CIRCULAR
DESIGN
ATLAS

FORT V

Architect(s):
BC Architects

Year:
2015

Location:
Edegem, Belgium

More info:
www.bc-as.org

Scales:
Buildings

Resources:
Biological materials, Technical materials

Design Approaches:
Design for disassembly, Regenerative design

R-Strategies:
Refuse, Rethink, Reuse, Repair, Refurbish, Repurpose

Aspects:
Technology, Design, Resource flows

TU Delft
BK Bouwkunde

Design: BC Architects | Photo: © BC Architects

Fort V is a project situated in a former military building that lays within the park Fort 5 in Edegem, Belgium. The project is used as a learning center for children in the region. It has the purpose to strengthen knowledge about nature and ecology. The building materials are carefully chosen in aspects of circularity with mainly two different techniques used. Those are a structure made of earth from nearby the site compressed into blocks and hempcrete that works both as an insulation facade and a roof. The old technique of building with earth itself can last for centuries under the right conditions. Another particularity is the possibility to reuse the earth, since the mass can be compressed into new blocks repeatedly. Hempcrete is also an interesting material which is becoming more frequently used, with two main benefits. The first benefit is that it requires less concrete, the second one is that growing hemp has a negative CO2 effect. Fort V is a project that focuses on using circular materials in an innovative way.

Layers of Change and Lifecycle Duration

The building is composed of a very limited number of materials in two simple layers in order to have a sustainable and a minimalistic structure. Nevertheless, each of those layers is composed of one or multiple materials that all have varying lifecycle durations.

Site
The site is per se unusual, Fort V being built inside an existing building. As it is protected from outdoor elements, we could deduct a longer lifespan. Indeed, the site is there to stay and for a long period, considering its materials (solid bricks and metal). However, because the site is a building itself, it is more ephemeral than a natural environment which could last indefinitely. The possible destruction of the existing building acting as a site could impact negatively Fort V's integrity.

Structure
The main structure of the building consisting of arched walls is made from stacked compressed earthed blocks out of local clay. The lifespan of the compressed earth blocks can be up to centuries. It therefore contributes to making the structure a good shearing layer.

Skin
The exterior skin of the building is in Hempcrete, having also a role of insulation for the walls and roof in addition to being the finishing coat of the facade. Being solid, waterproof, and fire resistant, hempcrete has a lifespan between 50 to 100 years. Here, as the building is situated inside a protecting structure against any outdoor harsh climate, the material will get very slowly deteriorated over time and will last much longer.

Services
The services for the building (plumbing, ventilation, and electricity) are currently managed by the city of Edegem in Belgium, and are necessary for the use of community center for an undetermined amount of time. If we consider Aluminum as one of the main material for these services, the lifespan of the material itself (decades) is not the issue here. The technology that these elements are using and their quick life cycle (7-15 years), would be more problematic, as they are partially inside the structure and the skin.

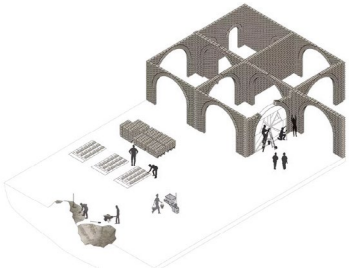
Space plan
The function of the building influences the floor plan which is supposed to remain the same for a similar time. The floor plan is very influenced by the main structural elements of the building. Being defined by the compressed earth blocks walls and arches, it is therefore fixed and will have the same lifespan as the building itself.

Stuff
Stuff inside the building is furnished by the owner, in this case the municipality. It may vary over the years or even the months depending on usage. Furnitures and frames mainly made of wood can theoretically last for centuries so even longer as the building itself.

Site
Centuries

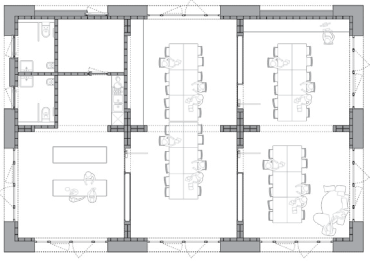
Skin
50-100 years

Structure
centuries



Services
7-15 years

Space plan
30 years



Stuff
Various

Design: BC Architects | Photos: © BC Architects

Carbon Footprint of Materials

The two main materials used for the walls of Fort V are Hempcrete and Compressed Earth Blocks.

Hempcrete consists of approximately 30% lime to bind the material together and 70% hemp shiv which provides the insulation (1). In the Carbon Footprint calculation, limestone and hemp fleece are used. Those materials can differ from the exact materials being used in the project.

The volume of 1 m2 of hempcrete (width = 0,5 m) is 0,5 m3. This means that the amount of limestone used in the hempcrete is 0,15 m3 (70% x 0,5 m3) and the amount of hemp (fleece) used in the hempcrete is 0,35 m3 (30% x 0,5 m3).

Compressed Earth Blocks are made from local clay. According to the website from BC materials, a small amount of concrete has been used to obtain stability and water resistance (2). The exact proportions are undefined. BC materials says that they use 3,85% of cement and an unknown percentage of crushed washed concrete. We guessed that the total amount of concrete in the Compressed Earth Blocks is about ~6%. This percentage is based on the idea that mortar is used for the joints.

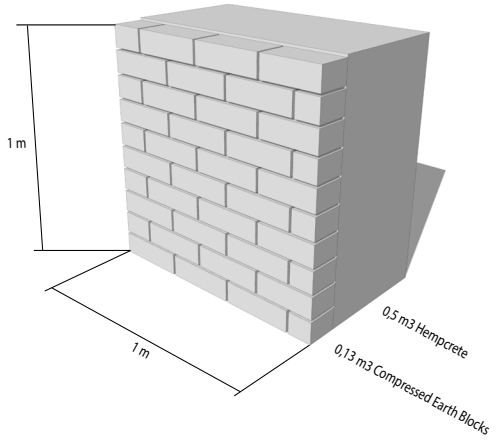
The volume of 1 m2 of compressed earth blocks (width = 0,13 m) is 0,13 m3. This means that the amount of clay in the compressed earth blocks is 0,12 m3 (94% x 0,13 m3) and the amount of concrete in the compressed earth blocks is 0,01 m3 (6% x 0,13 m3).

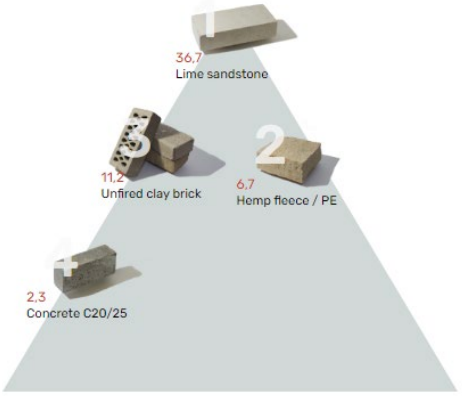
After filling in these data in the Material Pyramid a result of 57 kg CO2 per m2 is obtained.

According to BC Architects the insulation façade and roof of hempcrete left apparent as finishing contribute to making this building CO2-negative (3).

The earth used in the compressed earth blocks is a local resource that does not require fossil fuels nor energy intensive processes to be transformed into a building material, which makes this product carbon neutral (4).

The results of the material pyramid may differ from what BC Architects claims concerning the carbon footprint of the building.





| kg CO_2 eq
| module A1-A3

Fort V - BC Architects

Your pyramid:
57,0 kg CO_2 eq

show result in pyramid ↑	reset calculation	Fort V - BC Architects		1 m^2			
	material	group	impact / m3	volume [m3]	area [m2]	thickness [mm]	result
1	Lime sandstone	mineralsk	244.8 kg CO2eq/m3	0,15 m3	m2	mm	36,7 kg CO_2 eq
4	Concrete C20/25	mineralsk	229.0 kg CO2eq/m3	0,01 m3	m2	mm	2,3 kg CO_2 eq
2	Hemp fleece / PE	biobaseret	19.2 kg CO2eq/m3	0,35 m3	m2	mm	6,7 kg CO_2 eq
3	Unfired clay brick	mineralsk	93.6 kg CO2eq/m3	0,12 m3	m2	mm	11,2 kg CO_2 eq
							57,0 kg CO_2 eq

3D fragment made by David Barneveld | Material pyramid from www.materialpyramiden.dk

Building Material Origin

BC Architects also owns BC Materials, a company that sells components to build with earth. It was easy to find the origin of the earth blocks used for structure. However, it was more difficult to find information about the facade material made of hempcrete. Therefore we did an estimation based on production possibilities and companies in Belgium that could have been used. Fort V is made of a combination of biological materials such as sand, clay and hemp but also technical materials such as cement, concrete and limestone.

Earth blocks consist of a mix of four different materials that are then compressed into blocks on the site. These are sand, clay, crushed concrete and cement. Hempcrete is a mix of hemp, shiv (70%) and limestone (30%).

Biological materials

B1 Rhine sand from Cologne in Germany (5)

B2 Loess loam clay from outside of Brussels in Belgium (5)

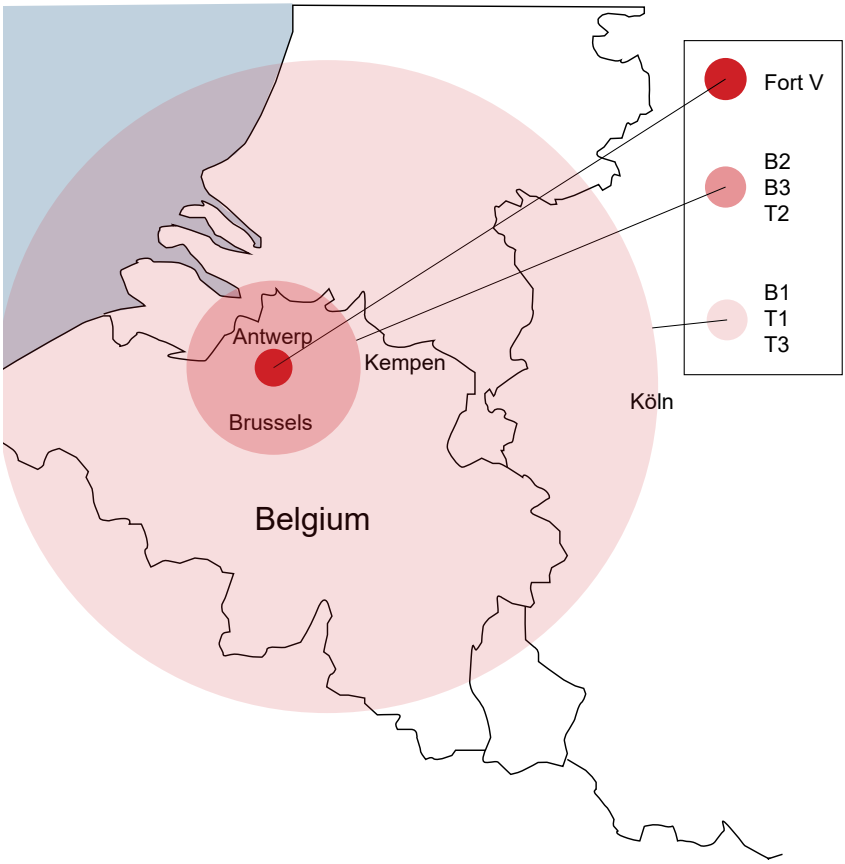
B3 Hemp and shiv from hemp plants. Estimation: origin in Kempen where 50 hectares of hemp are used to produce insulation (6)

Technical materials

T1 Cement from Belgium (5)

T2 Crushed washed concrete mainly recycled from demolition within Brussels (5)

T3 Limestone. Estimation: within Belgium (7)



Map of material origin. Made my Hanna Ambuhm.

R-Strategies

The fragment of Fort-V only involves two types of materials: earth blocks and hempcrete. This could be the reason why few R-strategies are achieved.

Refuse
As for the structure, the earth blocks consist mostly of sand and clay. An unknown amount of reused crushed concrete is used in the blend as well as 3,85% of cement. (8) Cement is added for extra resistance against rain and gives the material its load-bearing qualities. It is however possible to build with earth blocks made purely of sand and clay especially in smaller buildings located in dry areas. One could argue that since Fort V is situated inside another building it is unnecessary to add the cement since it is already protected from the weather. However, with a higher flood risk in the future and to enhance the chances of durability it might have been necessary to add the cement to the blend.

Rethink
The spatial structure is created through the load-bearing elements that also work as interior walls. It would therefore not be possible to change the structure. However, Fort V is situated inside and old military building with lots of spatial qualities such as light and volume. There are great possibilities to arrange the space within the military building, especially to fit a larger amount of people than what is now possible in Fort V.

Reuse
The earth blocks are 100 % reusable when being crushed and then compressed into blocks again. To reuse the blocks as they are it all depends on the mortar between the blocks. If cement is used it is harder to split the blocks and preserve the quality, but if only earth is used that might be easier. However, the best way to secure loadbearing qualities is to compress the blend into new blocks, preferably in a nearby location to reduce transportation. Earth blocks are an easy building technique that can be made without any specific knowledge. Yet it is preferable to have at least one person confident with the technique. This gives a greater opportunity for reuse since it is available for a larger part of the population. (8)

Repair
The structure of earth blocks and the facade of hempcrete which is stabilized with a wooden structure are not merged into each other. This enables the two different parts to be changed or to be repaired in case of damage without affecting the other layer. In terms of lifespan, hempcrete is the shorter of the two.

Refurbish
Earth blocks are very safe in terms of fire, humidity, and natural heating regulations. However,

the biggest problem regarding earth blocks is the weakening effect that water has on it. In a future with more flooding and heavier rains earth blocks might not be appropriate in this region of Europe. Historically, earth is more frequently used in warmer and drier climates. The former military building does work as a protection, but more water-resistant materials or surface treatments might need to be added in the future.

Repurpose
The structures could be moved as units as long as the dimensions are appropriate to the new function. This however would need special transportation.

Recycle
The recycle strategy can be included under the reuse topic. Earth blocks can be crushed and then compressed once again into new blocks. If cement and concrete are not used they can also be transferred back to nature in the same condition. It is also possible to add new qualities to the earth by adding more cement or different clays to achieve a higher quality in future use.

Photo from process of compressing earthblocks at the site. | Photo: © BC Architects.

The NEW Nexus

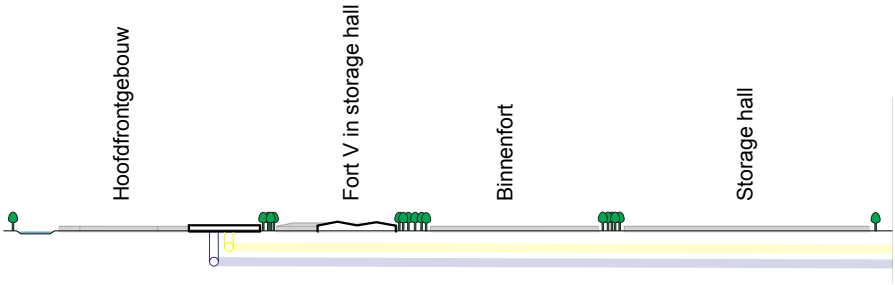
Fort V is located in a large storage hall, former military base building in Edegem, close to the city of Antwerp. This building has been re-used to build the Fort V project in it.

Other fort buildings are located in the surroundings of the storage hall building. There is a very dense wooded area in between them. The trees offer shade during summer days.

The building itself doesn't have any solar panels or other systems to generate energy independently. It is connected to the main electricity (yellow line) and water (blue line) network of the Municipality of Edegem (see section and site plan).
However the site provides potential to make it more circular and sustainable. For example, a big water canal is enclosing the South part of the military base district. Its water could be used in the future for the operation of sanitary services.

The roof of the storage hall already contains many windows which saves a lot of energy for artificial lighting. The addition of solar panels would make the building more sustainable and self sufficient.

If these features were added to the ecosystem of the building, the need of electricity and water from the main network would be reduced, which would save a lot of CO2 emissions and costs.



Section AA' | 1:1000, re-scaled to fit

Section made by David Barneveld based on the design from BC Architects

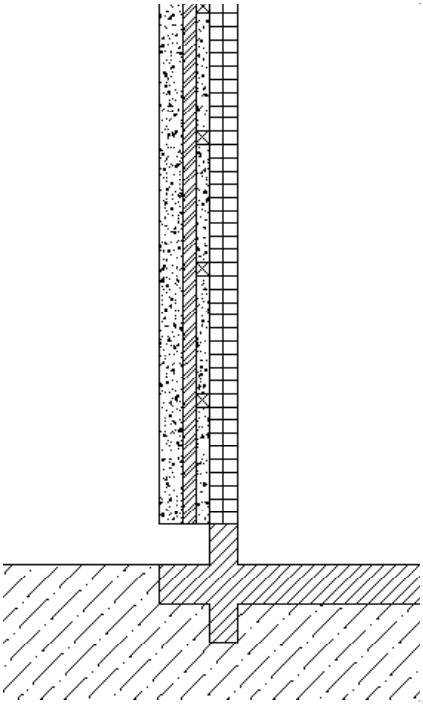
Siteplan made by David Barneveld based on the design from BC Architects

Design Approaches

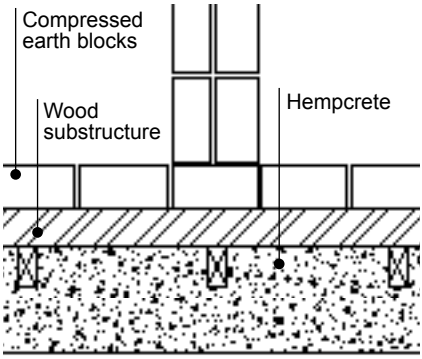
Overall, BC architects tried to minimize the CO2 impact of the building through a relatively circular process. They didn't do it by recycling existing materials but instead using the existing skin of the building where it sits in as well as the local materials from the site.

The shearing layer of the skin is structurally dependent on the structure layer made of earth blocks. The Hempcrete facade is attached to the bricks with a wooden grid substructure. It is then easily detachable from the other shearing layer without altering its quality. It also doesn't use any critical material for the structure.

However, an issue that we noticed is present within the hempcrete layer, blended with the wooden structure, these two materials would be difficult to separate without affecting the other one, creating a conflict for future adaptability.

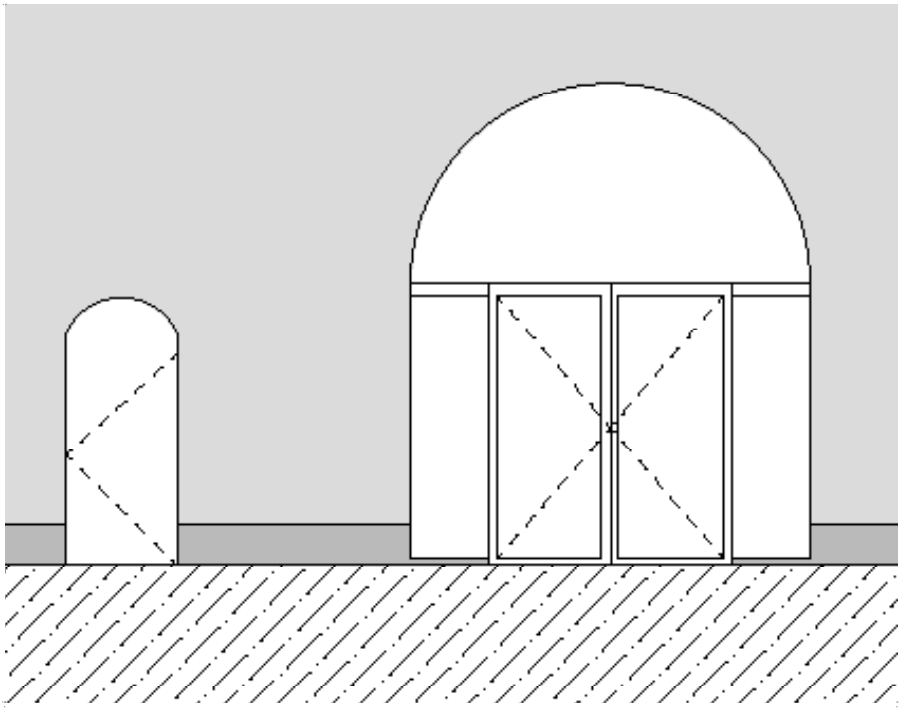


Section

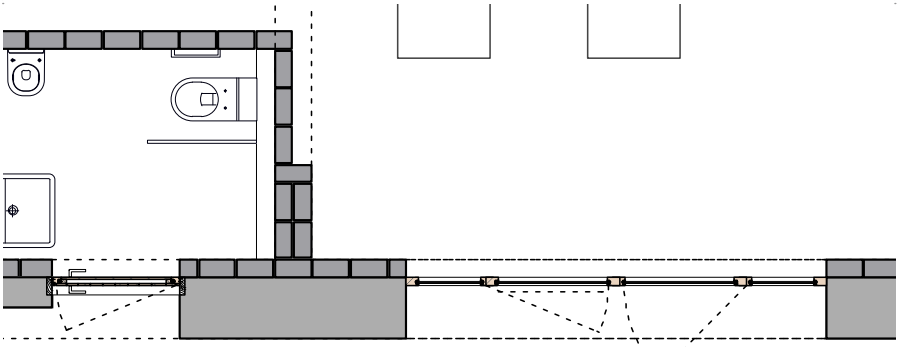


Detail 1:5

Section & detail made by Gaspard Marteau



Corresponding elevation



Corresponding floor plan

Elevation & floorplan made by BC Architects

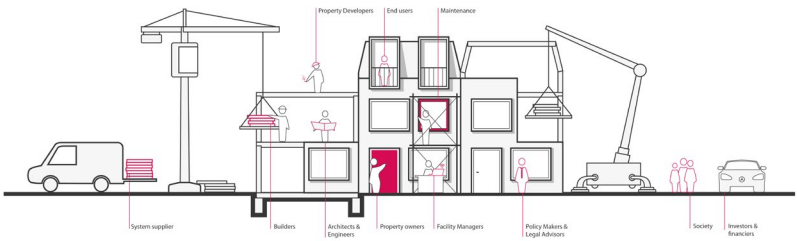
Stakeholders & Value Chain

Circular design completely changes the way buildings are created and engineered. Architects are now at the core of most of the decisions regarding the building elements, materials and details. The shift in society pushes also the industry to centralize the management of a project to a single job. By taking this responsibility now, architects are also due to focus on all circular aspects of the designed buildings in close relation with all stakeholders of the value chain such as manufacturers, builders, contractors and engineers. It is the case for Fort V. Here, the people involved in the construction were volunteers as the process was easy and accessible to everyone. This also saved costs on qualified professionals.

Architects wanting to design in a circular way have to take care of the different steps leading to the realization of buildings to push circularity at all scales and for all parts of the design. They should also have control and knowledge on the origin of each materials used in their building. For an easier circular process in the future, data availability like lists of material passports will be crucial. Some new regulation implementation like it is the case for example in the food industry may be needed.

Circular design can challenge the role of architects as well but in a stimulative and creative way. Indeed, for finding solutions to climate problems, architects have to come up with innovative ideas. They can also come back to traditions almost no longer in use that are sometimes more circular than the recent 20th century techniques, such as compressed earth blocks in the case of Fort V.

Architects have now to find circular sources for their



Based on a diagram by the CBE Hub, BK TU Delft

materials rather than keeping the basic supply chain of mass production based on polluting extraction and transportation of raw materials. They are also no longer at the beginning of the chain of construction but they can find themselves working at any radial point of the circle of life of materials in a building.

Their role can be to intervene in the urban mining process of an existing building to be demolished in order to find the best resources for the future project. It can also be to carefully design for easy refurbishing and disassembly. Both of these moments in the architects' job for instance, require a higher effort than just following the linear order of construction.

Architects can't just design for aesthetics, they have to change and to adapt the whole design process instead. It is however harder to implement this for existing and currently practicing architects than for future architects being formed today with these circular methods already in mind. Hopefully, the architects of tomorrow will have learned from the start to design in a circular way, respecting the separation of the shearing layers and the R-strategies in terms of the material they choose.

Lessons Learned

For all of us it was the first time working with a Circular Design Atlas. During this project we faced some challenges and learned different lessons.

By separating the shearing layers of the building, according to Stewart Brand's diagram, we were able to get a better understanding of the lifecycle duration per layer. In general, we think that the layers of our case-study Fort V, are experiencing a quite long lifespan, especially the site, a former military hangar which has been re-used as a covering for the new building. Except for technical services, all other layers will last for a longer time than 30 years which makes this building relatively sustainable.

Also, the use of the material pyramid is something new to us. We can imagine using this handy tool to calculate the CO2 emissions of the materials to use in our own designs. In the case of Fort V, we think that the architects have been carefully selecting materials with a very low CO2 emission. This is translated into the results of the material pyramid. In addition, the use of a CO2 negative material like hempcrete inspires us to consider designing with similar materials ourselves. Mapping the building material origin gave us a better understanding of the divergent sources of materials being used in a project. In case of Fort V we believe that the choice of the architects of choosing materials in the nearby area of the building site reduced the CO2 emissions caused by transportation of those materials. Even though BC Architects seems to be a company that values circular aspects it was still very hard to find informations about where they obtained everything from. For instance, we had trouble finding information about both the hempcrete and cement via the architects website.

The need of making the switch from a linear to a circular building economy is clear to us since the introduction of the R-strategies. For example the word re-cycle sounds very sustainable. In practice re-use responds much better on the need for a circular building economy. Also, our case-study of Fort V is responding on the need for a circular building economy. For example the compressed earth blocks can be fully re-used when the lifespan of the building will be ended.

In the case-study of Fort V, the NEW Nexus Approach is a part we have been struggling with. There has been a lack of local resources used to operate the building in a circular way. We suggested some opportunities to provide a more circular approach in case of renovating the building in the

future. Solar panels and the use of water locally will save a lot of CO2 emissions during the operation of the building.

There are multiple design approaches which can be used, such as design for adaptability, longevity and disassembly. BC Architects mainly focused on minimizing the CO2 impact of the building. They didn't do it by recycling materials but instead by using local materials which can be easily re-used in the future. After the life span of the building it should be possible to disassemble most of the building materials. Therefore we think that the main design approach should be design for disassembly. Also, this building can be considered as a preview to push the industry forward.

After all, we have learned that a circular design asks for a different approach by the architects in the cooperation with many different kinds of stakeholders. They are now at the core of most of the decisions regarding the building elements, materials and details. They have to focus on all circular aspects of the designed buildings in close relation with manufacturers, builders, contractors and engineers.

In conclusion, the use of the Circular Design Atlas helped us to better understand circularity in the case-study of Fort V. It gave us many insights in the possibilities of circularity and it showed us that circularity is nowadays not being used as a standard starting point during the design and production of a building. We think that the next generation of architects has the opportunity to make the transition to a more circular building environment.

Colophon

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