CIRCULAR DESIGN ATLAS

FRAC DUNKERQUE

Architect(s):
Lacaton & Vassal

Year:
2013

Location:
Dunkerque, France

More info:
https://www.lacatonvassal.com/index.php?idp=61

Scales:
Buildings

Resources:
Technical Materials, Energy

Design Approaches:
Design for Disassembly, Design for Longevity

R-Strategies:
Refuse, Reuse, Repair, Recycle, Recover

Aspects:
Technology, Design

TU Delft
BK Bouwkunde

Credits | Design: Lacaton & Vassal | Photo: © Philippe Ruault

The FRAC is a modern art museum completed by architects Lacaton & Vassal as a new addition to an existing shipyard on the site of the harbor in Dukerque, France. The significance of the design comes from the decision to make minimal interventions to the existing structure, and instead duplicate its form using contemporary light-weight materials.

The project is noted for its innovative approach to heritage design, but can also be referenced for some of the choices made to enhance the circularity of the building, most notably the adaptive re-use of an existing building, and the design for disassembly approach for the new facade. As well, the design of the space plan, both in the old and new building, allow for potential future use of the structure. Another prominent circular approach adopted by the architects is “reduce” — seen in the clear consideration to minimize material used through a light weight structure, as well as the adaptive comfort approach to bio-climatic design.

Layers of Change and Lifecycle Duration

Site
The built structure is located in the city of Dunkerque on the north coast of France. In this specific region sandy, calcareous soils are very common. Due to the thick layer of concrete at the bottom of the existing building it made sense to lay a foundation for a new structure somewhere else. In this case beside the existing building. The climate is temperate with temperatures as low as 5 degrees during the winter and as high as 30 degrees during the summer. This means both heating and cooling are important factors to take into consideration.

Skin
The facade includes an ETFE (Ethylene Tetrafluoroethylene) system and corrugated plastic plates both attached to a steel structure. Double layered plastic “pillows” (ETFE) substitute glass as the transparent material in the facade. These pillows have an expected lifespan of 25-50 years and can individually be removed or repaired on site. As they’re only 1% of the weight of the average glass window the supporting structure can be reduced. The plastic is recyclable and also bio-climatic as it lets in 95% of the UV light.

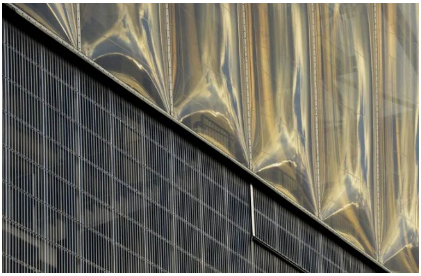
Structure
The structure consists of prefabricated reinforced concrete elements. If cast well the life expectancy of the concrete could reach up to 100 years. It’s a visible and efficient structure made up by columns, beams and slabs but at the end of the life cycle it’s difficult to re-purpose the material (Brand, 2012).

Services
To maintain pressure in the ETFE pillows an air inflation system has to be installed and an air handling unit is connected to them. Although the energy consumption of one unit is minimal (60 - 120W) the system is reliant on electricity to work. Additionally, metal is needed for the installation of this air inflation system. Few sources state the lifespan of the inflation system but it’s expected to be changed at least once every 50 years. All services in the building are visible and can easily be changed (Architen Landrell, 2017).

Space Plan
Due to the flexible floor plan not much energy or material is needed to alter the configuration of the rooms. In the example to the right a wood and plaster partition wall has been used to create a more appropriate space for an exhibition (which usually changes every 6-12 months). The floor consists of polished concrete with quartz hardener. This is a very durable material and depending on how well it is maintained it could last up to 50 years.

Site
Eternal

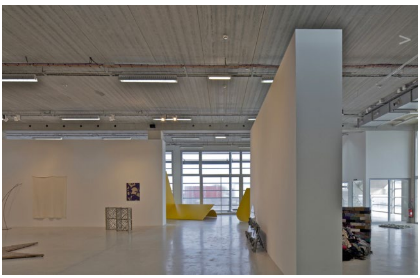
Skin
25-50 years



Structure
75+ years

Services
25-50 years

Space Plan
0.5-50 years



Stuff
Various

Credits | Design: Lacaton & Vassal (2013) | Photo: © Philippe Ruault

Carbon Footprint of Materials

To calculate the carbon footprint of the materials used in this building, an axonometric drawing was made of a representative square meter of the facade. This fragment consists of ETFE (ethylenetetrafluorethylene) membrane air cushions, attached with a metal strip to a SHS-180 steel tube profile. The metal strip is likely made of aluminum, due to its noncorrosive properties (Aguilar, C, 2021; Lynch, 2023).

The volume of the used materials was extracted from the vectorized axonometric drawing. The following values are recognized:

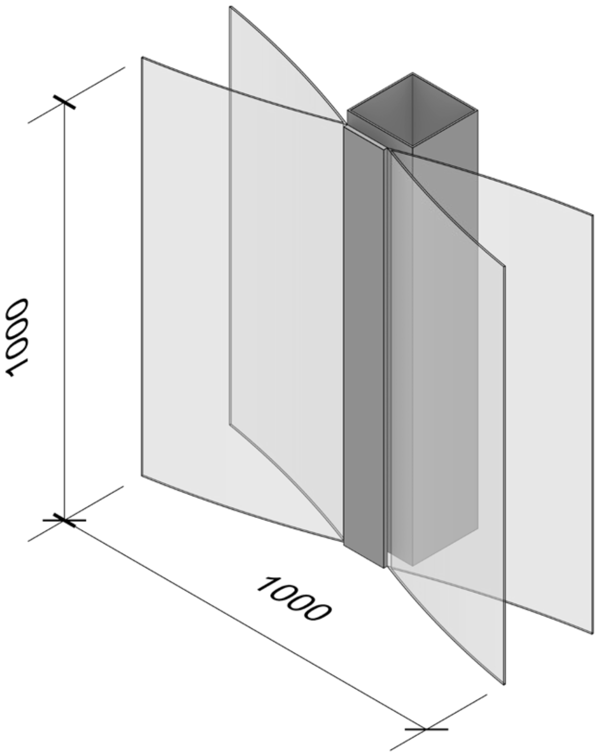
Aluminum:	0,001 m³
ETFE:	0,005 m³
Steel:	0,003 m³

These values were than imported into the Material Pyramid for Northern Europe and Scandinavia, leading to the resulting carbon footprint of 29,0 kg$CO2_{eq}$ per m^2 facade shown on page 6 (Byggeriets materiale pyramide, z.d.).

Due to the uncertainty of the used materials and the lack of ETFE in the material pyramid, two assumptions were made.

Firstly, the ETFE was replaced by the PE film vapour barrier that is represented in the pyramid; an all but accurate estimation. Secondly, the aluminum strip was replaced by aluminum window framing, due to its similar function. These assumptions mean that the estimated footprint could differ dramatically from reality.

To remedy this, the GWP of an actual ETFE-cushion system was found in a BREEAM ‘sustainability contribution declaration’. Taking into account only the product stage lifecycle phases A1 - A3 (just like the material pyramid does), the GWP of such a system is 58,2 kg$CO2_{eq}$ per m^2 of facade (Vector Foiltec GmbH, 2017) rather than 2,5 kgCO2eq that was manually calculated with (wrong) materials. Adding this system to the steel substructure results in a total GWP of 58,2 + 26,5 = 84,7 kg$CO2_{eq}$ per m^2 facade.



Credits |Axonometry Facade Fragment | Illustration: Tjeerd Prins (2023)

	material	group	impact / m3	volume [m3]		result
1	**Structural steel**	metal	8831.2 kg CO2eq/m3	**0,003**	m3	26,5 kg $CO_{2\ eq}$
2	**Aluminium frame window**	komponenter	1172.7 kg CO2eq/m3	**0,001**	m3	1,2 kg $CO_{2\ eq}$
3	**PE film (vapour barrier)**	kunststof	266.3 kg CO2eq/m3	**0,005**	m3	1,3 kg $CO_{2\ eq}$
						29,0 kg $CO_{2\ eq}$

Credits | Results GWP | Screenshot: Tjeerd Prins (2023)

Building Material Origin

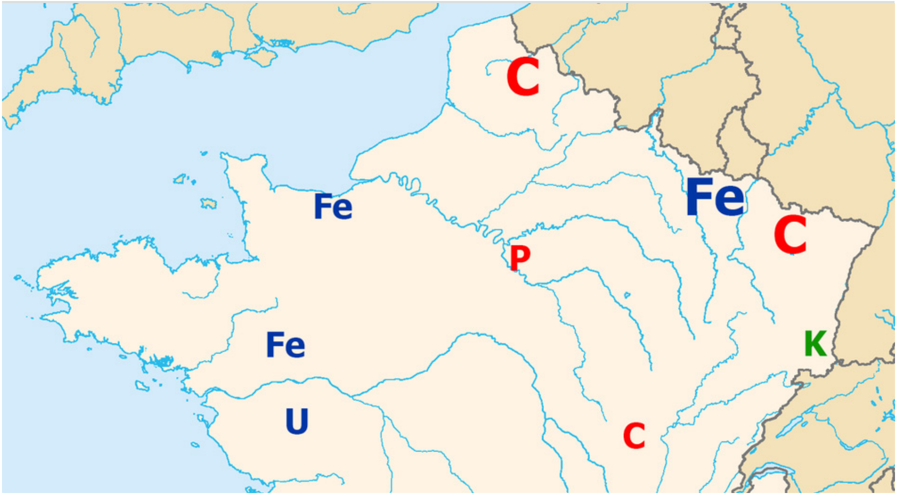
Three materials make up this facade fragment: Structural steel, aluminum framing and ETFE air cushions. None of these materials are classified as ‘critical raw materials’ in 2023, according to the EU (European Commission, z.d.). Additionally, none of these materials are biological. ETFE, steel and aluminum, respectively a polymer, an alloy and a metal, are thus all technical materials.

Steel Structure:
The steel construction was executed by a French company ‘CESMA’ (*C.E.S.M.A.*, z.d.). The supplier of the steel used in the building’s construction is not mentioned. It is however noteworthy that there is a steel factory close to the project’s location called ‘ArcelorMittal’ in Dunkerque (ArcelorMittal Dunkerque, z.d.). The steel might have come from here.

The exact origin of the raw resources needed for the manufacturing of steel are not given by ArcelorMittal. They simply state that they “[...] mine iron ore and metallurgical coal[...] at open-pit and underground mines around the world.” (ArcelorMittal, 2023). It just so happens that there are three iron mines and two coalmines in the north of France, close to Dunkerque, as seen on the map to the right, illustrated by Homoatrox (2018). The closest mines were assumed to be the most likely suppliers to Dunkerque. The trail, concerning the steel structure, ends here.

ETFE-system:
The ETFE cushion system (and its frame) was delivered and installed by a Munich-based company: ‘Taiyo Europe’ (Taiyo Europe, 2021). The product used is called ‘TensoSky® ETFE system’ by MakMax Australia, which is part of the same ‘Taiyo Kogyo’ company group (MakMax Australia, z.d.). The origin of the resources are not mentioned by Taiyo Europe nor by MakMax Australia. Further tracing is therefore not possible.

In the map on the next page, an illustration was made to visualise the (likely) origin of the materials used in this facade fragment. Keep in mind that much of this information is based on assumptions.



Credits | Natural resources of France | Photo: © Homoatrox (2018)

Credits | Material Origin | Illustration: Tjeerd Prins (2023)

R-Strategies

The FRAC Dunkerque building's overall approach to the design of its skin prioritizes adaptive comfort levels and minimizes the reliance on energy-intensive heating and cooling systems. It uses a lightweight bio-climatic envelope that allows natural light and ventilation, and acknowledges that occupants' comfort can be maintained without the need for strict, constant indoor climate control. This aligns with circular design's focus on resource efficiency and sustainability.
This approach rejects the use of extensive mechanical systems, aligning with circular design's "Refuse" strategy. The concept of adaptive comfort levels reduces energy consumption and connects occupants with the outdoor climate, embodying the "Reduce" strategy.

In terms of the materials used in this fragment of the facade, the r-strategies applied are primarily concerned with reducing initial unnecessary material consumption, and the prolonged future potential of the selected materials.

Refuse:
Within this facade fragment, the refusal of unnecessary components and materials is essential to its circular strategy and starts with minimizing the over-engineering of the steel structure. ETFE, as a material, contributes to this strategy due to its material properties, as it is notably lighter than traditional materials like glass or polycarbonate. This lightweight characteristic reduces the load-bearing requirements of the steel structure, as it doesn't necessitate as much structural support. For the ETFE cushions themselves, opting for high-quality, durable ETFE materials that require less frequent replacement is a form of refusing the use of inferior, short-lived materials. This strategy emphasizes the significance of making intentional choices in the design phase to reduce waste and resource consumption.

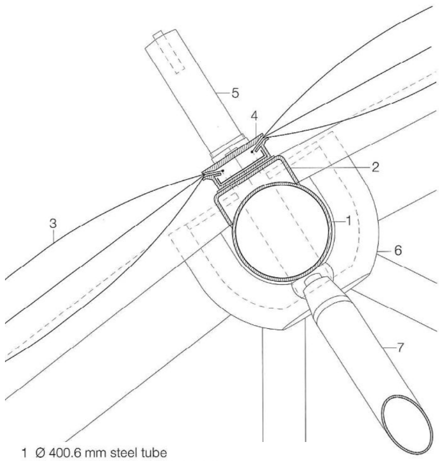
Reuse:
Given the durable nature of steel, considering the potential for reusing steel components, such as structural elements, in future construction projects can be a sustainable approach. These components can be disassembled, refurbished, and repurposed, extending their lifespan and reducing the demand for new steel.

For ETFE cushions, reuse can be challenging due to their specific use in building facades. However, exploring options for reusing ETFE in similar construction applications or temporary structures could be considered.

Repair:
Steel is highly repairable, especially with modular components, as damaged sections can be easily replaced or refurbished. For ETFE cushions, integrated mechanisms into the design allow for easy replacement of damaged sections without dismantling the entire facade. By designing with this possibility for repair, it can extend the lifespan of the components and reduce the need for replacements.

Recycle:
Steel is also highly recyclable, and at the end of its life, these components can be collected and recycled into new steel products. For ETFE cushions, due to their multi-layer composition, the process of recycling can be more complex, but still presents opportunities for reducing additional waste. The recycling typically involves melting down the ETFE material to its base resin form, either through mechanical or chemical recycling, which can then be re-used to manufacture new ETFE products, or other plastic/ composite materials. This procedure, however, requires more energy as the material is processed.

Recover:
In some instances, ETFE cushions may have to be down-cycled when they reach the end of their service life in architectural applications. This involves transforming the ETFE material into lower-value products, such as packaging materials or other non-architectural uses. While the material's use value may decrease, the circular design approach still minimizes waste and resource consumption, as it continues to contribute to the resource loop.



1 Ø 400.6 mm steel tube
2 6 mm sheet steel bent to shape
3 three-layer inflated ETFE cushion
4 aluminium clamping strip
5 Ø 70 mm steel cylinder as safety rail
6 cast-steel node
7 Ø 89 mm tubular diagonal member
8 extruded-aluminium frame to opening flap

Credits | Typical ETFE Detail | Design: Grimshaw Architects

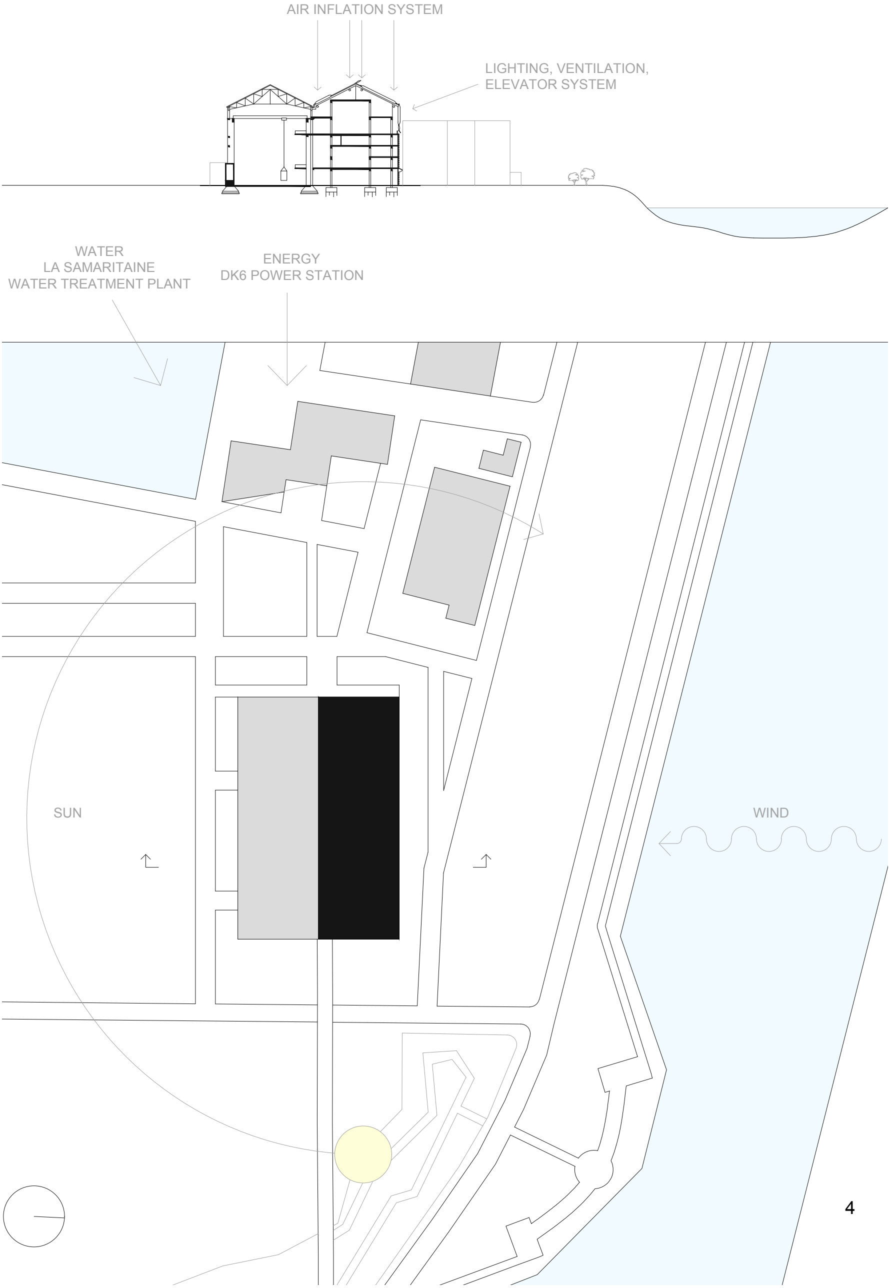
The NEW Nexus

The flowing resources that make the building function are mainly electricity and abiotic factors. Water is also a flowing resource.

The electricity is needed to power lighting in exhibition halls, ventilation exhausts, an elevator system and foremost the air pressure system that the facade needs to operate. The electricity is most likely generated at the DK6 gas power station in Dunkerque (800 MW). Both the DK6 power station and “La Samaritaine” water treatment plant, where water is biologically treated, are located within a 4 km radius of FRAC Nord-Pas de Calais (Ville de Dunkerque, n.d.).

The proximity to the coast, north of the building, and the vastness of the site means there’s a lot of wind. Together with the sun, that mainly heats up the east and west facade and parts of the roof that face south, the wind contributes to a more passive energy system. Operable windows and skylights make use of the wind for adaptive ventilation and the ETFE roof and facade system lets in 95% of the UV light to heat up the building.

Credits | Design: Lacaton & Vassal (2013) | Photo: © Philippe Ruault



Credits | Site Plan and Section 1:2000 | Nicholas Niemen (2023)

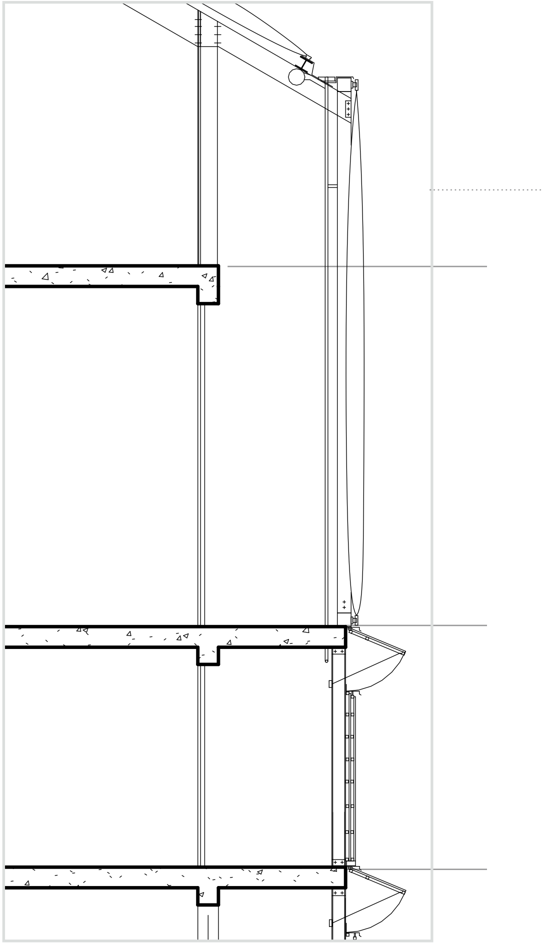
Design Approaches

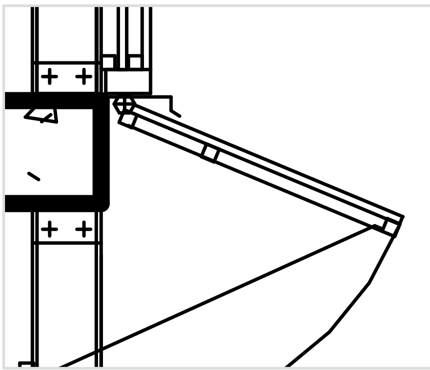
Design for Disassembly

Certainly not the entire structure has been designed to be easily dissembled but the facade (and other components) have been made to be disassembled. So have the steel columns and railings along the balcony assembled directly into the concrete structure. The facade consists of multiple steel structures with ETFE or Polycarbonate elements which are possible to disassemble into smaller fragments.

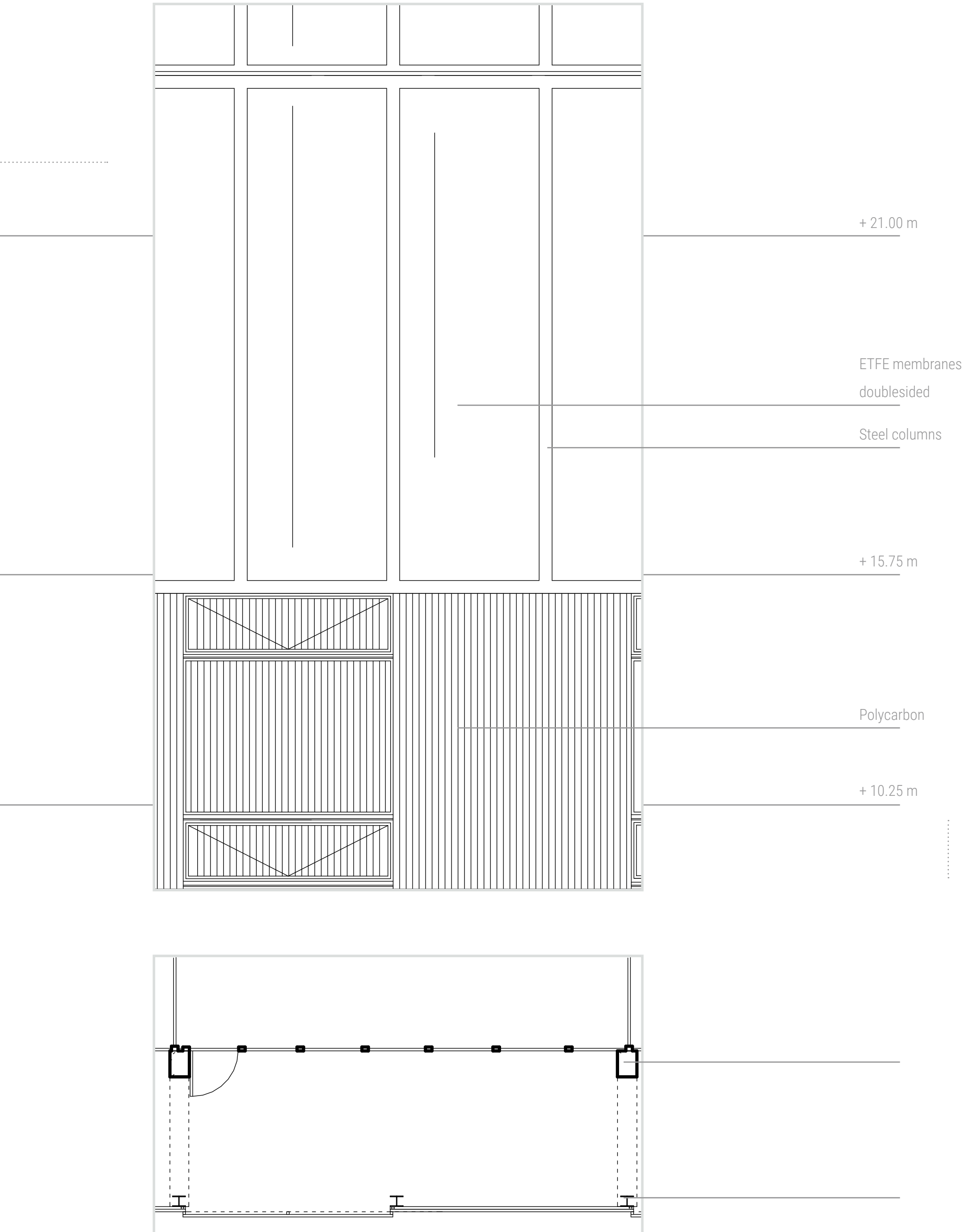
Design for Longevity

The design is also not entirely made for extreme longevity however the design does show some of the longevity traits. The original space-plan has been stripped or kept entirely empty. To be able to show the modern art the spaces in the addition have also remained mostly empty. If the future brings a new use to the building these spaces can be easily converted into another use. Mind that there must be made an improvement to the installations of the building if it is used in another manner.





Credits | Wall Section | Bas Jonker



Credits | Facade Fragment | Bas Jonker

Stakeholders & Value Chain

The adoption of a circular design strategy for the FRAC Dunkerque building by architects Lacaton & Vassal affects various stakeholders in different ways, and impacts the architect's role in the different phases of the building's life cycle.

Manufacturing Phase:

Stakeholders: Materials suppliers, manufacturers, construction companies, and transportation companies.

Influence: Architects, during the manufacturing phase of the FRAC project, can collaborate with suppliers to source more circular materials, emphasizing the strategies of "Refuse" (choosing sustainable materials) and "Reduce" (minimizing waste). This promotes the use of materials that align with circular principles within different stakeholders of the industry.

Design and Construction Phase:

Stakeholders: Architects, construction teams, clients, municipality and government, environmental consultants/engineers.

Influence: Architects in the FRAC project play a central role by designing for adaptability, incorporating "Repurpose" and "Reuse" strategies in the architectural design. This is achieved not only through the decision to transform and re-use an old building made of durable materials, but also by designing with methods capable of disassembly. This ensures that at the end of the functional life of this building, the same materials can be put to practical use elsewhere. In the design phase, commitment to circular design means architects might require additional research on materials and methods, and extra consideration of the whole life cycle of the building and its materials - in particular, the end-of-life treatments of these components.

Occupancy and Use Phase:

Stakeholders: Building occupants, management and maintenance teams, and local community.

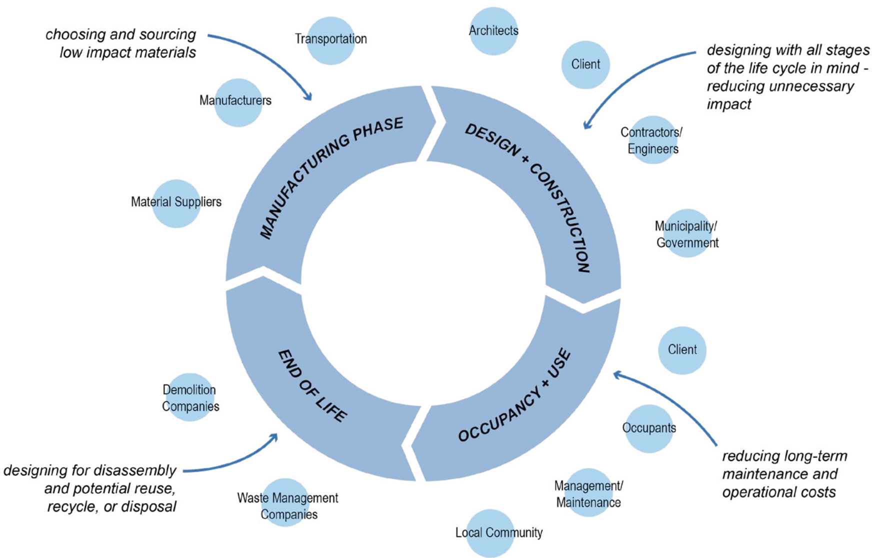
Influence: Architects influence the occupancy phase by designing for energy efficiency, "Repair" (easy maintenance), and "Refurbish" (upgradability). This reduces long-term maintenance and operational costs, promoting a sustainable building environment. The building occupants and local community can therefore benefit from a circular approach that fosters healthy communities and engagement.

End of Life Phase:

Stakeholders: Demolition and waste management companies, and the client.

Influence: Lacaton & Vassal's role in circular design can positively impact the end-of-life for the building through their choice to design for disassembly and potential reuse, thus minimizing the environmental impact during this phase. By considering the end-of-life for both the building and the materials, architects can ensure the responsible recycling and disposal of materials.

Architects' commitment to circular design principles significantly influences the value chain of the FRAC building. Their choices and designs guide the selection of materials, construction methods, and operational practices, making the entire process more sustainable and resource-efficient. This commitment reduces waste, lowers energy consumption, and aligns with a more environmentally friendly built environment.



Credits | Stakeholders throughout the Life Cycle | Emilee Chen

Lessons Learned

The implementation of many r-strategies in their design reflects Lacaton & Vassal's approach to circular principles. The biggest commitment to this is the decision for resource conservation and cultural preservation through adaptive reuse.

Their approach to the lightweight bio-climatic envelope reduces the load on mechanical systems and further enhances energy efficiency throughout the building's operation. This holistic approach highlights the importance of efficiency, conservation, and innovation in architectural design, acknowledging that materials' whole life cycles should be considered thoughtfully, and that non-biogenic materials can still be used in new architectural designs, provided they serve a purpose in enhancing the building's performance, such as the lightweight ETFE cushion.

Lacaton & Vassal chose to incorporate a light and replacable facade system and visible installations in their design. Seeing the building as a "kit of parts" where you can detach certain shearing layers when needed increases the life span of the building. Additionally, using a lightweight structure for the facade decreases the amount of material in the value chain.

The ETFE-cushion system was chosen as the one square meter facade fragment, as it represents a big and recognizable part of the building. This fragment was calculated to have a total GWP of 84,7 kgCO2eq per m2.

The steel for the construction was assumed to come from a local steel factory in Dunkerque, who may have collected their raw resources from mines in the northern part of France. The ETFE system was traced back to a company in Munich, whose main department is located in Australia. The origin of the raw resources of this system could not be found.

Additionally, Lacaton & Vassal saw the site as an important part of the design. The type of soil, the orientation of the building, the sun and wind together create the foundation for a sustainable design and have a huge impact on how to adapt circularity in the building practice.

The research conducted on design approaches for FRAC building displayed many commitments to circular design principles, most notably: the practice of deconstructing a building into its smallest components. Through this research, it was observed that for a modern building in France, the emphasis on insulation and climate-specific design may not be as critical as initially thought. By focusing on the specific program and purpose, in this case a modern art museum, the interior climate considerations, which are much more critical in residential design, can be somewhat liberated. This approach opens up greater possibilities for circular design.

Colophon

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Image credits:

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