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OVERCOMING OBSOLESCENCE: A CASE STUDY RENOVATION BUILDING - IDEAS ON REUSE IN PLANNING AND BUILDING PROCESS

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Abstract

In the context of sustainable buildings, closing lifecycle loops is ever more important. Energy efficiency in the use stage has long been the primary focus of these efforts. Recycling and reuse of building components that influence resource efficiency represent the next steps.

This paper presents a renovation building case study. With a main focus on planning instruments and managing reuse and recycling of existing buildings and their structural features, the methods and practicalities of a building's end-of-life stage are discussed in reference to the case study building. This exemplary residential renovation building demonstrates how recycling and reuse of building components could be planned, managed and implemented.

It first describes the existing building and the starting position. Then the planning process and the building process are explained. It details how much material was disposed of and which components were involved. Beside material itself also the pollutant content in different material types were monitored. Critical questions arise from the quality of the material. The planning process focused on how to influence a building's design in terms of easy recyclability and reasonable end-of-life scenarios. In a next step, practical implementation of reused material and components are outlined for the case study. In this example, reuse was possible for wooden flooring, tiles, sockets and switches, staircases, doors and handles, as well as energy recovery for all wooden material. Results also show under which premises material could be reused and which advantages and disadvantages arose from reuse decisions.

Keywords:

End-of-life; reuse; recycling; material flow; timber structures; lifecycle

1 INTRODUCTION

In the context of sustainable buildings, closing lifecycle loops is ever more important. In the building sector, energy efficiency in the use stage has long been the primary focus. Considering the division of lifecycle in stages according to EN 15978 [1], the focal point of the use stage has been on high-energy performance. In current building practice, highly insulated buildings with efficient building facilities are state of the art. In the product stage, energy consumption and emissions can be restricted through elaborate material choice. The end-of-life stage can be influenced by material choice and deconstruction options. It is linked to material in the product stage and can mainly be triggered through considerations made during the planning process at the beginning of projects. For building renovations, this process is more difficult and needs a sophisticated approach. Here preliminary studies of the existing building are necessary (material, toxic substances, fire regulations, load bearing capacity). Additionally, the question of demolition and rebuilding, or otherwise renovating requires careful consideration. Results vary strongly depending on building types and the need to preserve listed buildings. No general conclusions can be made on renovation or demolition/rebuilding. The general condition of the building, reuse opportunities, and time and money constraints demand careful consideration in each case.

Therefore, this paper explains ideas on reuse based on an exemplary case study building.

Recycling and reusing building components influence resource efficiency. In this paper, resource efficiency is synonymously used for

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efficient use of building material and is not defined according to the broad explanation of, for example, VDI [2]. Building components and structural elements can be separated and recycled in a controlled deconstruction process. By applying the Strategy for Resource Efficient Europe [3], accurate recycling, clearance of toxic substances, and lower waste accumulation, the environment and the resources can notably be preserved.

2 END OF LIFE OF BUILDINGS

This paper discusses the practicalities of a building's end-of-life stage with a focus on an existing building and its structures to overcome obsolescence. The explanations are broken down in:

- (i) Planning process: for renovation projects, in the first place, ideas for reuse and enhancement of the building are relevant. Questions arise from the aspired energetic standard, user requirements and possible new building uses.
- (ii) Managing reuse of buildings and their constructions: For renovation, the removal and disposal of construction waste, their amount, the cost, and possible toxic substance contamination are relevant factors.
- (iii) Reusing building materials: It explains how the reuse of building components was planned, managed, and implemented in a realized renovation of an exemplary inner-city residential building.

The paper explains the approach to the building's renovation and extension, in which considerations regarding how to achieve a sustainable solution played a leading role. This case study was built in Munich in 2013-2014, in a conservation area with high pressure on increasing residential living space.

3 CASE STUDY RENOVATION BUILDING

The initial building was a 3-story mixed-use building with a ground-floor shop and two small flats on the upper floors. The second floor was added at the end of the 1940s (postwar area) using very simple construction methods and a restricted choice of materials. Building facilities had not been renovated since the last interior renovations took place in the 1970s. The entrance to the building was located within a 2m-wide gap between the buildings. Due to its location in a conservation area, the extent of alteration to the façade and the height of the building were restricted. The maximal possible extension of the building could be achieved through loft conversion by lifting the cullies by 0,5m and closing the gap between buildings.

3.1 Planning process

Fig. 1: Existing building: street view and existing gap between buildings.

Figure 1 shows the then existing building with the narrow gap to the adjacent building. Different options were discussed during the planning phase, including renovating the existing house, renovating the ground and first floor, renewing second floor and roof, and closing of the gap to change the entrance situation and enlarge size of flats with the additional advantage of reducing façade to exterior. Complete demolition and rebuilding was not an option due to conservation area restraints.

Alongside the total renovation of the building, including replacing all windows and building facilities, closing the gap between the buildings with energy efficient façade over three stories and extending living space circa 35 m² was defined as minimum. Because toxic substances were found in the flooring of the ground floor, complete extraction and new ground floor slab with insulation were necessary.

Alternative planning scenarios included completely renewing the second floor and roof and extending the living area by about 35 m² (V0), or only renovating the building with a new, insulated roof (V1). Both scenarios were calculated to reach the same energetic level of 75 kWh/m²a. For scenario V0, an additional idea was rebuilding the two new stories with as much renewable material as possible and with an end-of-life concept in mind that permitted the reuse of sorted material. Therefore, structural elements were planned as cross laminated timber.

Figure 2 shows the results of lifecycle analysis calculations over 50 years per m² living space for erection, operation, and end-of-life. The calculations [4] were made according to the standard German sustainability assessment scheme BNB [5], ökobaudat 2011, and with program Legep. The green line shows the no-renovation scenario. Here, GHG emissions in operation exceed the renovation options within few years. Additional living area and the use of construction material with low GHG emissions (timber) give scenario V0 a slight advantage over

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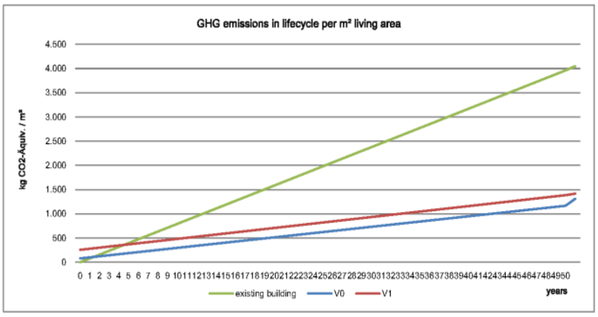

Fig. 2: GHG emissions of different scenarios in lifecycle per m² living area.

V1. The steep increase of emissions in V0 at the end-of-life originates from energy recovery of the timber and thereby produced GHG emissions.

Scenario V0 was ultimately built and all further remarks in this paper are based on that scenario. Lifecycle analysis assisted in deciding on the most favourable scenario.

3.2 Demolition process

Scenario V0 meant demolishing the second floor, chimney, and roof, completely replacing the floor slab (ground floor), demolishing concrete pavement in gap between buildings, and renewing the sewage inspection chamber. Due to current fire regulations and improvements in sound protection only structural elements remained on the first floor. During building work, the plaster quality was discovered to be very poor, meaning it also had to be replaced. All demolition material was calculated according to bills of quantities and is summarized in Table 1 – divided in different material types. The means of disposal are also shown.

Tests on potentially toxic substances were conducted and results showed high contamination of PAH in materials used in ground floor construction. It was not an option to leave toxic substances in the building and these materials had to be extracted under high security and adherence to health and safety measures.

Although the material mass of extracted toxic material was relatively small, expenses accounted for 33% of total demolition cost. Table 1 shows the percentage of cost for each type of material compared to total demolition cost. Costs were calculated by exact bills of companies and include costs of labour, containers, and waste disposal.

Material output			disposal	% of total demolition cost
Demolition waste	114,70	T	(1)	44
Soil excavation	34,60	T	(1)	20
Timber	9,42	T	(2)	0
Steel sheet	0,75	T	(3)	3
Toxic substances	10,5 (12,9	m³ T)	(4)	33

With (1) building debris dump, (2) incineration with energy recovery, (3) special sorting, then recycling, (4) special treatment by waste management

Tab. 1: Extracted demolition material calculated with bills of quantities.

3.3 Managing reuse of buildings and their constructions

As the author was part of the planning team, detailed insight into the process can be provided. The main design idea was not only to conserve the atmosphere of the existing building, but also to upgrade it to current standards. Aim of the renovation was to reuse as much extracted material as possible.

In this case study, reuse of wooden flooring, tiles, sockets and switches, staircases, internal doors, and handles was possible, as well as, on the waste management side, energy recovery for all wooden material. Windows were in poor condition and could not be renovated. Nearly half of the wooden flooring could be reused for window benches and interior works. As the floorboards had been painted several times, some work was needed to strip the paint. Additionally, it took time to find a carpenter who would agree to reuse material rather than introduce only new material. The interior doors and door-frames were removed and stored offsite. They were later remounted, sanded, and painted. Style-appropriate door handles and window handles were also mounted. All handles were relocated from other demolished buildings. The old wooden staircase only needed some cleaning and amendment. Sockets and switches were also collected from various other buildings. They needed to be completely cleaned and inspected, before being mounted again throughout the building. An open-minded electrician with a passion for environmental issues enabled this reuse. This, however, meant that labour time to install them increased and completely negated the saved material cost. Interestingly, 12mm thick tiles from the last renovation (end of the 1940s) could, due to their thickness, be removed and cleaned of cement quite easily without much damage. Only one third broke or could not be reused. All intact tiles were

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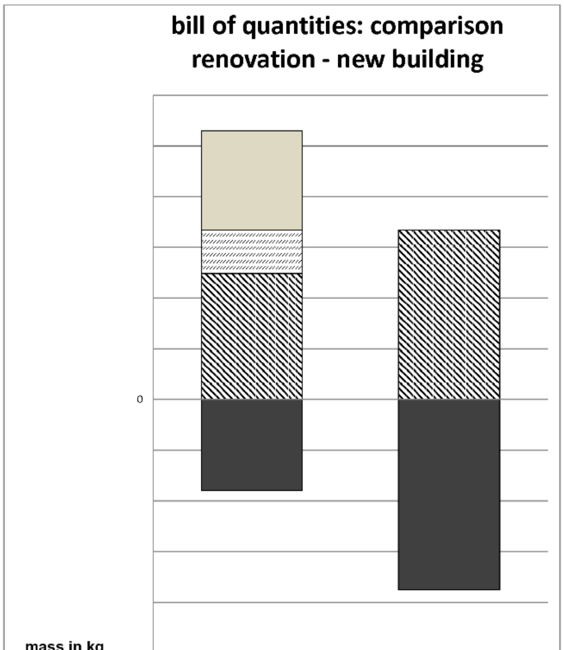
mounted after proper cleaning and are now an interesting feature of the building.

All wooden building material from the roof and floors was set aside for energetic recovery. As most of the wooden roof material had been treated with chemical wood protection, energetic recovery was therefore the only option.

In general, only a small part of the building material could be incorporated in a second lifecycle. In all cases of reuse, additional labour was necessary to renovate the extracted material. Thus, additional labour costs negated saved material costs. Especially for private clients, however, such an approach could offer an interesting option for on-site self-work and integrating do-it-yourself practices.

Figure 3 shows the bill of quantities for the renovation building (left) and material output and input for a fictional new building, that in addition to



	renovation	new building
material output	-179.799	-375700
material stock	195.901	
material input extension	85.764	
material input	248.144	333908

Fig. 3: Bill of quantities: Comparison renovation new building.

much higher amount of demolition waste, would also require a higher material input. This amount of demolition waste and new building material needs to be considered, when deciding on the most favourable option. In case of resource efficiency, renovation generally proves most favourable.

3.4 Material concept of renovation building

The planning target was to reuse as much material as possible. This also meant that it was important to focus on easy recyclability and possible correctly sorted reconstruction in detailing the new construction. During the planning process, the following questions arose: Is the construction easy to redo and can material types be separated completely. Are chemicals in paint and/or glues introduced? Can construction layers be omitted?

Regarding the material concept, the structural elements for the second floor and roof are made of CLT, and were neither further cladded with gypsum board nor painted. All the floors in the house are made of cement screed and are only embedded with sodium silicate. At the end-of-life stage, screed must first be crushed, and then chipped and sorted by an air pressure machine, whereby light parts (plastic tubes of floor heating) are sorted. Plasterboard was only used for vertical shafts (fire regulations) and necessary horizontal front-wall installation in bathrooms. The main focus for all building facilities was on realizing short routes and compact construction. Only the minimum necessary equipment was used: gas calorific value boiler for heating and warm water, and ventilation with heat recovery.

New construction to close the gap between the buildings consists of concrete wall (requirement for fire safety), internal prefabricated concrete staircases, and large triple-glassed windows with wood-aluminium frames on both façades. Windows facing the street were designed as wooden frames in historic style.

Fig. 4: Street view of renovated building.

Connections were optimized through focusing on low material consumption. For example, interior doors were fixed directly in the CLT walls without extra wooden doorframes. This was possible due to the high precision of CLT prefabricated walls. Thereby the decision was taken that no door sealing was to be used, which then resulted in a lower sound protection standard. However, given required air-gap ventilation, doors here couldn’t have been sound protective anyway. Such small adjustments helped in rethinking material consumption and desired standards.

During the planning process, end-of-life options and demolition process were also discussed. Set parameters for material were: (i) check material input on toxic substances (here paint, glue, etc.);

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Fig. 5: View from inside (loft extension) showing reduced material concept.

(ii) use only a small variety of materials; (iii) rethink construction, especially joints. This delivered a reduced material concept using as much non-treated material as possible. For example, frames for doors were left out as the hocks also could be connected to the wooden walls. The wooden construction is only fixed by easily replaceable screws and steel brackets. Only the insulation of exterior façades (wooden soft fibre board) is inseparably connected to rendering.

4 RESULT

4.1 General

The renovation project made it possible to extend the living area of the upper flat from 45 to nearly 120 m². Presently, a four person family and couple (first floor flat) inhabit the house.

Rethinking the design process by paying careful attention to demolition and sorting accuracy strengthened the design concept of reducing material selection and material consumption.

The paper shows the demolition material flows of the building. The input material was additionally calculated and compared to a new erection. All building facilities had to be renewed. As these building facilities are essential for long usage of building, their renewal helps to extend the service life of the building.

4.2 Material

When planning a renovation, early investigation of toxic substances is necessary in order to decide on reasonable options. Demolition may be the most favourable option if toxicity is too high. The reuse of extracted material could also be a design principle. To realize this, however, extra labour time is required to extract reusable material carefully and to find ways to store it properly for the intermediate period. The reuse of material adds quality to renovation and makes it incomparable to standard buildings. For the described building, the owner and visitors perceive it as an advantage of the building. On the other hand, the careful extraction of material and reuse demands good preparation, labour time, and good craftsmen. This eventually adds to the costs and overturns the saved material expenses. Good quality craftsmanship, however, reduces cost in the long run (repair, maintenance, quality of detailing).

One example presented here were electrical sockets and the work of electricians. As most of the sockets and switches were reused, no cost was accrued for these technical parts. However, the labour required for mounting these items nearly

Fig. 6: view from inside showing material concept.

doubled as the mounting was more expensive, as two screws were always needed instead of one. The final cost of this part of electric renovation was in the end the same as using new sockets. Figure 6 shows the reuse of tiles (green) in a new context alongside additional tiles (white). Reuse of tiles was possible because of limited breakage due their thickness and careful extraction. Wood used as construction material can be reused after demolition as CLT parts for floors and still have a reasonable size and complete disassembly is possible. This can be achieved by unscrewing building parts, extracting cellulose insulation, removing floor screed, and sound protection. Only when reuse is not possible should energy recovery be an option. For the case study building, current construction drawings of building parts exist (as built) in addition a material list that are helpful for end-of-life considerations.

5 DISCUSSION

Overall results for the case study can be outlined as follows: From a design perspective, reuse is an interesting issue and could help to showcase

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individuality of projects. Reuse of building material needs sensitive craftsmen with interest in that sort of work. Only a small selection of building parts could be reused on an economically efficient basis.

Reuse of buildings always maintains the existing load bearing structure. Amendments needed to be realized for additional loft conversion in compliance with fire regulations and sound protection. In considering renovation as an option, required standards mandate critical assessment.

The issue of grey energy and resource efficiency preservation is the most adventurous procedure.

“Re-building” requires extra examination and discussion from the architectural side. It demands a higher planning effort. On the other hand, exactly this effort is a creativity engine in terms of design solutions that would not have been considered without the building stock. Material discussions could be an interesting issue to create individual solutions that, on the environmental side, incorporate end-of-life options into the design process.

6 CONCLUSION

The documentation of the case study showed an environmentally friendly renovation of an existing building with energetic upgrading to overcome obsolescence. A precise investigation of the building, which included investigations on pollutant content of material, was necessary. This emission control adds strongly to the cost. The reuse of building materials was possible for wooden flooring, tiles, sockets, switches, staircases, and internal doors. The environmental advantage of reused material was not accompanied by economic advantages. Rethinking construction detailing can help to optimize the construction. From this case study general results are transferable to other cases with a focus on reuse:

- Exact investigations on the existing structure, material qualities, and pollutant content in building constructions is necessary.
- Additional costs through reuse of building material in terms of disassembly and labour time are incurred. Here, environmental advantages still outweigh economic advantages.
- Building process on site and positive input and willingness from craftsmen are necessary to achieve good results.
- Construction details need to be discussed in the light of reduction of layers under compliance with building codes.

Generally, the focus of new construction needs to be on easy disassembly, sorted parting, and high reusability or recyclability. It is important to avoid material with pollutant content. In this case, this was achieved through timber walls and roof. To use these parameters as design principals is not new [6], but there are only few examples in literature which describe the entire implementation process. The described case study is one of them.

Resource efficiency in building sector needs to also focus on the reuse and renovation of buildings. As the existing building stock has already carries environmental burdens, demolition and rebuilding must only be an option when pollutant content is too high or reuse is impossible. To overcome obsolescence of buildings the renovation is a second chance for the building stock which contributes to reduced mass flow as only part of the material needs to be demolished. In case of new buildings resource efficiency on material side must include demolition of the old building, thereby accounting for mass flow for both demolition and new building.

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