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City as Material Bank – Constructing with Reuse in Musicon, Roskilde

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Abstract. Roughly 90% of building materials for an 880sqm construction project were made from reused material components, existing structures and old shipping containers, and designed for disassembly. The paper is a case study that introduces the implementation of reuse in the project, a recently completed transformation of *Hal7*, a former industrial building. Two other undergoing projects are also introduced. These have not yet been completed but contain reused materials at the current stages, a series of *Recycling Centers* and the housing project *Indfaldet*. All three projects are part of the urban development of a former industrial area. Selected themes and courses of events are summarized from interviews with the project architects to list particular conditions in these cases with successfully implemented circular ambitions. End-user engagement is introduced to highlight a method to prioritise when maintaining a low budget. It is the argument that the city, represented by an individual employee, plays a central role to catalyse the implementation of reused materials and circular economy in construction. The city can guide to local resources to be mined, as well as provide the facilities and organization to handle the logistical issues when resources go from being waste to be built-in.

Keywords: Reuse, implementation, reversibility, collaboration, architecture, construction

1. Introduction

The projects introduced in this paper demonstrate that it is possible to design for reversibility and to apply roughly 90% of reuse in a built project with a very limited budget. The paper summarizes some organizational and human factors that have been present in the case that was constructed in Musicon, a 250,000m² mixed-use district being developed on the grounds of a former concrete element factory in Roskilde, Denmark. The projects in the paper are all by Vandkunsten Architects who has several recent and ongoing commissions there including: the latest *master plan* of building plots 5 and 6, the transformation of *Hal7* that has recently been completed [1], a mapping of specific materials and components for potential mining on the former factory grounds; architectural investigations of



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potential use of reused materials for *14 Recycling Centres* [2] that is currently put out to turnkey design competition; and currently two housing projects, including *Indfaldet* [3] that is in pre-tender.

Hal7 is the case study of the paper with emphasis on the implementation of reused materials in an architectural practice. The case study is introduced in detail, followed by an analysis of events and an interim conclusion. *Recycling Centres* and *Indfaldet*, the two undergoing projects, are introduced and discussed. Following the conclusion of the paper, the perspectives of the practical experiences are discussed.

The paper is based on qualitative methods by interviewing the project architects who has also provided the figures used. Based on these interviews, it will be argued that city administrators have an unprecedented role as a driver in the implementation of circular economy in construction.

1.1. Action research at Vandkunsten Architects

The Danish architecture firm of 80 employees has activities within all aspects of an architectural practice ranging in scale between city planning, cultural and commercial, residential, renovation and transformation, and landscape projects. The paper discusses elements of a central agenda of the company's concerning the cultural value of resources. Projects that have inspired or directly led to the cases in this paper range between educational studies, research and development projects, and commercial assignments thus reflecting the action research and development practice at Vandkunsten Architects. Here, development is done in part through built projects and commercial assignments, and in part by research and development. For the firm, each project provides qualitative or quantitative evidence, reflections, visualizations, and built work that assists as evidence to assure future clients of several layers of experience, competences, and visions.

2. Case - Hal7 Transformation in Musicon

The project is the transformation of an unheated former industry warehouse to accommodate a mixed group of users and activities: the Orange Maker Space that is an offspring of the well-established Roskilde Festival; a youth maker space; and the Makers' Corner which is a city-run meeting place and activity for mentally vulnerable citizens of all ages. The project had a limited budget of €900/m² for the refurbishment of the 880 m² area and following a €791,000 donation. The tenant organizations have a tentative lease of 10 years. Hence, the concept was developed for the elements to be disassembled and reassembled on location or elsewhere when spatial requirements changes or the lease is not renewed.

2.1. Repurposed Shipping Containers

Repurposing shipping containers were a premise of the project. Some containers were already in use on the previous location of the Orange Maker Space and this inspired the city to commission the architects based on their experience with discarded shipping containers. The architects had previously developed and tested housing concepts in full-scale for repurposing discarded containers for *CPH Shelter* [4], a Copenhagen start-up with the vision to develop temporary student villages in urban 'perspective lots' that are centrally located dormant lots. The start-up worked actively with legislators and 10-year leases to temporary student villages have since been allowed in the national planning act. The first CPH Village is near completion in Copenhagen.

2.2. Design and construction of Hal7

To minimize the expenses for construction as well as maximize the comfort of using the facility, a concept was developed with a division of activities based on their noise levels and four climate zones as illustrated in figure 1. The design process went through iterations with end-user feedback. The architects made a principle layout, which formed the framework for a series of end-user workshops. These then formed the disposition of zones for various activities and the plan layout illustrated in figure 2.

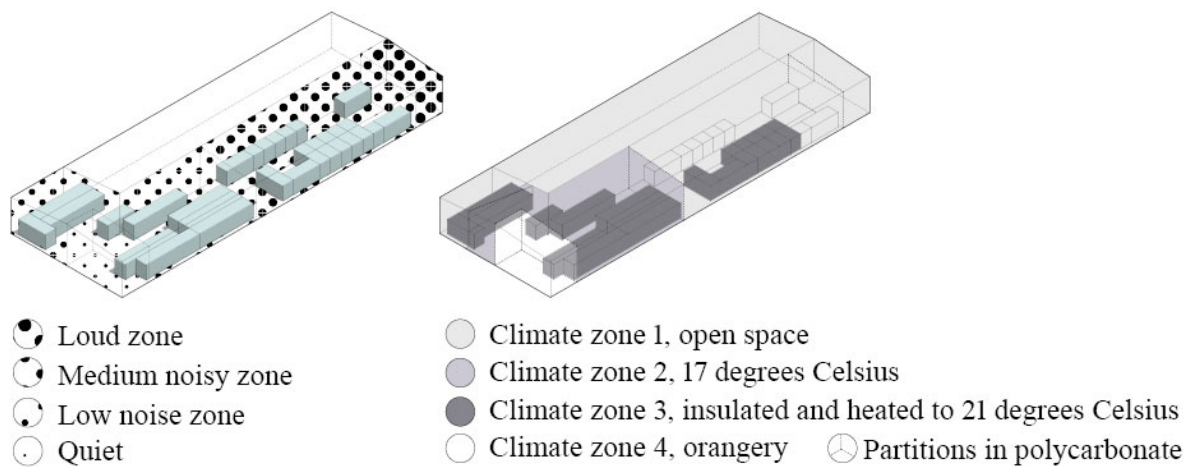


Figure 1. Zoning diagrams of Hal7

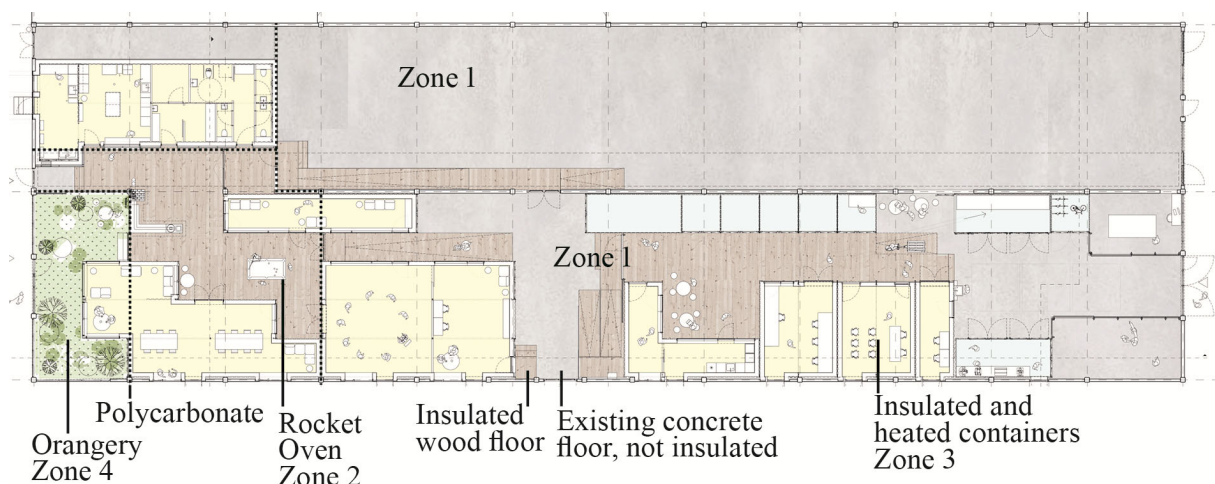


Figure 2. Plan of Hal7 with climate zones

2.3. Four climate zones

Zone 1 is uninsulated and unheated, for active use such as playing games or working in the workshop, illustrated in figure 3. The space was cleaned and fitted with equipment and tools for a Maker Space such as power tools, CNC-routers, and table saws. Zone 2 is defined by its heat source, a large low-tech rocket oven shown in figure 3. Here the heat is led by the oven, through a pipe under a bench to a chimney. This element is central to the space and its use. The zone has not additional insulation besides a raised and insulated wooden floor. Polycarbonate panel partitions separate climate zone 2 from the rest of the hall as seen in figure 3 and 4. Zone 3 is heated for a comfort temperature of 21 degrees and it is comprised by a number of shipping containers that can be seen in figures 3, 4, and 6. To maintain the exterior container aesthetics, each unit has been reinsulated with paper-granulate on the interior and fitted with central heating. Zone 4 is the orangery, seen in figures 5 and 7, has facades of polycarbonate and windows accommodate passive solar heating. Containers are accessed from a raised insulated floor.



Figure 3. Flooring, partition, and containers



Figure 4. Users gather around the rocket oven in zone 2



Figure 5. Corner facade of Orangery



Figure 6 Containers on an insulated plinth in Zone 1



Fig. 7 Zone 4, Orangery

2.4. Construction process of Hal7

The final design and construction of interior and exterior facades and structures has been an iterative process in which the architect would produce principle compositional drawings for the refurbishment. It was included in the tender that reused materials were acceptable. In practice, the contractor would source material components fitting the principle and the architect would then finish the design and refine the drawings based on the available component. The contractors have then developed special solutions and reversible construction details on site and in collaboration with the architect.

2.5. The level of reuse in Hal7

The industry building was an existing, unheated structure, with a 1600 m² concrete floor which has been reused. All containers were discarded shipping containers, of which 10 were reused a second time because they had been used by the makers in a previous location. All added windows were reused, and some of the doors. The wood flooring has been sourced from a sports hall renovation.

New materials include paper-granulate insulation for the floors and containers, the polycarbonate partition walls, plywood lining for the containers, the wooden structures supporting the containers, the raised floor, and the polycarbonate walls. In total, the amount of reuse can be assessed roughly to 90% of the project.

2.6. Analysis of the Hal7 Case

The architectural nature of Hal7 can be described as contemporary vernacular design based on local needs, availability of construction materials and reflecting traditions and skills of local builders. It is our experience that a new vernacular aesthetics of available resources is the core of the concept of *rebeauty* defined in [5] as the “open-minded and continuous search for beauty through new use and

new compositions of sourced materials and components in reversible architecture.” to push modernist appreciation of ‘newness’. The orangery and the rocket oven are two examples of old technologies that are looked upon anew. While the use of the sun in such a winter garden is well-known and was a popular element in energy efficient architecture in the 1990s, such as Vandkunsten’s building Økohus99 [6], the rocket oven is a social as well as low tech aspect of the Zone 2. Users gather physically around the heat source and consequently sit close together.

The (re)introduction of climate zones in buildings will minimize the cost of operation. It calls for a more engaged user who must bring an extra sweater and sit closer to others around a heat source, and so on. This mode of active and adaptive use fits well with the entrepreneurial spirit of the space and it.

The construction process of *Hal7* construction has been described by the architect as based on trust that had to go be mutual to acknowledge the effort and intention at both parties. The iterative process has been time consuming far beyond a conventional project as well as beyond the fee and the architect suggests that neither have entered the assignment with a goal of profit. Each has spent many hours to fit the budget as well as to fulfil the ambition of reuse and reversible construction.

2.7. Interim Conclusion

Roughly 90% of materials in the project were reused components and the *Hal7* building is proof that it is possible to build a custom designed space with a highly social profile and with a very limited budget. Traditional qualities in construction such as craftsmanship, collaboration, creativity, and trust appear to be the important driver as well as the benefit of pushing frontiers in construction. The project could not have been built if one party had acted conventionally.

So-called small or temporary projects appear to be optimal for testing Design for disassembly and assessing whether the solutions are in fact in a state to be reassembled and reused.

3. Undergoing Project - Recycling Centers in Musicon

When developing the master plan for Musicon in 2016, the architects at Vandkunsten placed 14 asked-for recycling stations. Around the same time the office finished the research and development project Nordic Built Component Reuse (NBCR) [7], which documented value in reuse material systems in terms of culture, economy and energy. Part of that project included 1:1 material prototypes and the report includes visualizations of a recycling station [8]. Figures 8 and 9 show how old roof tiles, ventilation ducts, windows, and metal sheets are used a cladding in a series of small structures. A similar concept for recycling stations was introduced to the Musicon planners through another student project affiliated with NBCR visualizing such architecture constructed using discarded materials from the local area in order to inject local culture and history in the new district.



Figure 8. Material recycle centers could look similar to this visualization of the structural principle with facades from glazing and pan tiles



Figure 9. Visualization of variations in scale and materiality. Pan tiles, concrete, and metal sheets

3.1. Mapping of local materials

As part of the following concept development, the architects were commissioned to map the local area for material mining in a report suggesting which material components to keep, from which local buildings, and for which potential applications. In the collaboration with the city project manager, 'Gunilla' has worked actively to deliver materials for the project and suggested tiles sourced from a specific local building ready for demolition. While the quality of materials did not have a quality fit for purpose, roof tiles are likely to be sourced from a local roof renovation where roof tiles are discarded. Furthermore, the city has suggested empty facilities to store sourced materials to be reused instead of down cycled. Local labour will be used to source and administer the materials.

3.2. Construction of the Recycling Stations

The concepts and urban mining maps for the small recycling stations have been developed by the architects. The mining report and sourced materials form part of the competition brief as the final design and construction of all of the 14 reuse centres have been bid out to a turnkey design competition.

3.3. Discussion of the Recycling Station project

It is the experience that this introduction of visual and tangible architectural references have impacted the city similarly as would have a built example. It is the experience that the city is in fact represented by 'Gunilla', an individual who has been key to involve city resources and to go out of her way to achieve change. Still uncertainty prevails of the possible economic result of the scenario in which materials are saved.

The city has mapped and mined materials and components with a potential for reuse. Also providing storage for the components prior to potential reuse and including them in the tender, lays the foundation for a circular economy the city as material bank.

4. Undergoing Project – Indfaldet in Musicon

Indfaldet is a housing project in the detailing stages pre-tender, which was won in a turnkey team and with the client's right to purchase the lot from the city of Roskilde. It consists of apartments and terraced housing in six rows of low-rise buildings in 2-3 storeys. Reused materials were proposed by the architects as part of the façade as illustrated in figures 10-13.

The city is represented by 'Gunilla' (again) in a new position as project manager for the Musicon development. In order to achieve a joint understanding and vision for the expression of four neighbouring projects in the master plan, an unconventional activity has been a series of city-led workshops that included all the construction teams (turn-key contractor, architects and client) for each of four neighbouring building projects. The contractor of *Indfaldet* expressed to agree to our proposal of reuse in the project. With two projects among the four, the Vandkunsten architects had a mutual understanding. This proved more challenging for the remaining of the group. The workshop process resulted in the local plan for the area, which includes the term eclectic facades.



Figure 10. Visualization showing reused materials that embellish the ground floor façade. The project has single story flats below and terraced housing above.

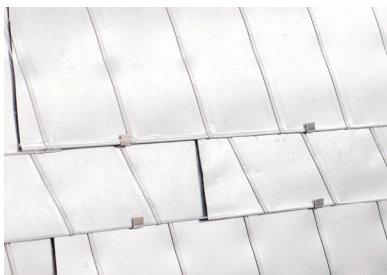


Figure 11. 1:1 mock-up of steel facade designed for disassembly (dfd) from reused ventilation ducts. [7]

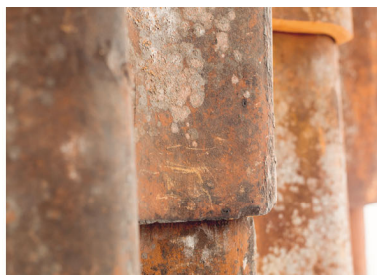


Figure 12. 1:1 mock-up of facade cladding from reused pan tiles and dff. [7]



Figure 13. 1:1 mock-up of steel facade from reused sheet metal and dff. [7]

4.1. Discussion of Indfaldet

It is still too early to make any conclusions until the project has been built. Yet it can be highlighted that the city-led workshop with construction partners has been key to the contractor's agreement to use pre-used materials for facades. It was the experience of the architect that the contractor appeared more accommodating and ambitious in front of city officials and agreed at an early stage to using reused materials, something that would traditionally be very difficult to achieve by the architect alone.

It appears to strengthen the potential of repurposed facades in *Indfaldet* that the series of local *Recycling Centers* will also feature reused materials.

5. Conclusion

By introducing aspects of reuse and the role of the city in the case and two undergoing projects, it can be concluded that it is possible to build with a very high level of reuse and reversible construction at a very tight budget. Also, it has been highlighted that how city plays a practical and central role in the implementation of reusing materials and circular economy in construction. Based on the role of 'Gunilla' who is central to all Musicon projects in this paper, the initial ambition of reuse expressed in the planning stages appear to be followed through in construction when city planners follow projects from a planning stage to an implementation stage. The city has actively mapped and mined materials and components with a potential for reuse. When also providing storage facilities for the components prior to potential reuse and including them in the tender, the city of Roskilde has laid the foundation for a circular economy and for the city as material bank.

6. Discussion

The case highlights that successful projects may be carried through city administrations by the approaches and efforts by individual officials. Through key employees cities have an unprecedented opportunity to make the projects happen that will lead the way for circular economy in construction. With a demographic movement from rural to urban, cities worldwide grow in area, in population and

in density cities can exchange knowledge on how to maintain their resources in-city as their own material bank. It is our experience that it takes dedicated representatives of the city administration to make things happen, and that such individual representatives are equally as important as grand city slogans.

This paper's analysis of positive factors leading to circular construction is limited by the informal way of gathering information as well as focusing on the project architects. The factors that are seen here as mainly positive will be nuanced by adding the course of events as experienced by the city, the clients, and the contractors. Future work could include more actors and more formalized assessment of positive factors leading to implementation of circular approaches. It could also map the motivational factors that drive circular first movers and investigate a hypothesis expressed by the project architect that short-term profit is not the driver for the first generation of circular projects.

Modern headlines for sustainability are classical Vitruvan virtues that architects traditionally pursue for all projects as achieving architectural quality is a constant aim – and building buildings that are resilient – in terms of technical, aesthetical, and cultural quality.

6.1. Temporary projects as a city tool to implement DfD

The reversibility of the Hal7 design will be tested in practice if the space is adapted to changing needs by disassembly and reassembly of elements, or when the lease comes to an end and the entire space is dismantled. It is in their nature for temporary structures to have a limited lifespan. Thus, temporary projects are optimal for implementing Design for disassembly in practice and assessing whether the solutions are in fact in a state to be reassembled and reused. Consequently, if cities take the opportunity to demand reversible construction at the smallest and most temporary scales, they can be drivers of the circular economy.

6.2. The city as material bank

As highlighted in the paper, the city is represented by individual employees who appear to be essential in the development of new circular practices. With an engaged city official such as 'Gunilla', any city could be viewed and used as a material bank to preserve resource assets of culture, energy, and economy.

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