2017). The whole structure is designed by one architect, so it has a uniform design. The cornerstones for Haltia are ecology and environment, functionality, and technical advancement (Haltia, 2019).

Haltia is the first public building in Finland, where everything is made of cross laminated timber (CLT). (Haltia, 2019). Also, the load-bearing structure is made of CLT panel elements (Mahlamäki, 2013, p. 15).

The curving lines that meet rectangular shapes symbolize the encounter between nature and human environment. With these different shapes Haltia shows the possibilities of wood construction, which are shown with different wooden joints, on site and prefabricated elements, and traditional and modern wood treatment methods (Haltia, 2019).

Fig. 61. Three pictures of different kind of shapes in Haltia (Huisman, n.d.)

11.3. Materials and finishes

The CLT-elements have been supplied from Stora Enso's Austrian factories as raw plates. The board are made of Austrian spruce, because CLT was not produced in Finland during Haltia's construction. They are glued together with an emission free M1 grade urethane adhesive. They were finished in Pälkäne, where, for example, the insulations were added (Haltia, 2019).

The façade is made of pine saturated with quartz sand. It does not contain any harmful substances and it is fire resistant and as durable as wood saturated with arsenic. Haltia is the first building in the world, where this material has been used for exterior trim (Haltia, 2019).

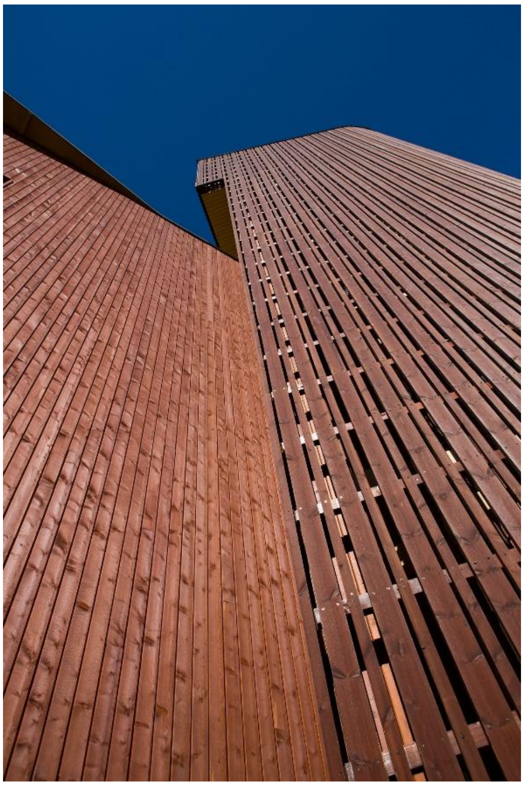


Fig. 62. Picture of the façade (Haltia, 2019)

Fig. 63. Different sized panels to create a rhythmic design (Siparila, 2018)

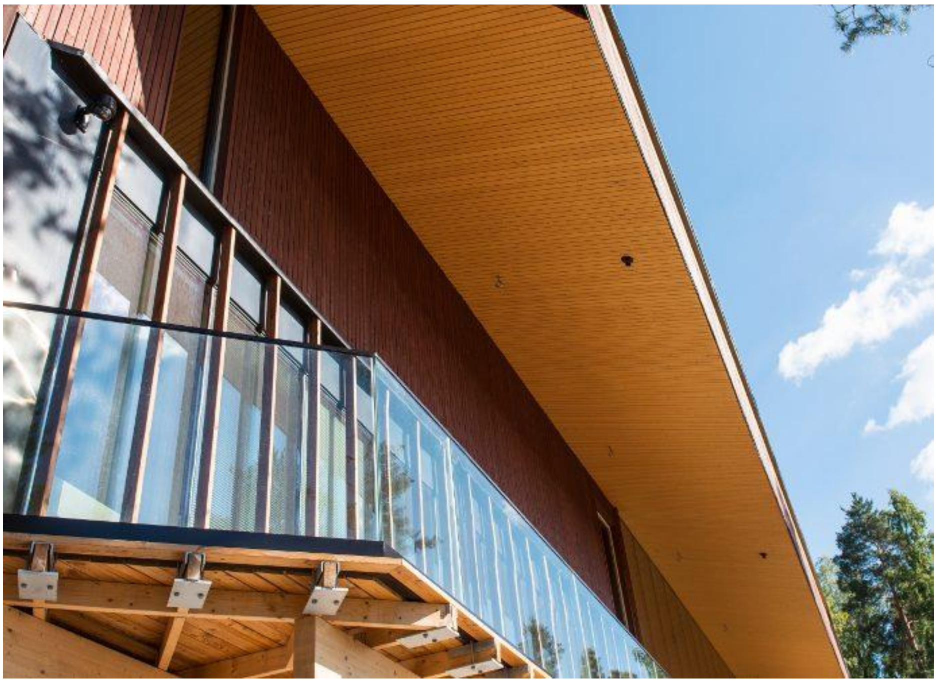


Fig. 64. Surface treatment gives the possibility to achieve harmonious colours (Siparila, 2018)

11.4. Resources consumption in the use stage

The whole building is designed to consume as little energy as possible. The round shape of the building makes the building envelope small in relation to its volume. Also, the lowest floor is underground, which makes the heat loss smaller. The terrace is located so, that it shades the lower floors, which makes the need to cool lower during summer. The number of windows is small, so the heat loss is smaller (Haltia, 2019).

The aim in heating Haltia is that it is 75 per cent self-sufficient in heating and 100 per cent self-sufficient in cooling. This is reached byground source heat pump with 15 bore wells, which reach depth of 250 meters. They contain geothermal pipes with length of 11 kilometres. These are used for both heating during winter and cooling during summer (Haltia, 2019).

There are evacuated tube collectors on the roof of Haltia.The transfer fluid, which is heated with the rays of sun, is used to support the ground source heating. When the collectors give more heat than needed, it is directed to the base rock (Haltia, 2019).

The ventilation and water use are controlled by automatic systems. This makes sure that no water is wasted, and that the ventilation is on only in spaces that are in use. The water is mainly heated with the sun collectors and the geothermal energy (Haltia, 2019).

Fig. 65. Solar panels on the roof (Kuvataivas, n.d.)

2.5. Additional information

Haltia was given the first sustainable development award by European Museum of the Year competition in 2015 (Haltia, 2019)

CONCLUSIONS

- 11 Public Buildings constructed in timber from were picked for the O4 intelectual output report. The buildings were constructed in the period from 2014 to 2019.
- The Public buildings ranged from a simple shed building, built in recycled timber to a renovated retrofit timber Barn. A hybrid timber multi-purpose tower.
- The floor areas ranged from 30 m2 to over 3500 m2. The buildings where from 1 to 18 stories.
- Most of the buildings are hybrid buildings which are constructed in timber, concreate and steel.
- Timber was used as a load bearing construction, external cladding and interior design.
- Some of the buildings implemented recycled timber
- Types of engineered timber implemented in the buildings are mostly Glulam beams and columns.
- Also there are few buildings with CLT panel construction (stairway enclosure, stairways, roof construction and floor/wall construction).
- In one case LVL was used as a stabilizing load bearing structure.
- Prefabricated timber modules were implemented in one building.
- Concluding on the examples of existing public buildings designed and constructed in engineered timber it seems to be a lack of know-how, information, experience, education and national production of different types of engineered timber construction.

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