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NEW HQ COPENHAGEN
A NEW STANDARD FOR SUSTAINABLE BUILDINGS IN AN INTERNATIONAL CORPORATION

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ABSTRACT: This paper provides an insight into the process of developing the new headquarters for an international client in Copenhagen. The preliminary analysis leading to the decision to go for a timber construction, as well as the direct and derived effects of using a timber construction in the new headquarters.

KEYWORDS: Headquarter, office building, Copenhagen, Denmark, Arkitema, COWI, timber frame, timber building, hybrid structure, glulam, CLT, LCA, exposed timber, upcycling, recycling.

1 TIMBER HYBRID STRUCTURE AS A DRIVER FOR SUSTAINABILITY

1.1 INTRODUCTION

The client is the Danish branch of a global corporation but wishes to stay anonymous. The client is planning a new headquarters in Ballerup on the edge of Copenhagen.

The client has its current headquarters in an existing building from the 70s in Ballerup, near Copenhagen. Over the past years the needs of the corporation have outgrown the existing facilities, so when the client approached Arkitema/COWI in 2019, the question was how to either accommodate future needs in the existing building, or completely rethink the site and create a headquarters that would be state of the art and show the way forward for future facilities in the global corporation.

Figure 1: *Interior and exterior visualizations of the future building, Arkitema/COWI.*

1.2 PRELIMINARY ANALYSIS AND BACKGROUND

The preliminary analysis showed that the existing buildings would be unfit for the functions needed in the future, and therefore the choice was made to start from scratch. In the early phases, the strategy for the building was laid out. The client's wish to create a futureproof and sustainable new headquarters acted as a main driver.

Sustainability can be interpreted very widely. For their new office building in Ballerup, the client chose to set ambitious goals regarding environmental sustainability.

Giving environmental sustainability highest priority makes good sense. The 2016 illustration of Stockholm Resilience Centre shows this precisely: there is no functional economy without a functional society, and there is no functional society without a functional biosphere.

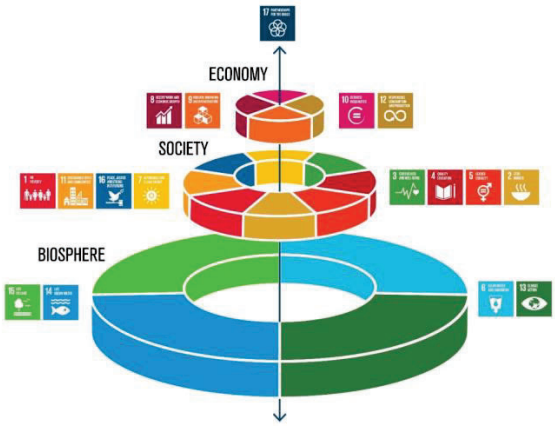

Figure 2*: There is no functional economy without a functional society, and there is no functional society without a functional biosphere. Source: Stockholm Resilience Centre 2016, Contributions to Agenda 2030 - Stockholm Resilience Centre*

Furthermore, this is much in line with the direction of the corporation globally, which aims to conserve natural

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resources and to become CO_2 -neutral by minimizing energy consumption and investing in compensating measures. To the client, minimizing energy consumption is a key element.

Different design strategies for achieving these goals were assessed, and the eventual preferred choice was a timber grid, with timber columns, beams, and slabs, which would allow for maximum flexibility in the future layout while also having a markedly lower CO2 impact on the overall Life Cycle Assessment (LCA) analysis. The lower CO2 impact from the timber structure was a key element in the overall strategy to create the sustainable headquarters for the future.

Due to the early stage of design, a comparative analysis was done on a timber structure vs. a traditional concrete structure, giving the client an overview of the advantages and disadvantages before choosing the method of construction.

The following topics were mentioned as facts regarding timber:

- Timber is a renewable resource.
- Timber is easy to recycle.
- Green energy is used to manufacture the building material, and timber uses considerably less energy than for concrete.
- The timber structure requires no maintenance provided the timber is protected from moisture.
- There is not yet the same tradition in Denmark for using timber as the main structural elements in multi-story office buildings as there is for concrete structures.
- It is not yet routine work for construction companies, architects and engineers in Denmark.
- Using timber as a structural material is in line with the Danish government's recommendation and ambition towards a climate-neutral construction sector.
- It is very good branding for the client to be one of the front runners in Denmark.

Topic	Advantage	Neutral	Dis-advantage
CO_2 emission	+		
Recycling	+		
Energy used on site during construction	+		
Maintenance		-	
Tradition in Denmark, few contractors			÷
Branding	+		
Prefabricated elements		-	
Composite solutions		-	
Shorter grid for columns and higher structural beams and decks			÷
Less foundation required	+		
Time schedule during construction	+		
Construction costs			÷
Planning costs			÷
Limitation of highest floor level			÷

Figure 3: *Advantages/disadvantages for timber construction compared to concrete construction, summarized in note "Timber versus concrete", Arkitema/COWI February 2020*

2 AMBITIONS & FOCUS POINTS

With inspiration from the client's draft for a 'sustainability laboratory', environmental sustainability has the following focus points:

- The GWP (CO_2 -equivalents) should be minimized for the building's whole life cycle by energy efficient design and choice of energy supply.
- LCA should be applied in the early design. No specific limits will be defined before this project. In Bl110 no specific requirements for the use of BIM tools have been defined.
- The clint's "sustainability checklist" applies.

Furthermore, indoor climate is part of the client's project-specific goal about working conditions. No special effort will be made within design regarding "electro smog". For thermal indoor climate and indoor air quality, the requirement is category II according to DS/EN 16798-1:2019.

In alignment with the 'sustainability laboratory'-goals, efforts will be made within the masterplan, building design, renewable energy on site, choice of materials as

well as design of mechanical installations. The stages described correspond to DS/EN 15978:

- Stage 0: The demolition of existing structures (outside system boundary)
- Stage A: Product stage and construction process stage
- Stage B: Use stage (operation and maintenance)
- Stage C: End of Life
- Stage D: Reuse, recovery, and recycling of materials

3 SUSTAINABILITY STRATEGY

A sustainability strategy for the life cycle of the building was decided at the beginning of the outline proposal, and the status was updated at the end of the outline proposal.

3.1 STAGE 0 + A, ENERGY USED ON SITE

This is usually not considered in Danish building projects, even though significant GWP and PE are related to this. The client has decided that within this field no special measures will be carried out.

3.2 STAGE 0 + A, EMBODIED GWP

This is usually not considered in Danish building projects.

Focus is to minimize GWP and PE related to the materials, which are demolished as well as materials used for the new building. Demolished materials should be utilized/recycled in the best possible way.

The GWP and PE of new materials will influence the building design and the choice of materials.

Included: Sensible, qualitative considerations by the general choice of new materials generally and applications of LCA for the selected cases:

- Foundations: Comparison of sand bed or pile foundations
- Construction of floor slabs (3 alternatives)
- External façade cladding (3 alternatives)
- Whole building LCA according to Danish DGNB to provide the client with a benchmark for GWP and PE

3.3 STAGE B, OPERATION AND MAINTENANCE

The building is to meet the (strict) low energy option of the Danish building regulations (for heating, cooling, domestic hot water and auxiliary energy).

The energy demand in operation is to be optimized during design with an eye to the future renewable energy system.

The client will consider all energy demands (GWP and PE) during operation, and not only operation of the building. The client will revise its purchasing policy and implement tough requirements regarding energy demand (GWP and PE) for all equipment.

This is in line with the client's interest for the passive house criteria, which include all equipment, not only the building itself.

The client will apply a commissioning period covering the first 14 months of operation in order to ensure proper operation.

Commissioning covering the first 14 months of operation supplied by COWI/Arkitema.

3.4 STAGE C + D, END OF LIFE AND RECYCLING

The building will basically be designed for long-term usability, in order not to repeat the choices, which led to the planned demolition of the client's buildings dating from 1970-1990.

Included: Design of sensible (in the designer's interpretation) extra space for ducts and in technical rooms. Designing for higher live loads (3.5 rather than 2.5 kN/m²).

But inevitably, possibly for other reasons than its usability, the building will be demolished at some time. This should be accounted for with a "design for disassembly" approach or at least in a way to minimize resources required in demolition and recycling. Demolition is closely connected to the recyclability of the materials and the choice of materials.

Included: minimal, qualitative considerations.

This set of initiatives is in line with the corporation's principles for product development:
"As a matter of principle, we start optimizing products in the development phase, applying the following criteria: energy and material efficiency, emissions education, and repairability.", Client, Sustainability report 2018 spotlights.

4 TIMBER AS ADDED VALUE TO THE OFFICE ENVIRONMENT

4.1 MENTAL HEALTH BENEFITS

Several studies have shown that, as humans, we perceive timber surfaces as more natural and calming compared to other traditional building materials. This added benefit of timber has also become a significant factor in design, and efforts have been taken to ensure as much visible timber in the interior as possible. [1]

4.2 SUSTAINABILITY AS PART OF THE CORPORATE STRATEGY

Utilizing the mental health benefits of timber by exposing the surfaces has several other benefits. The strategy to build and focus on sustainability becomes visible

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throughout the building and speaks clearly to the employees and visitors that sustainability is an integrated part the client's identity in the 21st century. This is possible due to the general perception of timber as a natural material.

With the organization of the building around one large multi-story atrium, where all employees and visitors pass through, the strategy is further emphasized by maximizing the amount of exposed wood surfaces in this space. Furthermore, extra steps will be taken by using upcycled wood (offcuts from the wood industry) in the construction of the auditorium podium to save CO2 and improve the overall footprint.

In the vison of the future headquarters, the client had the concept that the use of wood is to be visible and the building material would represent "Nordic Nature".

5 CHALLENGES

5.1 GEOMETRY AND LAYOUT

An appropriate module is 6 x 6 meters. A larger span affects the thickness of the timber required for the constructions, which is not economically viable. A wooden construction requires many pillars, and this can affect floor plans. Therefore, it is important to think about the construction principle from the start.

5.2 BUILDING PARTS

Though timber has been chosen as the main material for the structural frame, concrete still has its place in modern buildings. For example, concrete is required for in foundations, basement and parking facilities and stairwells, since timber is not a viable option.

Another example is if a cantilevering structure is chosen for aesthetic reasons to make the top part of the building ("the cloud") free from the building base. In this area, steel in combination with timber will be necessary to ensure stability and strength.

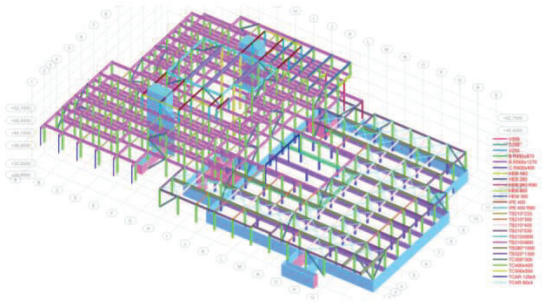

Figure 4: *Structure, Isometry – Building. Outline Proposal, Arkitema/COWI*

Finally, floor-slabs have been designed with a layer of concrete on top of the CLT elements to meet the demands for acoustic dampening between floors in a modern office environment.

At an early stage the client decided not to use wood as the façade cladding, since this would increase maintenance costs, although an exception was made in the courtyard. A panel system of thermo dried FSC-wood lamellas and 100% collected and recycled Green Aluminium offers a distinctive and sustainable façade.

5.3 ACOUSTICS

Wood generally has lower sound insulation than concrete. Therefore, noise and vibrations will spread more easily through the construction. The client's headquarters will be a multifunctional building with office, education and noisy workshops. The noisy functions will be located away from noise-sensitive functions. Some workshops will be "box in a box". Floor partitions made of CLT wood with floating concrete floor will create sound insulation due to the increased weight. Due to few reference projects in Denmark, there is some uncertainty in relation to calculation methods. We must learn through measurements of these new buildings. Until then, Arkitema/COWI have learned from, among others, Norwegian projects through COWI Norway and thus obtained evidence for calculations.

5.4 FIRE SAFETY

The project is favoured by the fact that in Denmark the limit for the maximum height has now been raised for wooden buildings from 9.4 m to 12 m. Less documentation is therefore required.

Requirements for the maximum extent of internal exposed wooden surfaces is 20%, and this must be documented.

Constructions are designed for 60 min. fire. The underside of CLT decks need to be covered with mineral wool or plaster boards for fire protection of the wooden surface.

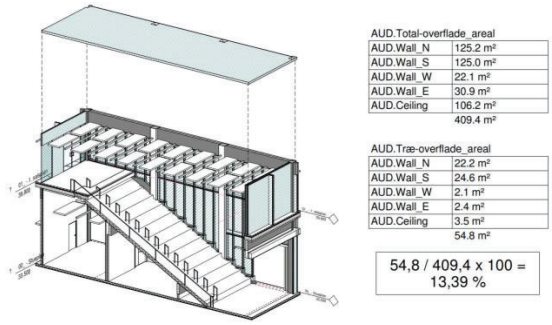

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Figure 5: *Quality check/documentation of max 20% exposed wooden surface in the auditorium. Arkitema/COWI*

Great attention must be paid to how installations are routed through a load-bearing wooden construction. It is recommended to plan with longitudinal guides to minimize the number of cross main penetrations. When drilling holes, great attention must be paid to fire sealing and fire joints.

5.5 BUILDING PROCESS

A significant challenge during construction is how to deal with the rain and moisture of the Danish climate. The proposal is to use site-cover weather protection during construction of the building, but this cover comes with the drawback of extra cost compared with traditional construction methods. However, the cover is storm proof and snow proof to Danish standards and offers factory-grade production facilities for the work and therefore gives the possibility to minimize the overall construction time. In the project, it was decided to only cover the taller part of the building. The single-storey part of the building has a steel-trapeze roof, which has interim weather protection.

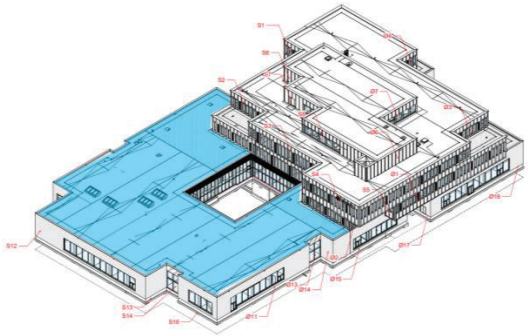

Figure 6: *Lower part of the building with a steel roof solution to minimize use of site-cover. ARKITEMA/COWI*

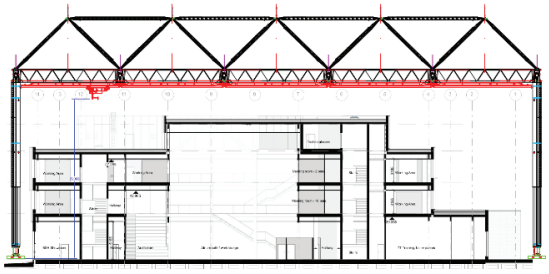

Figure 7: *Site-cover planned as protection for the tallest part of the building. Arkitema/COWI*

6 LIFE CYCLE ASSESSMENT

6.1 ASSESSMENT AS A DESIGN TOOL

Throughout the design process comparative studies have been made on balance aesthetic, functional, financial and sustainability requirements. Life cycle assessment (LCA) was an important design tool in defining building parts and technical solutions:

- The first LCA study compares the GWP and PEtot of a pile foundation and a gravel bed foundation solution. Results of the calculations showed that the gravel bed is the best option in terms of LCA. Based on this, it was decided to use the gravel bed for the project, as there was no significant difference in cost for the two scenarios.

- Lightweight balloon frame exterior walls with slate as façade cladding, was chosen due to good LCA performance.

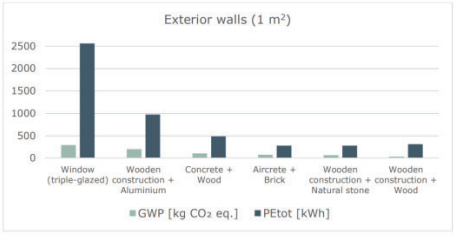

Figure 8: *LCA CALCULATIONS, Outline proposal. Arkitema/COWI, August 2020.*

- Climate sails were chosen in favor of a full-covering climate ceiling, as this solution has significantly lower CO2 emissions

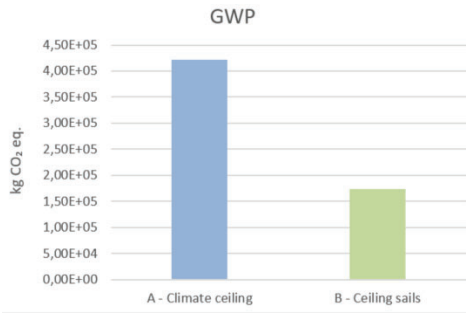

Figure 9: *Integrated design LOG, Arkitema/COWI,*

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October 2020.

- 6 relevant types of floor construction were analyzed and the one with the best GWP performance was chosen

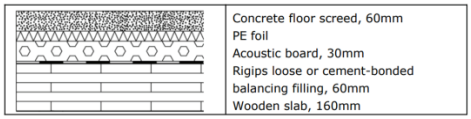

Figure 10: *LCA CALCULATIONS, Outline proposal. Arkitema/COWI, August 2020*

- Acoustic ceilings; Wooden lamellas were chosen due to best GWP performance.

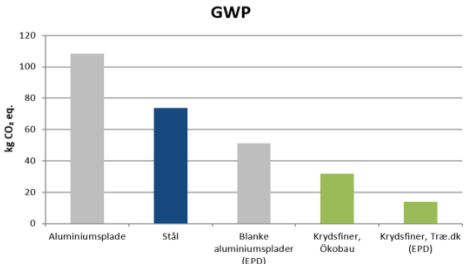

Figure 11: *LCA CALCULATIONS, Outline proposal. Arkitema/COWI, August 2020.*

6.2 ADDITIONAL POTENTIALS

Late in the design process, the client decided to explore additional potentials for sustainability. The following focal points were investigated and incorporated into the final tender project:

- Circular potentials / Reused materials: One aspect, which in the future could be better integrated into the early-stage design process, is the use of recycled/ upcycled building materials. One example is the aforementioned podium stair in the auditorium, which will be built with recycled timber. Other building parts like the choice of carpets have also been chosen with circularity in mind.

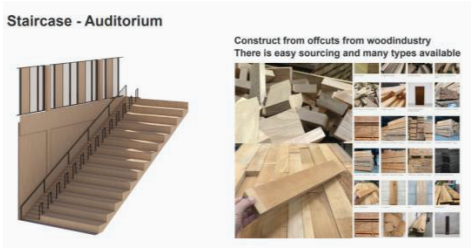

Figure 12: *Circular potentials presentation, Arkitema/COWI, March 2021.*

- Design for disassembly and material loops: Design for disassembly in selected construction details and overview of material loops (facade, floors, interior walls).
- Minimizing harmful substances in building components: Purpose is to protect building workers, building users and the environment in general.
- Reusing rainwater: Rainwater for watering plants, is collected in an underground tank.

6.3 FINAL ASSESSMENT

A life cycle assessment (LCA) was carried out for the full building to have a benchmark for future buildings in the corporation. The assessment describes the full LCA-calculation for the building based on the main project. The results were analyzed with focus on global warming potential (GWP) and total primary energy (PEtot). The additional environmental impact categories were included in the overall results. Generic data were used for all materials except aluminum facades, carpets and wooden floors. Environmental data for wood was also changed to Danish EPD data to represent the Danish market. The method follows the Danish 2020 DGNB manual for new buildings, except for the use of uncertainty factors.

The building has a total GWP of 6,752 tonnes CO_2 eq, which is 9.6 kg CO_2 eq/m²/year over the 50-year calculation period. The results have been compared with the Danish CO_2 requirements from 2023, where the limit is 12 kg CO_2 eq/m²/year. The results show that the slabs, walls, roof, windows/ doors/ curtain walls and solar panels contribute to the largest GWP and PEtot impact. For PEtot especially slabs, beams/ columns and roof have a large impact caused by the wooden constructions. Results have been compared with the Danish DGNB reference office building. Compared with the reference, the client's headquarters in Denmark has a lower environmental impact on all categories. The building would score 56 out of 75 possible DGNB points in the LCA criteria.

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6.4 SUSTAINABILITY STRATEGY – STATUS END MAIN PROJECT

By the end of the main project, the following measures will be included in the strategy and design:

- A sustainability manager has been involved in the project since the beginning and will participate in meetings regularly to maintain the focus on sustainable solutions.
- The building will be constructed with timber as a large part of the structure.
- The extent of concrete basement and foundations will be minimized.
- Energy demand for building operation will meet the low energy requirements of the Danish building code.
- Cooling and heating will be supplied by groundwater.
- Demolished materials will be used in the best possible way.
- Sensible, qualitative considerations by the choice of new materials and LCA for selected cases.
- Reused and recycled materials will be used in selected areas (carpets, wooden stair by the auditorium and some lighting fixtures).
- Rainwater will be collected and reused for irrigation of plants and rinsing machines.
- Improved operation and energy efficiency of heating and cooling heat pumps through whole building simulation.
- Indoor climate mostly category II according to DS/EN 16798-1:2019.

The client's project in Ballerup makes a special effort regarding SDG13 by reducing the GWP throughout the life cycle of the building and SDG7 by improving energy efficiency.

REFERENCES

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