Energy Conservation vs. Heritage Conservation:

Evaluating Thermal Rehabilitation Scenarios by the Case Study of Terrassenhaussiedlung Graz

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Abstract. Both, energy conservation and heritage conservation are declared goals of the European Union and the Austrian government. In the case of historic landmark buildings, these ambitions conflict with and sometimes even exclude each other. At the same time the public interest of conservation often collides with the private interests of the owners and inhabitants. The present paper addresses these conflicts of interest by the case study of Terrassenhaussiedlung Graz - a late Modernist housing estate in Graz, Austria, and a rare example of Brutalism and Structuralism in this country. Three potential thermal rehabilitation scenarios are being proposed and further investigated: Interior insulation, exterior insulation and the replacement of non-structural elements. These strategies are evaluated and discussed in terms of their impact on energy efficiency, building physics, architectural appearance and their practicability. The paper shows a work in progress and seeks the discussion with the audience. It poses the question of how far energy conservation measures can go in a culturally valuable building complex and of how much heritage conservation is appropriate for a sustainable housing estate.

1. INTRODUCTION

1.1. Background

The appropriate way of refurbishing historically valuable post-war building stock is a topic of growing urgency. Being built with little regards to energy efficiency and making up for about 40% of Austria's building stock,[1] thermal rehabilitation of these buildings plays a key role in reducing overall energy demand and reaching EU's ambitious 2030 climate goals.[2]
Many of these buildings are historically and architecturally valuable, but in spite of recent initiatives, such as *SOSBrutalism*, not under heritage protection.[3] Such buildings are under particular thread to get disfigured by inappropriate retrofitting methods, as has already happened to many architectural monuments so far.[4]
A recent special issue of the *Journal of Architectural Conservation*, dedicated to the preservation of post-war building stock, underlines the actuality of this topic.[5]

1.2. Aims

This paper builds upon the results of the exploratory study *Smarte Modernisierung Terrassenhaussiedlung – SONTE*,[6] funded by the *Climate and Energy Fund*, Austria[7] and led by the *Institute of Housing Research*, Graz.[8] This study was carried out by an interdisciplinary team, including the author of this paper, with the participatory involvement of residents of the estate and had the goal to develop a general guideline for assessing the modernisation possibilities of participatory inventory designed residential buildings.
Striving for an appropriate refurbishment strategy that lowers the energy demand significantly, respects the cultural significance of the buildings and allows a gradual rehabilitation of the estate, three potential thermal rehabilitation scenarios for Terrassenhaussiedlung Graz were proposed and further investigated.[9]
The present paper evaluates these refurbishment strategies in terms of energy efficiency, building physics, architectural appearance and practicability.

1.3. Terrassenhaussiedlung Graz

Terrassenhaussiedlung Graz was envisioned and planned by the Graz based architects of *Werkgruppe Graz*.[10] Planned in the mid 60ies and realized in the 70ies, it was one of the first large-scale housing projects in Austria to apply user participation in the planning process.[11] With its modular structure and large exposed concrete surfaces, it combines elements of Structuralism and Brutalism and is a prime example of late modernist architecture in Austria. Even after 40 years of usage, it still offers a high quality of living and a high popularity amongst its users. Yet, several measures should be done to preserve its qualities and to improve known weaknesses. One of these measures is the thermal rehabilitation of the estate, which involves many challenges:

1.4. Challenges

1.4.1. Legal Framework

Unlike in most housing estates of that size, Terrassenhaussiedlung Graz was privately financed and houses owner-occupied apartments. The estate counts more than 800 different owners at the moment, which turns any structural intervention into a difficult process. A circumstance that lead to a good preservation of the estate but which is at the same time an obstacle for major improvements. Keeping this in mind, refurbishment strategies that allow a gradual rehabilitation of the estate are favoured.

1.4.2. Heritage Protection

The structural, aesthetical and functional concept of the estate builds upon a clear separation between primary and secondary structures:
While primary structures are materialized by exposed concrete surfaces, the main facades of the building are characterized by “infills” of lightweight walls. This is an architectural reaction to the user-participation process and allowed to adapt the apartments to the buyer’s wishes during and after the construction process of the primary structure. The architects’ vision was to create a “megastructure” with a potential for transformation. Following this intention, several spaces were deliberately left open and undefined (see Fig.1).
Ironically these spaces remained in the same undefined state even 40 years after completion, moreover the “infills” proved to be more durable than the primary structure: While the concrete facades had to undergo several refurbishments until today, most windows, doors and lightweight walls remained in comparably good condition. It should be also mentioned that the exposed primary structure leads to many thermal bridges that negatively influence the thermal performance of the buildings and may lead to condensation problems if not treated properly (see Fig.2).
This leads to a dilemma when it comes to heritage conservation:
The exposed concrete surfaces are a testimony of the era and the architect’s intentions and at the same time they are a main structural weakness of the building.

1.4.3. Energy Demand

Apartments in the estate have an average heating energy demand of about 100 kWh per m² usable floor area (UFA) and year.[12] This is slightly better than the typical energy demand for multi-family buildings of the1950ies to the 1970ies in Austria and corresponds to an energy efficiency class between C and D.[13] [14] To meet the national 2020 requirements for comprehensive rehabilitation, the heating energy demand should be reduced to 56 kWh per square meter (m²) total floor area (TFA).[15] These requirements can only be met by introducing additional thermal insulation measures to the existing buildings.

1.5. Hypothesis

The hypothesis of this paper is that Terrassenhaussiedlung Graz has an inherent potential for modernisation. Its clear separation between primary and secondary structures allows for an upgrade or exchange of the latter without compromising the design intents of the architects, the use of repetitive elements bear a potential for a modular approach and prefabrication in renovation.
However, this potential is confronted with structural problems which make thermal rehabilitation difficult. These include thermal bridges at junctions

between primary and secondary structures, as well as ageing phenomena of exposed concrete.

2. RENOVATION STRATEGIES

In the preceding study, three potential thermal rehabilitation scenarios were proposed and further investigated: Exterior insulation, interior insulation and the replacement of non-structural elements. These strategies were evaluated and discussed in terms of their impact on energy efficiency, building physics, architectural appearance and their practicability. Special attention was given to the many thermal bridges caused by the exposed concrete structure of the estate, moreover the potential for building-integrated energy production was investigated. Results were derived by different simulation methods, including small scale hygrothermal simulations and large scale dynamic thermal simulations. This chapter gives an overview of these scenarios.

2.1. Strategy 1: External Insulation

In this strategy, the whole building envelope is packed in thermal insulation material, while existing constructions remain largely in place (see Fig.3). This requires scaffolding and is only economical if larger building parts get refurbished at once. In contrast to the other proposed rehabilitation strategies, inhabitants can occupy their apartments during the refurbishment process.
To minimize the effect on the appearance of the building, *aerogel* has been proposed for insulation measures, which allows to reach today’s thermal standards with low layer thicknesses. While light-weight façade elements will be protected by additional aerogel sheets, concrete elements will be covered by an aerogel insulation plaster.
This strategy should be uncritical in terms of condensation and it would reduce the effect of thermal bridges. Apart from that, the additional insulation layer would protect the concrete from weathering.
With an additional insulation layer of only 30mm thickness, a thermal energy demand of 57 kWh per m² TFA and year could be reached, which is close to the national 2020 requirements for comprehensive rehabilitation (see Fig.6).[16]

2.2. Strategy 2: Internal Insulation

Thermal insulation measures on the inside of the building envelope allow the refurbishment of individual residential units, without a need for cranes and scaffolding and without altering the external appearance of the building (see Fig.4). In contrast to the other proposed variants, however, it is critical in terms of vapour condensation: Damage to the required vapour barrier may lead to condensate failure in the construction. Moreover, interior insulation will reduce the temperature of concrete walls which may increase the risk of frost damage.

There are also economical and practical issues: Interior insulation means a reduction of usable and therefore lettable and sellable floor space. To minimize this negative effect, 25 mm thin vacuum insulation panels (VIP) were proposed as insulation material. It should be noted that this material is significantly more expensive than conventional insulation material and requires careful handling. Applying and connecting insulation materials and vapour barriers requires constructive measures at floors, ceilings and interior walls, and careful execution of these measures.

According to the preceding study, a heating energy demand of 53 kWh per m² TFA and year can be reached with the proposed interior insulation measures (see Fig.6). This is slightly below the national 2020 goals of 56 kWh per m² TFA. It should be noted, that roofs and terraces were assumed to receive no additional internal thermal insulation layer in this scenario, as these elements are most endangered for condensation failure. By applying additional external insulation measures instead, an even lower energy demand would be achievable.

2.3. Strategy 3: Replacement of lightweight elements

This refurbishment strategy doesn’t touch the exposed concrete surfaces at all. Instead of adding additional insulation layers, the lightweight facades will be replaced entirely (see Fig.5). This strategy leads to higher costs of materials and higher embodied energy expenditure than the aforementioned measures. Also it will be difficult to conduct these measures during usage.

Apart from that, it leads to higher heat losses through the concrete walls, which make up for roughly 30% of the building envelope and which can only partly be made up by a better thermal quality of the lightweight wall elements. This leads to a heating energy demand of 62 kWh per m² TFA when the present window-to-wall ratio is kept, and exceeds the national 2020 requirements by 10% (see Fig.6). If this strategy is followed, additional measures to reduce the thermal energy demand will be needed.

3. DISCUSSION

3.1. Strategy 1: External Insulation

This strategy has the highest impact on the appearance of the buildings but at the same time ensures the best physical conservation of the structure. Even though thermal insulation is kept at a minimal layer thickness, there will be significant impacts on the appearance and character of the building: The proportions will change slightly, especially when it comes to narrow elements, such as the demising walls, which protrude beyond the light weight façade elements (see Fig.1). Raw concrete surfaces and their details will disappear, thus concealing the “authenticity of materials” as propagated by the movement of Brutalism, which had influence on the architect’s design and thinking.[17] On the other hand, this insulation strategy would still be able to reflect the structuralist ideas behind the design: An external layer of insulation plaster on concrete elements would keep the homogenous character of the primary construction elements and would also keep a clear visual separation from secondary construction elements. Another argument in favour of external insulation is its contribution to the physical conservation of the structure, by protecting it from weathering.

3.2. Strategy 2: Internal Insulation

The interior insulation strategy is the typical approach when it comes to the renovation of historically relevant buildings. Following this strategy, significant reductions in energy demand can be reached without any significant changes in the outer appearance. A major downside of this approach is its inherent risk of condensation failure as outlined under point 2.7.

Arguably, it is not the façade that makes the estate historically valuable, but rather its’ underlying pioneering and experimental ideas and design processes and it seems questionable if it is the right approach to conserve an estate, which was led by structuralist design ideas of transformability and adaptability, in its initial state.

3.3. Strategy 3: Replacement of lightweight elements

In this strategy the original lightweight façade elements and the original windows will be replaced, which will lead to a change of the visual appearance, be it in material, proportion or in rhythm of the façade. It should be noted that the existing windows are to a large extent made of mahogany wood and were custom made by the manufacturer for this building project, thus the replacement of windows will inevitably lead to a loss of original architectural qualities.

At first glance this strategy doesn’t appear to be an attractive option: The potential for energy savings is lower than in the aforementioned strategies, still it has significant impacts on the appearance of the buildings.

Bearing in mind that this potential was calculated on the basis of the present window-to-wall ratio and reflects a classical punctuated facade, it becomes apparent that the calculated value doesn’t represent the full potential of this strategy:

Exchanging entire façade elements allows to optimize window-to-wall ratios and passive use of solar energy and also opens up many possibilities for building integrated solar energy production. These systems could be probably integrated into the existing façade as well, but most likely not in the same extent and with the same potential for optimisation. Last but not

least it opens the opportunity to readapt the façade to changing user needs and current technical possibilities.
Obviously this potential for optimization is also a thread to the visual quality of the building, as an optimized design in terms of energy might not integrate well into the existing façade system.

4. CONCLUSION AND OUTLOOK

While Strategy 1 – External Insulation has the highest impact on the appearance of the estate but is least critical in terms of building physics, Strategy 2 – Interior Insulation allows a complete conservation of the outer appearance of the estate but is most critical in terms of building physics. Both Strategies allow to reach Austria's 2020 requirements for comprehensive rehabilitation. Strategy 3 - Replacement of Lightweight Elements implies the highest heat losses but has the highest potential for building integrated energy production and passive solar energy use. It implies a significant impact on the appearance of the estate but also bears the potential to readapt to changing conditions and user requirements. These potentials should be further investigated.
All proposed strategies require a high quality of design and workmanship to be successful. While Strategy 2 requires diligent planning and execution internal insulation measures, Strategies 1 and 3 are highly dependent on the visual quality of finishes and details.
A replacement of lightweight façade elements, as proposed in strategy 3, should revive and reinterpret the idea of freedom of choice within a predefined construction system, as it has been realized in the existing façade system. To allow a smooth and gradual renovation, this should be in line with the aesthetics of the existing façade elements.
Further investigation is also needed on measures to preserve the concrete structure of the building. This issue cannot be be regarded separately from the rest of the building and must be taken into consideration before a final renovation strategy can be proposed.
These issues are planned to be investigated and elaborated in the near future.

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6. ILLUSTRATIONS

Fig. 1 Werkgruppe Graz, Terrassenhaussiedlung, Graz, Austria, 1972-1978, South-East façade of house No. 33, © Alexander Eberl 2017.

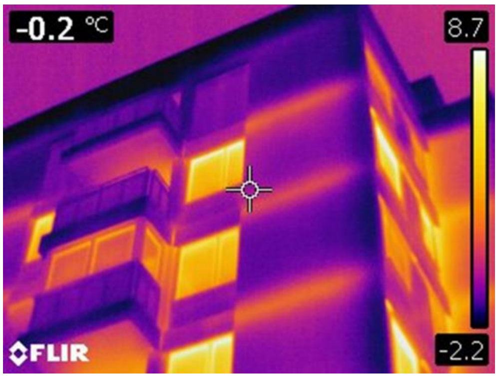

Fig. 2 Thermography of Terrassenhaussiedlung Graz, house no. 33, © Alexander Eberl 2017.

Fig. 3 Building elements affected by the external insulation strategy: Except for the windows, most parts of the building envelope will be visibly affected © Alexander Eberl, 2017.

Fig. 4 Building elements affected by the internal insulation strategy: No external surfaces will be visibly affected © Alexander Eberl, 2017.

Fig. 5 Building elements affected by Strategy 3: Windows, lightweight walls and roofs will be affected © Alexander Eberl, 2017.

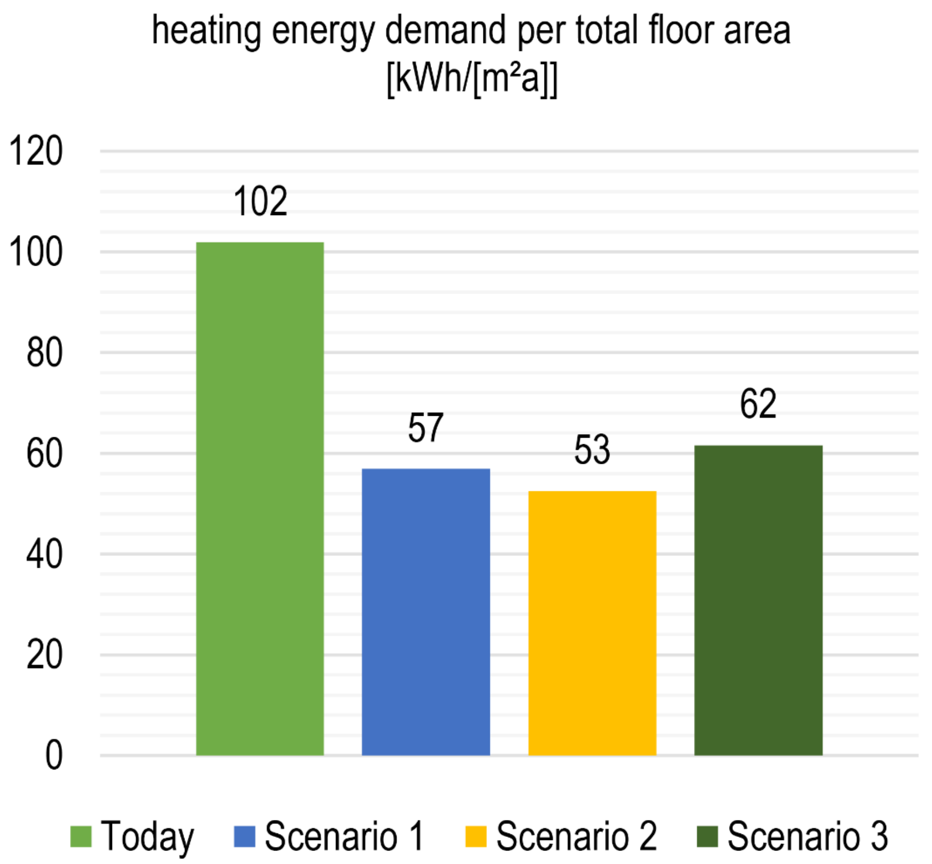

Fig. 6 Heating energy demand for all investigated refurbishment scenarios © Edina Majdanac, 2018.

7. BIOGRAPHY

Alexander Eberl is a university assistant at the Institute of Buildings and Energy, Graz University of Technology, since 2014. He holds a Master's degree in Architecture and is currently working on his PhD thesis on the revitalisation of buildings of the era of Structuralism.

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[3] For more info on the initiative see: http://www.sosbrutalism.org/cms/15802395 (accessed on April 15, 2018)
[4] One prominent Austrian example of inappropriate retrofitting is the "FRZ Leoben" by Eilfried Huth, for more info see: http://www.gat.st/en/news/die-demontage-eines-denkmals (accessed on April 15, 2018)
[5] See: *Journal of Architectural Conservation*, 23:1-2, accessed on April 15, 2018, https://www.tandfonline.com/toc/raco20/23/1-2
[6] For more information on the research project see: http://www.smartcities.at/stadt-projekte/smart-cities/smarte-modernisierung-terrassenhaussiedlung-graz/ (accessed on March 10, 2018).
[7] This project was funded by the Climate and Energy Fund Autria, see: https://www.klimafonds.gv.at (accessed on March 10, 2018) and conducted under the program Smart Cities Demo, see: http://www.smartcities.at (accessed on March 10, 2018).
[8] For more information see: http://www.institut-wohnbauforschung.at (accessed on March 10, 2018).
[9] The study is yet unpublished and is currently in the phase of finalisation. In this document it will be referred to as follows: Alexander Eberl, Edina Majdanac, *Publizierbarer Endbericht Smart Cities Demo - 7. Ausschreibung – Sondierungsstudie Smarte Modernisierung Terrassenhaussiedlung*, unpublished manuscript, Graz, 2018.
[10] In this project the following architects were involved: Eugen Gross, Friedrich Groß-Rannsbach, Werner Hollomey, Hermann Pichler, Walter Laggner and Peter Trummer
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[16] Figure taken from: Alexander Eberl, Edina Majdanac, *Publizierbarer Endbericht Smart Cities Demo - 7. Ausschreibung – Sondierungsstudie Smarte Modernisierung Terrassenhaussiedlung*, unpublished manuscript, Graz, 2018.
[17] As stated by architect Eugen Gross in a personal conversation.