World Conference on Timber Engineering Oslo 2023

ARBORETUM, THE LARGEST EVER WOOD OFFICE CAMPUS IN EUROPE: TECHNICAL, ORGANIZATIONAL, AND SUSTAINABILITY CHALLENGES : AN EXAMPLE OF LOW CARBON PROJECT FAR BEYOND THE ALIGNMENT WITH THE EUROPEAN TAXONOMY

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ABSTRACT: this article describes the design and construction of the Arboretum office campus, near Paris, which represents the largest complex built in CLT solid wood; through this experience, the developer shares their convictions: the resolute hunt for carbon emissions, which needs science based tools to measure the efficiency of the design and monitor possible improvements; the sobriety of design, which consists in getting rid of all materials that are not absolutely essential, and giving some of them a double function, structural and decorative, without any addition of other materials; the aesthetic interest of structural wood, which, if it can be left visible, provides unparalleled comfort. The article also describes specific test campaigns, regarding the efficiency of sprinkler or water mist on constructions entirely made of apparent wood.

KEYWORDS: Arboretum, Visible Mass Timber, Sobriety, Low Carbon Building Initiative, LCBI, European Taxonomy, BBCA

1 INTRODUCTION

Arboretum, the largest wooden structure office complex ever built in Europe, will be completed in autumn 2023.

This project, developed by WO_2 on behalf of the ICAWOOD investment fund, is located on the banks of the Seine river in Nanterre, 15 minutes away from Paris and includes 5 buildings with a wooden structure totalling 118,000 m² as well as two refurbished industrial buildings for 8,000 m².

WO_2 is a developer created in 2014 with the main objective of reducing the carbon footprint of construction. WO_2 is currently developing 370,000 m² of office buildings and mixed-use projects. When the company was created, little attention was paid to controlling emissions related to building materials; Many efforts had been made throughout Europe to reduce energy consumption: the hunt for kWh/m² had already begun, but there was still little interest in the materials themselves, although traditional materials are very emissive. WO_2 naturally turned to biosourced materials by associating them with a very broad approach of sobriety and control of quantities.

The Arboretum project is the best example of this approach: it responds to several challenges:

- A considerable reduction in carbon emissions (-47% compared to traditional construction, namely concrete post and beams, hollow core slabs), measured according to the BBCA ("Bâtiment Bas Carbone") association method [1]. This methodology has been recently revised in order to be used in all European countries. This initiative known as "Low Carbon Building Initiative – LCBI", is further presented in 2.3.
- The use of timber, as the main structural material, at a never seen before scale: This needed very efficient supply logistics, enabling the wooden structure, representing 28,000 m³ of CLT and Glulam, to have been erected in 15 months. The job required delivering around eight 50m³ loads of precision-packed wood materials from Stora Enso mills every week.
- Very high energy sobriety, the buildings consuming only 61 kWh/year /m², in accordance with the new French 2020 regulations, one of the most demanding in the world.

In short, Arboretum demonstrates the very latest in what is possible with industrial processes to reduce the embodied emissions from buildings by utilizing wood. Efficient construction employing prefabricated CLT has never been taken to this scale before. This instills fresh thinking and optimism for a future with a low-carbon architecture for all.

2 THE HUNT FOR CARBON EMISSIONS

2.1 UNDERSTAND, MEASURE, ACT

In many European countries, authorities encourage economic players to reduce their CO_2 emissions. It is up

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https://doi.org/10.52202/069179-0579

to developers and real estate companies to comply with the new Corporate Sustainability Reporting Directive, by revising their business model with the aim of reducing their emissions and aligning themselves with the objectives of the European Taxonomy.
For corporations, the point is to create a new culture of carbon calculation, which must now even supplant economic criteria alone.
This requires understanding where CO_2 emissions come from and making LCA a major decision criterion. WO_2 has therefore based its emissions reduction strategy on:

- The sobriety of design,
- Low-emitting materials
- The detailed ACV calculation, as exhaustively as possible.

2.2 2015, THE FIRST STEPS OF COMPLETE LCA WITH BBCA LABEL

BBCA pioneered the first carbon calculation method for a complete building; the methodology can be summarized in several stages, which can also be found in the European Level(s) methodology:

- Breakdown of the building into 14 construction lots: the entire building is assessed. It is relatively easy to assess construction materials, the manufacturing processes of which are well described in the EPDs (Environmental Product Declarations), but it is still difficult to precisely measure the embodied carbon of technical equipment (which includes many materials, electronic components, and require complex industrial processes). Despite this difficulty, and the vagaries that still exist in the calculation of the building's technical equipment, it was deemed essential to have a complete assessment. Carbon savings must be made wherever possible, and not only by substituting emissive materials with biobased materials.

  In this, the BBCA Label differs from many environmental labels, which consider carbon emissions as one parameter among others without requiring a performance on complete emissions.
- Definition of a reference surface: to make the projects comparable with each other, the calculation of the ratio of embodied carbon per m² requires great transparency in the choice of the denominator, namely the reference surface.
- Finally, the heart of the evaluation process lies in knowing the impacts of each component: the EPDs are the key to the quality of the evaluation; about 7000 EPDs are available on the INIES (French government initiative) database. This revolutionizes the way projects are designed, since in addition to the technical properties of the materials (fire resistance, mechanical resistance, thermal conductivity, etc.), their aesthetic appearance, their cost, they are selected according to their embodied carbon. This new design approach is just emerging among most architects and design offices. It is therefore the role of the developer to foster this new approach in the design team. Nice challenge!

2.3 FURTHER DEVELOPMENT OF BBCA LABEL : LOW CARBON BUILDING INITIATIVE (LCBI)

The number of buildings assessed in LCA is still very limited in Europe; differences in approach are noted between EU countries, which lead to significant differences in results. Although the LCA is based on European standards (EN 15804+A2 and 15978), some LCA modules are not systematically taken into account in all countries; and the evaluation of buildings is most often uncomplete, limited to the envelope.
This makes a pan-European view of property company portfolios relatively confusing. Different European real estate players have therefore come together to adopt a common methodology [2], which can be applied in several countries. This is based on:

- A breakdown of the buildings by allotments (according to the Level(s) Standard of the EU)
- A complete analysis of the building, if necessary, if the assessment is partial, supplementing it with fixed data
- The use of EPDs for materials and equipment that web platforms are able to recalculate according to the country of use, or production (depending on the energy mix of each country).
- This new LCBI Label, which should be available after a calibration phase at the end of 2023, will make it possible to certify the compliance of a building with the European Taxonomy, and will make available figures that can be used in the SBTi strategies of real estate companies.

https://doi.org/10.52202/069179-0579

2.4 DESIGN SOBRIETY

Sobriety is not penance! But this can be achieved by removing unnecessary architectural features, while paying attention to what is meaningful to users.
In the case of the Arboretum project, wide terraces on each level provide fantastic comfort to people, making the building desirable and therefore sustainable. Each occupant can benefit from direct access to the park, via stairs that combine the dual function of escape routes and pleasure stairs.

Figure 1: *"enjoyable stairs" to replace dull lifts – dec 2022 © Raffin*

Wood (CLT and glulam) was used both for the structure and for the decoration: rather than designing banal structures, of poor aesthetics, which are then hidden by decorative materials, as it is often the case, the designers of the project have chosen to leave the timber structures exposed.

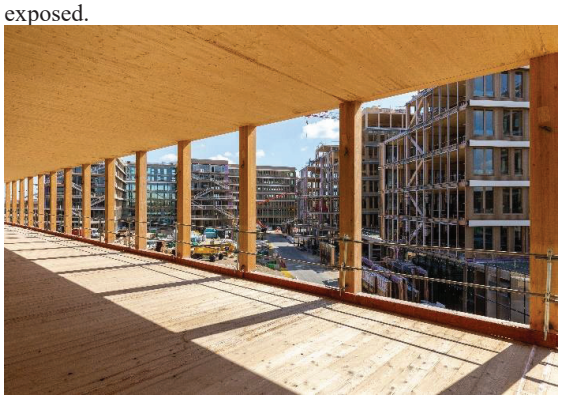

Figure 2: *Erection of CLT slabs meant to remain visible in the project © Raffin*

This is yet another challenge for the design team, which requires excellent collaboration between the engineers who design the structure that must remain visible and the architects.

Figure 3: *Mock-up of the office floor, with visible CLT ceiling © WO_2*

Great attention has been paid to the exposed wood: all the assemblies have been designed so as to remain invisible: in addition to aesthetics, this gives the connecting metal elements a degree of protection against fire. Complete tests had to be carried out to size the sprinkler system. These tests are described in section 4.
Finally, a very meticulous site organization was put in place to ensure flawless installation of the wooden elements that must remain visible.
WO_2 is convinced of the qualities of a wood environment, both for comfort and aesthetics, and quality of life in general.

Figure 4*: View of the construction site (Aug. 2022) – © Raffin*

2.5 LOW EMISSION MATERIALS

Significant reduction of CO_2 emissions has been achieved by replacing most of the concrete with wood and reusing materials from former industrial building. Each part of the building had its own "CO_2 budget", carefully monitored by engineers, in order to challenge the selection and optimise the choice of materials. The project used the INIES database, a government initiative, assessing more than 7000 building components.

2.6 ENERGY SOBRIETY

The project uses heat pumps to heat or cool the building using groundwater as the energy source or sink. Combined with excellent insulation, limited need for

https://doi.org/10.52202/069179-0579

artificial lightning, the project will require only 61 kWh/year /m².
The renewable energy source of geothermal energy is transformed into electricity that powers the heat pumps. The energy-related CO_2 emissions are therefore very low, i.e. 3.9 $kgCO_2eq/m^2$/year; for comparison, the emissions generally observed in European office buildings, according to CRREM data, are 51.4 $kgCO_2eq/m^2$/year (average AT, BE, DK, FR, DE, IT, ES, UK).

2.7 FULL CALCULATION OF LCA

The project was awarded the highest distinction from "Association Bâtiment Bas Carbone" (BBCA). This CO_2 focused certification is the first ever to assess emissions from building materials as well as over the 50 year life cycle for energy. The full LCA amounts to 673 $kgCO_2/m^2$, **ie -47 % compared to a panel of recently designed projects.**
This matches the 2028 cap of CO_2 emissions set by the new French regulation (Environmental Regulations RE 2020): For the first time a cap has been set, requiring to assess emission when filing a building permit. Construction of a building exceeding this cap is not allowed.

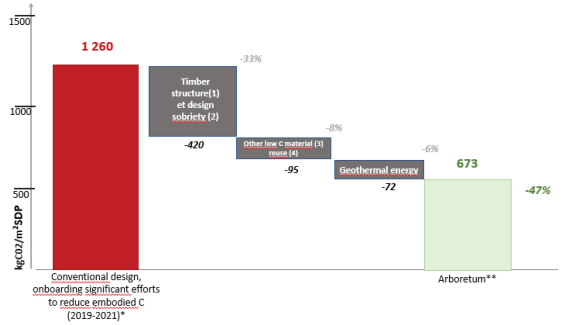

Figure 5: *breakdown of CO_2 savings for Arboretum*

* Benchmark LCA – Artelia 2021 – GHG BBCA v3.1 comparison of 6 concrete buildings located in the Paris region, designed between 2019 and 2021.

** Source: BBCA v3.1 calculation, Artelia 2021

(1) Wooden structure: Storage effect (142 $kgCO_2e/m^2$), superstructure substitution effect (129 $kgCO_2e/m^2$) and wooden facades (33 $kgCO_2e/m^2$)
(2) Sobriety: reduction of car parks, no false ceiling, wooden frame wall on the facade instead of curtain walls (single or double skin) in a conventional design
(3) Low-carbon materials: Recycled carpet, CEM III type concrete
(4) Reuse: Crushed concrete, aggregates

3 BENEFITS OF CLT

3.1 PERFECT LOGISTICS

Thanks to a disciplined and efficient design process the CTL supplier (Stora Enso), was provided with precise manufacturing drawings. The erection of the building superstructure, completed in 15 months, was as fast as expected.

3.2 PRESERVATION OF THE QUALITIES OF THE CLT DURING THE WORKS

It proved impossible to fully protect the 9-hectare site from bad weather as it is sometimes done in Nordic countries. The contractor, French company MATHIS, therefore developed specific tools in order to:
- Guarantee a perfect erection of CLT panels, with extreme care, without any scratches and fully controlled adjustment tolerances;
- Protect the open connexions from moisture
- And if needed, an efficient procedure to clear the stains which might affect the CLT ensuring a perfect finish.

4 FURTHER TESTS: FIRE PROTECTION

The design of Arboretum, whose timber structures are widely visible, required the development of a fire protection system using water spray. WO_2 brought together the various manufacturers to test the two available technologies:

- On one side, the traditional sprinkler (described by the European standard EN 12845)
- On the other hand, the water mist technology (according to the EN 14972 standard): this technology, although less widespread in buildings, has many advantages: the mode of action is different from the traditional sprinkler: rather than drowning the start of a fire by spraying water at a pressure of about 3 bars, it is a matter of instantaneous vaporization of micro-droplets diffused at a pressure of 80 bars, to absorb a large quantity of heat and lower the temperature of the room. The propagation of the fire is then controlled, and it becomes possible for the firemen to intervene. The amount of water sprayed is less than that of a traditional sprinkler system, and it is the preferred technology for all sensitive premises, such as historical buildings, museums, luxury hotels, where water damage can be more important than fire outbreaks.

From the point of view of the building owner, this technology also has the advantage of requiring very small diameter pipes (from 12 to 32 mm), in crimped stainless steel, which is a guarantee of durability.
WO_2 therefore had a test campaign carried out by the EFECTIS laboratory, accompanied by the LISI

https://doi.org/10.52202/069179-0579

engineering office, which allowed each of the concepts to be fine-tuned (choice of nozzles, spacing, flow rate, etc.) in order to verify their effectiveness.

4.1 TEST MODEL

A 300 m² test mock-up was built at the EFECTIS test site in St Yan (FR); it includes CLT and Glulam structures identical to the real building: exposed ceiling (height 3.10 m) along the facades; glulam columns and beams; central part of the mock-up with a false ceiling.

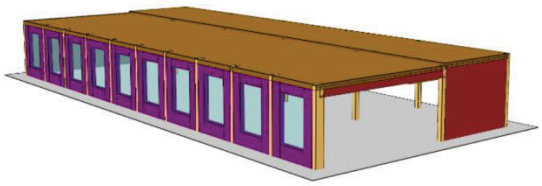

Figure 6: *mock-up*

The model was equipped with side wall nozzles (in green) and hanging nozzles located under the false ceiling (in red) or protecting the space of the technical airducts (in blue).

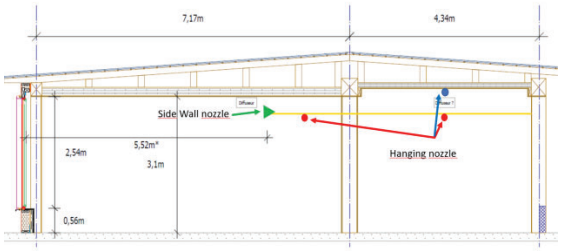

Figure 7: *cross section of the mock-up*

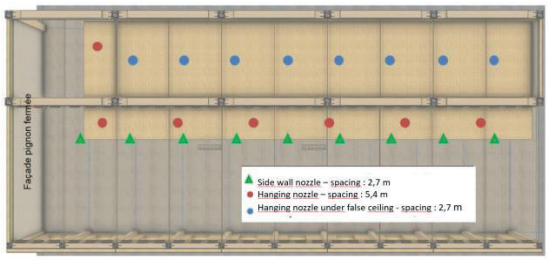

Figure 8: *plan view of the nozzles*

Different locations of fire starts were tested: at the foot of a facade post (figure 9), and at the end of an office floor (figure 10): each fire start being located at the farthest location from the nozzles and at the foot of a glulam post. The purpose of the test was to verify that the rapidity of action of the sprinkler system or water mist allowed to counter the ignition of the wooden structures. Indeed, there are many test reports in the technical literature attesting to the effectiveness of these systems for furniture fires in non-combustible rooms, but few demonstrating their effectiveness in the event of flashover of a solid wood structure, particularly the ceiling.

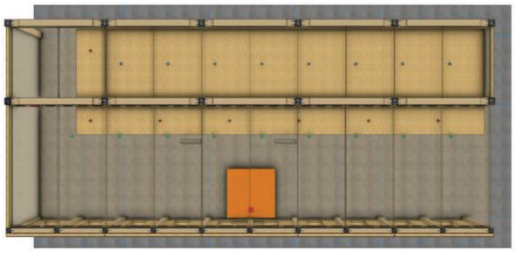

Figure 9: *the orange square shows the fire start, at the foot of a post*

Figure 10: *fire start at the end of the office floor*

4.2 CONDUCT OF THE TESTS

The fire starts were carried out with relatively high start-up kinetics (1 MW in 5 minutes), in order to stress the structures even before the nozzles were triggered.
4 fire start locations were tested for each extinguishing technology. In all configurations, fire control was observed, demonstrating the effectiveness of the extinguishing systems in the case of exposed timber structures, including the ceiling.

Figure 11*: fire start at the end of the office floor*

Photo 12 shows the activation of the nozzles, after the fire has started; photo 13 shows very limited damage to the ceiling after activation of the water mist system.
In conclusion, the tests carried out have allowed the design of the systems to be finalized, and offer a wide choice of technologies (traditional sprinkler, high or low pressure water mist) likely to meet the need for protection of a largely exposed timber structure.

https://doi.org/10.52202/069179-0579

***Figure 12**: activation of water mist*

***Figure 13**: limited damage to the ceiling structure*

5 CONCLUSIONS

The critical need for decarbonisation increases the value of biobased materials.

The Arboretum project demonstrates the ability to significantly decrease carbon emissions. As the largest development of its type, it has been a laboratory of solutions which have shown their relevance.

ACKNOWLEDGEMENT

Architects: LECLERCQ ASSOCIES, NICOLAS LAISNE, DREAM.
Engineers: TERRELL, BARBANEL, AIDA Acoustics, ARTELIA
Contractors: MATHIS, GCC
Fire Lab & Engineers : EFECTIS, LISI
CLT Supplier: STORA ENSO

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