Zukunft Bau

SHORT REPORT

Title

Development of basic principles for modular and fully recyclable, massive construction residential houses, based on zero-energy- standard for a wide use.

Az.: SF-10.08.18.7-09.26

Motive / Initial Position

Today, massive constructions are a part of the greatest rubble sources in the building and construction industry. The reason for that is the composite design between different building materials or building parts. The highest degree of indissoluble connections can be found at production in situ. Unmixed disassembling of a building sometime is impossible or only possible with a high expenditure of energy. The aim of the research project was the development of the basic principles of modular and fully recyclable, massive constructions for a wide residential use, based on zero-energy-standard. The primary goal was defind by the ability of the construction to be separated in all components without a significant use of energy at the end of the building’s life cycle. The research intends to direct reusing or recycling of the components. A wide applications in residential constructions are going to be developed considering the requirements of the zero energy fundamental principles for a massive basic material with high strength.

Scientific scope

With the research project the feasibility of the research idea should be checked and:

- the theoretical bases for such a design method is to be compiled,
- a constructive consideration with environmental performance evaluation, specification of the framework conditions, aim brands and variant drafts are to be carried out,
- an experimental assessment of the main issues are to be produced
- and a view of further developments and applications are to be given.

Taking the specific context of the research project into account, the most important terms such as, “module”, “element”, “component”, “layer” and “link”, has been defined. An assessment of the different options based on the following parameters “Assembly", "disassembly", “recycling”, “wide scale residential use”, “zero-energy-standard” and “life cycle assessment” has been given. The advantages and disadvantages of each design principles were highlighted and analyzed using an evaluation matrix for decision. Based on the developed theoretical scheme an Analysis of common solid structures has been followed. Using a geometric-constructive framework, the conditions for theoretically and experimentally examined constructions had been developed and defined. The interfaces for technical building services according to project objective were fixed to that setup.

With regard to the structure, the design basics for the primary structures had been presented and applied to dry masonry. These can be summarized as follows:

- Using dry joints for the construction elements of limited size and comply with a reasonable degree module can be designed in varied buildings.
- Joining layer by layer is been given priority over joining whole elements. The chance is carried out selectively at the interfaces of the module lines.
- By applying the pre-stressed force at the element level, the friction force between the elements is going to be increased, by which the load bearing capacity against lateral forces can be increased significantly. This effect can be advantageous for walls under eccentric loading or for bending slabs.
- Pre-stressed elements can improve the shear capacity against frictional sliding of the dry units on each other..
- The ring anchoring effect in the masonry also can be replaced according to the leader principle. It doesn't require any monolithic approach.
- The basic principle of the slab in dry building is based on the eliminating the tensile strength by using a pre-stressed elements in which no bonds are used.

To examine the stability, realistic component dimensions (application, usual load) can be selected and a structural analysis of the buildings can be perforemed.
For this purpose, a so-called prototype house was designed within the project. The structure of the prototype house was examined by a numerical ANSYS model, taking contact joints into account. The results of modeling showed that the chosen principle is authentic and is suitable for further construction processing. For experimental verification, detailed component tests have been carried out. Legal questions weren't examined.

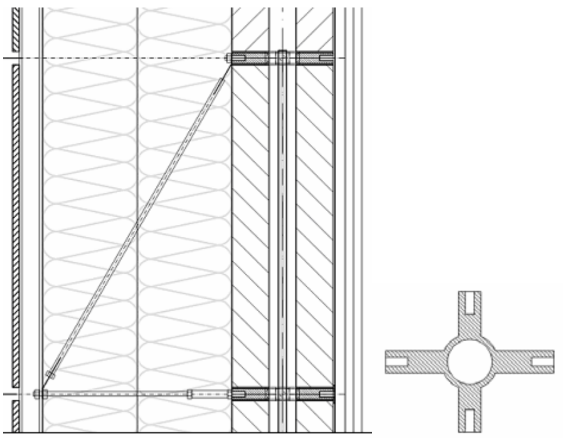

Figure 1 Option A "Cross-connector"

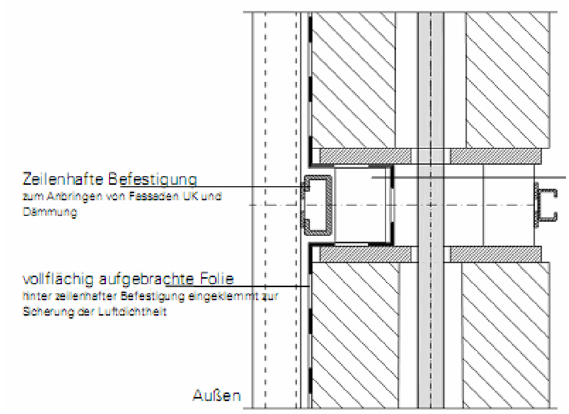

Figure 2 Option B "line-connection"

Considerations of possible demountable building constructions were made. At beginning of the project, two approaches were choses among maby variations and examined in more detail. These two approaches are:

- Point-like: Option A "Cross-connector" Figure 1
- Line-shaped: Option B "line-connection" Figure 2

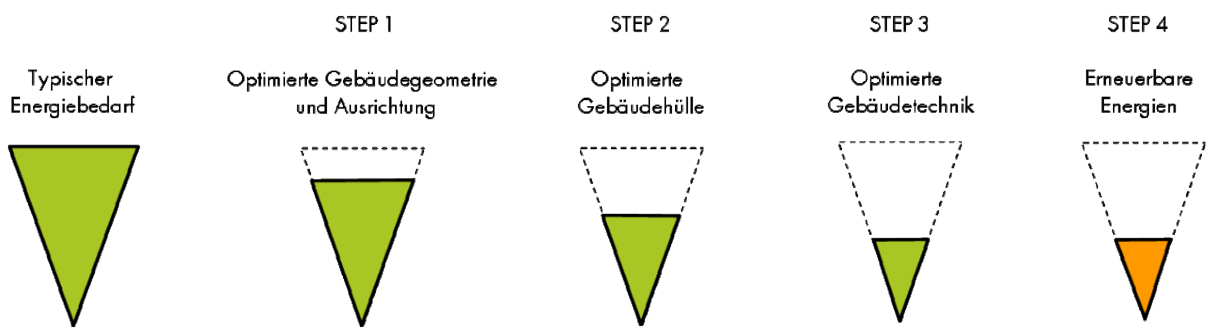

Figure 3 Strategy to achieve zero energy standards

With regard to the physical requirements the general framework has been defined and a strategy to achieve zero energy standards has been developed (see Figure 4). Arising from the physical requirements the building envelope and the technical expansion followed. A classification system for the planning process of the mechanical equipment is given:

- systematic organizing and summarizing of the mechanical equipment
- by using radio-based systems a reduction of transmission lines can be achieved
- greatest possible separation of raw and expansion modules

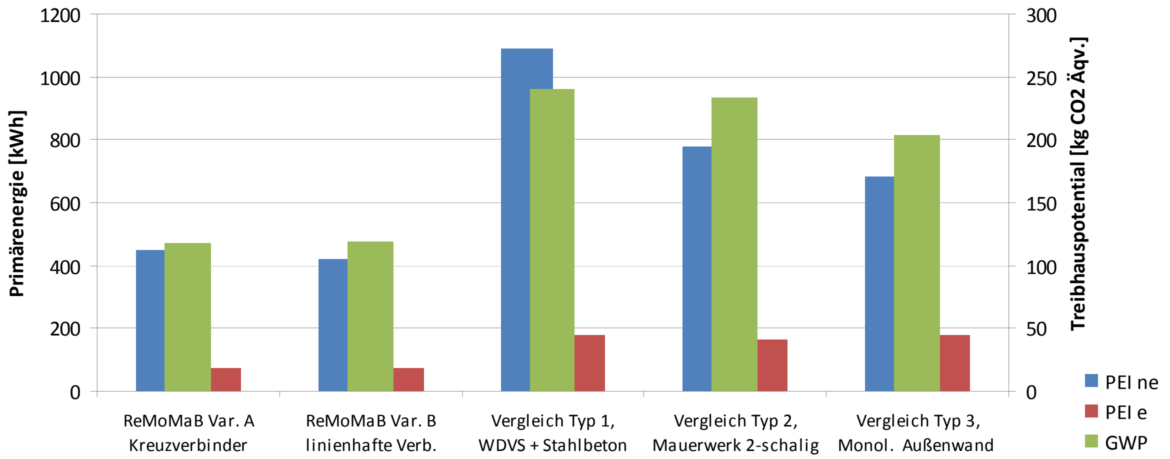

Figure 4 Primary energy demand and global warming potential with end-of-life product recycling scenario (PEI ne: Primer is not renewable energy requirements; PEI e: Primary Energy Demand renewable GWP: Global Warming Potential)

A detailed comparison with life cycle assessment followed. Therefore the two constructions shown in Figure 1and Figure 2 have been also compared with currently established solid structures (see Figure 4). The assessment is undertaken on the following data sets:

- Umweltproduktdeklaration (EPD, Typ III-Umweltzeichen, ISO 14025)
- Ökobau.dat 2009

The following comparisons were made:

- Environmental effects of initial production including dominance analysis
- Environmental impacts over 50 years, including maintenance and end-of-life according to DGNB
- Environmental impacts with the end-of-life scenario for product recycling materials with use duration of more than 50 years

The research proves that in comparison to conventional construction methods demountable, heavy structures achieving a significant benefit under ecological aspacts.

Figure 5 Viability tests on prestressed on stone ceiling

The developed designs were tested by material and component tests. The following tests were performed:

- Materials and compression tests on single stones
- Compression tests on a wall speicemen according to DIN EN 1052-1 (RILEM)
- Capacity tests on prestressed masonry slab (see Figure 5)

By transfer to the other parts of a building (see Figure 6), the proposed method of unbonded prestressing as flexibly deployed, detachable connecting principle is demonstrated.

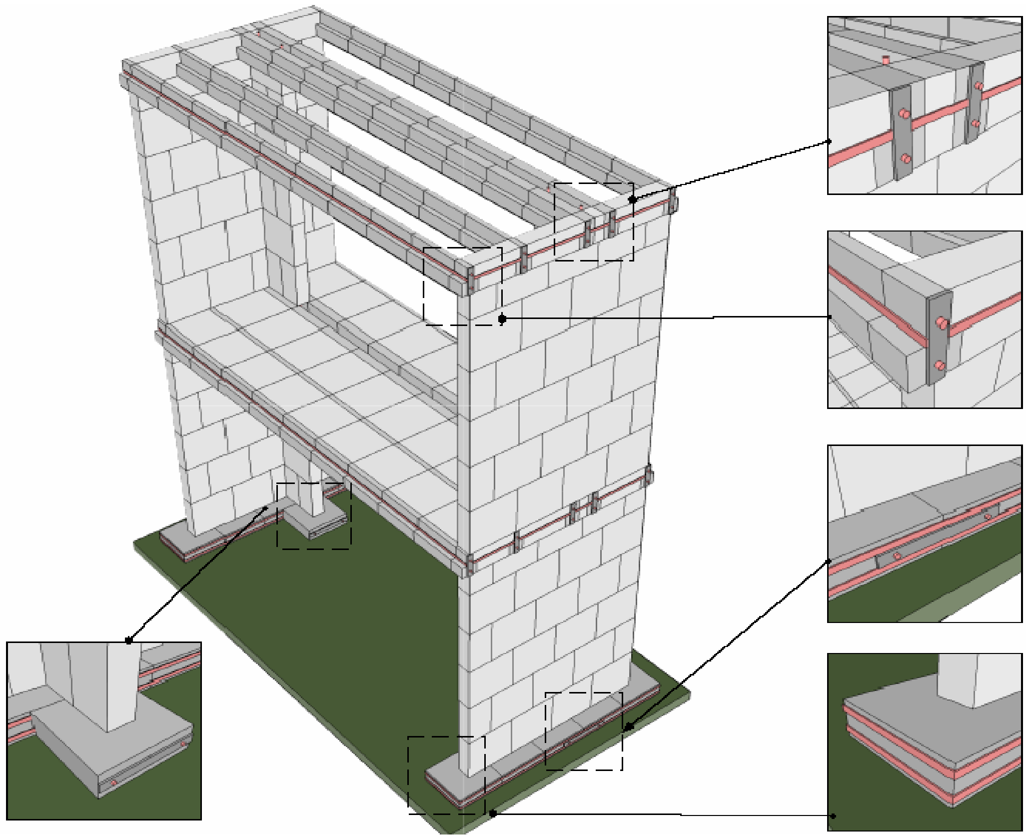

Figure 6 Transfer to the other parts of a building

Conclusion

Concluding the results the following points can be summarized as essential:

- The research project demonstrates that massive construction under the objective of separation at the end of the life cycle with recycling or reuse is possible. This could be done without the interconnection of different building materials.
- This statement applies to all components of a building in wall construction
- It is of particular importance to use the dry addition elementary geometry, in terms of tolerances and element strength.
- With the principle of prestressing, the dry addition is optimized to bending stressed components are enabled. This requires a certain strength of the element (or stone) material.
- Connection between raw and expansion construction “layer solutions” takes precedence over “element solutions“.
- For Construction and Building Services system components on the market, which require only minor adjustments needed to be fully demountable.

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Total Cost: 320.836,00 Euro

Federal Grant: 159.836,00 Euro

Project Time: 04/2010 bis10/2012