Analyzing the Separability separability of Material material Layers layers of hybrid exterior Building building elements elements concerning repair repair and rrefurbishment

Compilation of a practically oriented database for sustainability assessment

Short report

This research project was funded by the initiative “Future Building” of the German Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR).
(Project: SF-10.08.18.7-10.10/ II 3 – F20—10-1-066)
The author is responsible for the content.

1 Introduction

Currently there is a paradigm shift towards sustainable buildings and towards an approach that focuses on the life cycle of building measures and building products in Germany. The objective of sustainable use of natural resources is transformed by life cycle-orientated planning into account aspects of design, for example by efficient dismantling and recycling-friendly components.

The introduction of the German Sustainable Building Certificate (DGNB) provides an assessment system to measure the sustainability of buildings in terms of environmental, economic, socio-cultural and functional quality. These certifications require a quantitative assessment of environmental effects over the entire life cycle by means of an ecological balance sheet. At present there are no objective empirical values available for the assessment of rehabilitation and deconstruction measures with regard to the separability of different material layers of hybrid building elements.

Currently, an increasing number of refurbishment measures are necessary to fulfill the demands of the Energy Saving Regulations as the German Energy Saving Ordinance for new buildings (ENEV), for example by using additional insulation layers or renovation of existing external thermal insulation composite systems (ETICS). At the same time, the requirements based on the three pillars of sustainability –i.e. environmental, economic and social aspects– must be fulfilled, above all the protection of natural resources.
The purpose of this research project is to examine the environmental effects of rehabilitation and deconstruction measures of exterior building elements in terms of the reduction of energy and material consumption. In addition, a method for assessing the separation processes has to be developed and a data base with information on the separability has to be provided as a basis for the planning and certification of sustainable buildings.

This research project was the first analysis of the separability of hybrid exterior building components. It attaches great importance to the chosen ETICS and flat roof sealing especially, because in both systems the single layers are glued together. In addition to analyzing the environmental effects of rehabilitation and deconstruction measures of exterior building elements, an assessment method was applied that was developed during the predecessor

project “Analyzing the solubility of material layers of interior building components” and the transferability of this method onto other types of building components was tested.

2 Procedure

The research project consisted of the evaluation of all the energy and material consumption needed for the deconstruction process during the entire life cycle of a building. A total of 30 hybrid walls and 14 hybrid roof systems, typical restructuring cases and repair methods were defined in collaboration with experts and manufactures. In practical experiments, these systems were constructed in accordance with the generally recognized state of the art and deconstructed under controlled conditions down to the base layer. By the selective demolition of the different material layers, we intended to achieve a high recycling or reuse rate. Any energy and material consumption as a consequence of maintenance and preparation of the sub base was properly recorded. Further qualitative data of the dismantling were provided such as strong dust pollution. The results obtained from testing prototype components were subsequently verified by real projects.

For the life cycle assessment (LCA) of the reported material flows, the available material properties of the German federal ecobalance data base “Ökobau.dat 2011” were used. Missing data were completed from other data bases such as the Environmental Product Declaration (EPD). For comprehensiveness and in addition to the ecological evaluation and analysis of the material flows, we also determined the cost for labor and disposal. Based on the investigation results, a methodology was developed that will provide an objective assessment of the dismantlability and recycling-friendliness of different wall and roof systems in the future.

Finally, the results of the tests and the LCA/LCC are assembled in a catalog of building components.

The procedure of the research project is displayed in figure 1.

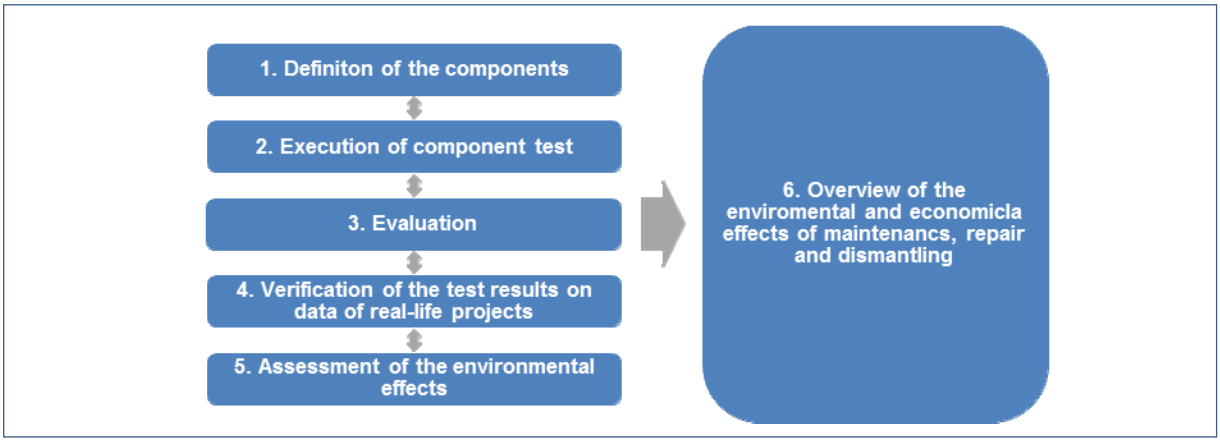

Figure 1: Procedure of the research project

3 Scope

Our analysis of the separability of material layers of hybrid exterior building elements does not take into account the whole life cycle of the elements but rather concentrates on the dismantling of wall and roof constructions that is realized during the utilization phase and the disposal phase. All environmental and economic impacts of the demolition, recycling or disposal of waste and the associated transport were reported on the balance sheet. Special attention should be paid to the question whether transport and energy consumption of tools could be neglected in the future for being insignificant.

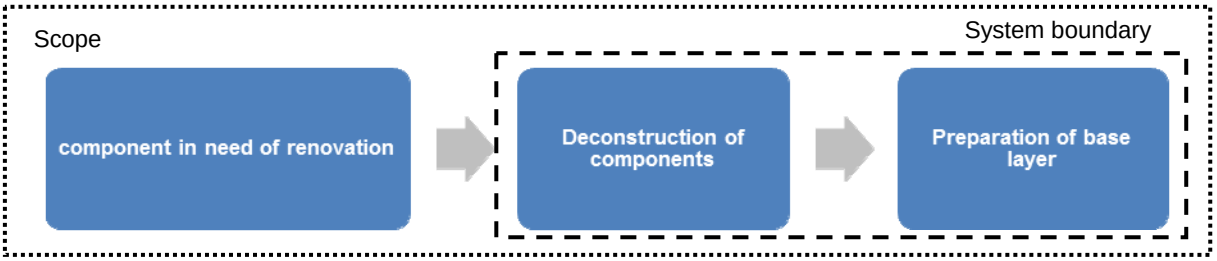

Figure 2: Representation of the system boundary

To define the scope of this research, we adopted the approach of the predecessor project ”Analyzing the solubility of material layers of interior building components”. The pure repair and disassembly process and all necessary preparations illustrated in figure 2 represent the system boundary. The base unit for the results of the investigation is “1 sq.m. of repaired component”.

To guarantee a realization of the research project in step with actual practice, we used full-scale specimens of 2.0 m x 2.3 m (width × height) and roof specimens with the dimensions 2.3 m × 2.3 m (width × length). To simplify the tests, an insulation material thickness of 10 cm was applied. In the comparative assessment, the existing examination results were adapted according to the requirements of the current energy saving regulation (EnEV 2009). As additional information, passive house standard components are included. Further technological characteristics such as humidity protection, water vapor diffusion, fire protection and noise insulation have remained unconsidered in the interpretation.

On the basis of a component catalog, a survey plan with 30 hybrid wall systems and 14 roofs systems (new building, energy-related renovation and modernization of the housing stock) was developed.

Within the scope of the test series, 3 different wall scenarios were distinguished, “new building” (construction 02), “old render” (construction 01 + 02) and “additional ETICS” (construction 02 + 03). All structures, insulations and various plaster systems shown in figure 3 were combined.
For the flat-roof assessment, the roof construction typologies “new building” and “energy-related renovation” were realized jointly as “additional insulation”. Figure 4 depicts the different roof-systems on steel concrete and trapezoidal sheet metal.

Taking into account the general selection of impact categories of the sustainability certification of BNB and DGNB, the following impact categories were used:

- Primary energy, non-renewable (mj)
- Primary energy, renewable (mj)
- Abiotic consumption of resources (ADP) (kg Sb-equivalents)
- Global warming potential (kg CO2-equivalents)
- Ozon-depleting potential (kg R11-equivalents)
- Acidification potential (kg SO2-equivalents)
- Eutrophication potential (kg PO4-equivalents)
- Photochemical oxidant potential (kg C2H4-equivalents)

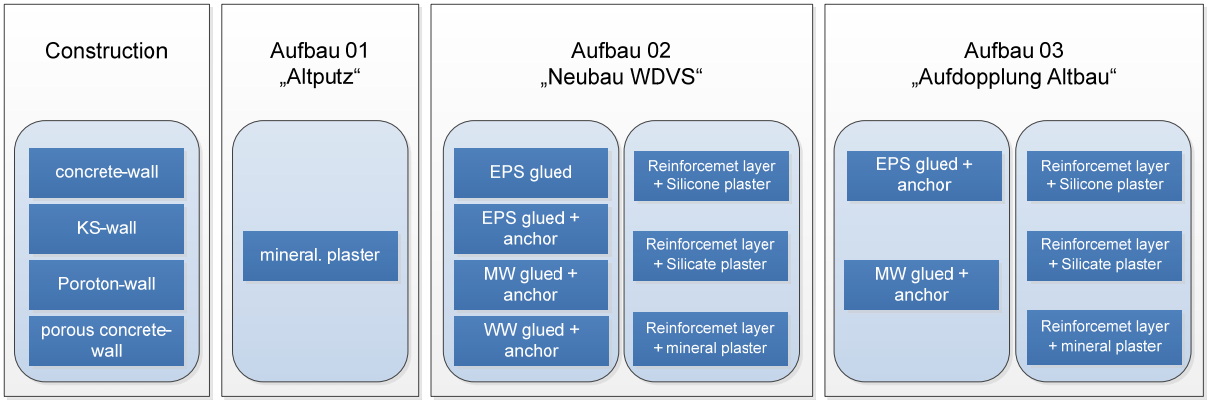

Figure 3: exterior wall components

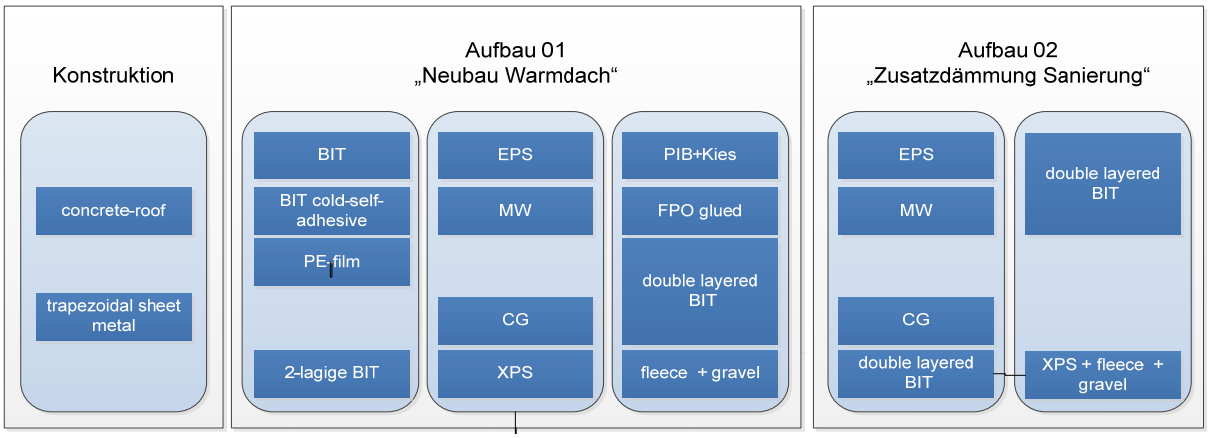

Abbildung 4: Flat-roof components

4 Test results

All experimental information was reported on in the form of test protocols and data collection sheets. After completion of the trials, all results were reviewed for plausibility and consistency. They are outlined in the following sections:

mass balance and purity

The evaluation of the collected data has shown an average loss in mass around 8 % of the input material. The removing of old render achieved the the largest loss (16 %). In the case of the flat-roof test the losses were lower and amounted to around 3 % of the input mass. The

separability of layers in accordance with the requirements of individual waste fractions was only possible for loosely laid sealing systems.

Separability and degree of damage

Except for the porous concrete-walls, the damage to the base layers of wall and roof systems were minimal and could have been renewed without further preparations. Considering porous concrete-walls, the covering of big holes with leveling mortar caused a considerable extra effort.

Concerning the destruction after partly dismantling the walls, all renderings of the ETICS were separated without undesired residues. In the case of the roofs, only the dismantling of loosely laid sealing systems and the compact roof were possible.

Labor

For the dismantling of ETICS, the following values were calculated: For the scenario “new building” an average of 17.5 min/m², for the renovation scenario “old render” and the scenario “additional ETICS” around 23 to 24 min/m². Considering the demolition of flat roofs, we determined 11 min/m² for one-layer flat systems and 16 min/m² for the renovations scenarios. The dismantling of the trapezoidal sheet metal only showed an average of 3 min/m².

Influence of external parameters

Between March 2011 and April 2012 all tests with sample constructions were performed outdoors under varying weather conditions and by different craftsmen. The temperature varied between a minimum of 2 to 4 °C and a maximum of 35 °C. Our assumption of a causal link between temperature, motivation and workload could not be confirmed, instead the workload is more dependent on the person realizing the work.

Based on the experimental results of the roofs, a relation between workload and temperature was detected. The time for removing bitumen-sealings increased almost ninefold, depending on the temperature.

Verification

The results based on model tests were verified by selected renovation and reconstruction measures in real-life projects.

5 Results of the Life Cycle Assessment (LCA)

LCA were realized for all three sample cases "model component", "component in accordance with “EnEV 2009” and “component in accordance with passive house standard (PH)”. In the following text the evaluations of the LCA and LCC will be presented.

Environmental performance

The environmental performance of the dismantling of ETICS is especially dependent on the choice of insulation material. For EPS (expanded polystyrene) and wood fiber insulation (WW), the performance depends strongly on the credits for thermal recovery of the high-calorific fraction, especially for WW. In the case of the removal of the flat roofs, the credits for the thermal recovery of the bitumen-sealing and XPS/EPS dominate the value of the impact category indicator except for the global-warming potential.

Environmental performance "transport and energy for tools"

The environmental impacts of the transport exceed 1 % of the indicator values of the separation process and thus must be taken into account. In general, the energy used for transport and tools increases the environmental effects of the deconstruction measures.

For all components, the importance for energy for tools has been very low and hence the proportion on the environmental impact of the whole component. For the removal of roofs, energy for tools accounts for less than 1 % and can be ignored. For ETICS, the relevance of energy for tools correlates with the indicator values for reuse and cannot be neglected in general.

Costs

The costs for the removal of wall and roof systems varied according to the disposal and the labor costs. The deconstruction cost for ETICS defers between 8.50 €/m² (ETICS EPS steel-concrete) and 33.70 €/m² (ETICS on porous concrete with old render). For the dismantling of ETICS with EPS and WW, labor expenses outweigh the costs of disposal, which, on the contrary, is not the case for mineral wool insulation (MW). For MW the main cost driver are the high costs for land fill.
The costs for roof dismantling vary between 4 €/m² and 24.50 €/m². For EPS and CG the labor costs outweigh the disposal costs.

6 Assessment

For a practice-oriented assessment of the repair and deconstruction measures, it is useful to list and compare all environmental consequences with the expenditures. For this purpose, we used a rating matrix with varying importance factors, based on the system of weighting factors and the evaluation score-card of DGNB/BNB are used. Equal weight is attributed to the environmental on one side and economic qualities on the other side.

The results of the assessment, displayed in tables 1 and 2, show that no component fulfills the relevant environmental and economic requirements in an optimal way. From an environmental point of view, it would be recommendable to use ETICS with WW and roof systems with bitumen sealing that obtain high credits for thermal recovery.
We recommend to include the economic benefit ETICS with EPS without anchors because of the low amount of labor. The same applies to the use of loosely fitted roof sealings. Despite their low amount of labor, exterior building components with mineral wool insulation received a lower rating due to their bad environmental impact.

The assessment of the components according to passive house standards shows that the effects further increase with growing insulation thicknesses.

Table 1: Assessment of dismantling ETICS (according to ENEV 2009)

totoal efforts for dismantling

Tragschicht	EPS glued	EPS glued + anchor	MW glued + anchor	WW glued + anchor	EPS glued + anchor on old render	MW glued + anchor on old render	WW glued + ancho on old render	EPS glued + anchor on ETICS	MW glued + anchor on ETICS
steel-concrete	good	medium	poor	good	poor	poor	good	poor	very poor
KS-wall	medium	medium	poor	good	poor	very poor		poor	poor
Poroton-wall	medium	medium	poor	medium	poor	poor		poor	poor
Porenbeton-Wand	very poor		poor	medium	very poor	very poor			

environmental efforts for dismantling

Tragschicht	EPS glued	EPS glued + anchor	MW glued + anchor	WW glued + anchor	EPS glued + anchor on old render	MW glued + anchor on old render	WW glued + ancho on old render	EPS glued + anchor on ETICS	MW glued + anchor on ETICS
steel-concrete	medium	medium	poor	very good	medium	very poor	very good	poor	poor
KS-wall	medium	medium	poor	very good	medium	very poor		poor	poor
Poroton-wall	poor	poor	poor	medium	poor	poor		poor	poor
Porenbeton-Wand	very poor		poor	medium	very poor	very poor			

economic efforts for dismantling

Tragschicht	EPS glued	EPS glued + anchor	MW glued + anchor	WW glued + anchor	EPS glued + anchor on old render	MW glued + anchor on old render	WW glued + ancho on old render	EPS glued + anchor on ETICS	MW glued + anchor on ETICS
steel-concrete	very good	medium	medium	medium	poor	poor	medium	poor	very poor
KS-wall	medium	medium	poor	poor	very poor	poor		poor	poor
Poroton-wall	medium	medium	poor	medium	medium	poor		poor	poor
Porenbeton-Wand	very poor		poor	medium	very poor	very poor			

Table 2: Assessment of dismantling flat-roofs (according ENEV 2009)

construction	roof-components	total assessment	environmental	economic
steel-concrete	warm roof loose laying with ballast, EPS with PIB	good	medium	good
	warm roof loose laying with ballast, MW with PIB	poor	poor	poor
	warm roof glued, EPS + Bitumen	poor	medium	poor
	warm roof glued, MW + Bitumen cold-self-adhesive	poor	poor	poor
	warm roof glued, MW + Bitumen welding procedures	poor	medium	poor
	compact-roof	poor	poor	poor
	inverted-roof	good	medium	good
	warm roof glued, EPS + sealing FPO with fleece	medium	poor	medium
	warm roof glued, MW + sealing FPO with fleece	poor	very poor	poor
steel-concrete renovation	warm roof glued, EPS with Zusatzdämmung	good	medium	good
	warm roof glued, MW with Zusatzdämmung	poor	medium	very poor
	warm roof glued, EPS + bitumen sealing 4-lagig with Zusatzdämmung inverted-roof	good	good	medium
	warm roof glued, MW + Bitumen im Schweißverfahren with additional isolation inverted-roof	medium	good	poor
	compact-roof with additional isolation	poor	medium	poor
trapezoidal sheet metal	warm roof loose laying mechanisch befestigt, EPS with PIB	good	poor	very good
	warm roof loose laying mechanisch befestigt, MW with PIB	poor	poor	medium
	warm roof glued, EPS + bitumen sealing cold-self-adhesive	good	medium	good
	warm roof glued, MW + Bitumen cold-self-adhesive	poor	poor	poor
	warm roof glued, MW + bitumen sealing welding procedures	poor	medium	poor
	compact-roof	medium	poor	good
	warm roof glued, EPS + FPO with fleece	good	poor	very good
	warm roof glued, MW + FPO with fleece	poor	very poor	medium

7 Conclusions

This research project is the first investigation on the separability of common wall and roof constructions. The results show that a general entire strip-off of single layers of hybrid exterior building elements is not possible, but several layers of ETICS or compact roofs are removable. Furthermore it could be shown that in practice during repair and deconstruction measures, the dismantling of components is rarely used. Usually, new layers are added to the existing system. The results obtained by this study should be used as a supplement to the existing definition of durability published in the “Guideline for sustainable building" by the Federal Ministry of Construction, for example with examples of applications. This would facilitate a uniform application of expected life-cycle durability values of constructions.

By the results of this research project, the transferability of the assessment method of the analysis of interior building components could be verified. Comparing the results of both projects, the end of life phase of the materials plays a crucial role for the assessment results of exterior components. Unfortunately, it has not been possible to evaluate the environmental benefit of a mono-material separation due to the lack of generic data, for example with regard to the recycling-potential of EPS, PVC or MW. The sensitivity analysis was able to prove the great potential of high-quality recycling to protect natural resources and reduce costs.

The scope of the research project included all economic and environmental impacts of repair and deconstruction measures. The study provides the lacking information necessary for the integration of the maintenance and deconstruction process into the life-cycle assessment of buildings and for the creation of Environmental-System-Declarations (ESD). Based on the results of the study, instructions and processing guidelines that allow an optimal dismantling can be developed. In addition to this, the data provide the German building industry with insights into development potentials with regard to exterior building elements. Manufacturers of ETICS and roofing materials can see the problems that arise during deconstruction and the potential for product optimization. The project also revealed deficiences in the recycling and waste disposal systems that should be overcome by a sustainable utilization of secondary raw materials such as EPS and MW.

When we looked at the balance of the material flows, we could see that –contrary to the simplifying assumption of the LCA (input stream = output stream) – deconstruction is entails an average loss of material of 10 % of the input material. There is an open issue as to whether and how this fact has to be considered in LCA/LCC.

Unfortunately, only a small range of products for common wall and roof constructions could be examined exemplarily. This means that further comparative tests have to be carried out, for example with other systems, and the process of aging should be studied. It would be desirable to include the quality attribute “separability” in Environmental-Product-Declarations (EPD).