FORSCHUNGSINITIATIVE Zukunft BAU

Building for the future

BRIEF REPORT

Title: RCWE

Development and application of complete dismountable living units from resource-husbanding concrete

File no.: SWD-10.08.18.7-16.54

Occasion/ Starting point

Following on from the energy transition policy announced by the federal government, there has been increasing focus on recycling-friendly and resource-husbanding building construction. The problem of raw material consumption, the increasing variety of raw materials used and rising raw material prices, on the one hand, and the excessive quantities of building waste generated every year, set against falling landfill capacities and restrictive recycling alternatives (umbrella ordinance), on the other, calls for sustainable solutions.
Moreover, the problem of providing residences and accommodation which are subject to tighter planning and implementation deadlines plays an important role in the project.

The objective of the research project

The aim of the research project was to develop and demonstrate a solid, modular, transportable and completely dismountable/recycling-friendly living unit that could swiftly provide living space and, if necessary, could serve as temporary accommodation as well as being capable of conversion at the end of its period of utilisation. At the same time, the requirements made on the next generation of buildings needed to be fulfilled and material cycles that were based on the principle of cradle-to-cradle (cycle-friendly building at the component level) closed. This meant systematic (modular construction) and flexible (quick, dismountable, adaptable etc.) construction which was both free of harmful substances and which husbanded resources. This would include the separation of materials for disposal and the recyclability of entire components of the shell as well as its sustainable manufacture by employing recycling material. Once produced, entire modules are to enter the utilisation cycle without shredding at the end of the utilisation period. This would mean that the recycling option would contribute to value retention (upcycling). The project focused on the testing of the devised principles and the optimisation of repeatable, adaptable construction solutions as applied to entire building components.
Dismountable structures require a high degree of non-permanent connections. The composite principle had to be completely dispensed with. Point connections are planned for the individual elements or components (cf. Figure 3)
Moreover, variable structures require a high degree of modularity. In order to do justice to the principle of eco-efficacy or in order to achieve a high level of sustainability, the individual modules – consisting of foundation, wall and ceiling components are manufactured from resource-husbanding concrete or recycling concrete (RC concrete).

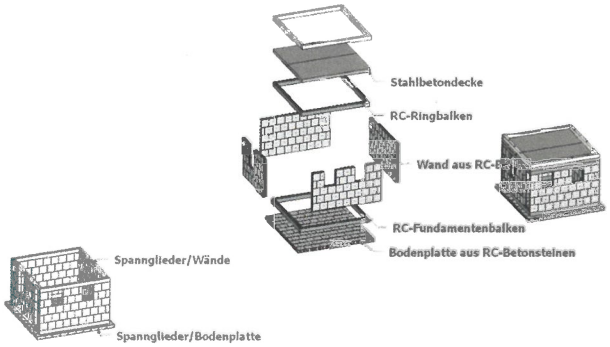


Fig 1 First draft of the unit at the beginning of the project

Figure 2 Screw connections of the RC ceiling slabs

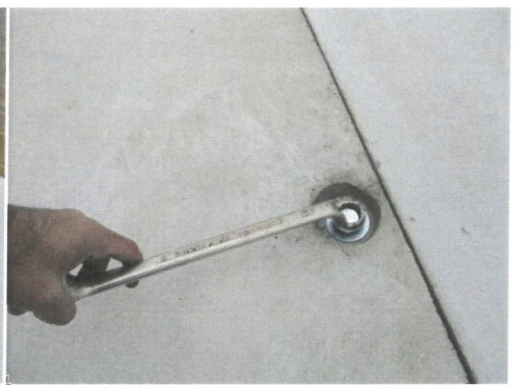


Figure 3 Screwing together the RC ceiling slabs

Depending on the available production techniques, wall and ceiling elements as well as small-format concrete stones were to be examined. The approach consisted of considering the constructive design of the dismountable, modular living units of RC concrete taking into account the separable material connections and functional partitions (load-bearing construction separate from finishing work) and testing them as regards feasibility and usability (cf. Figure 4).

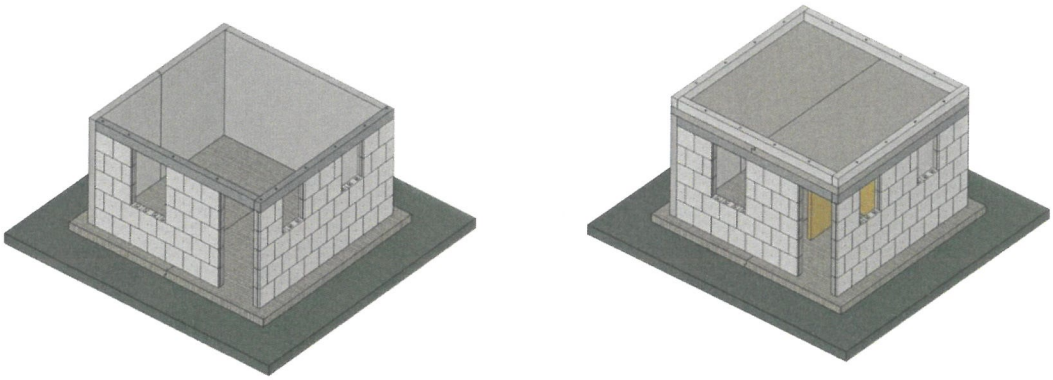


Figure 4 Implemented unit consisting of concrete plate, wall slab and wall components

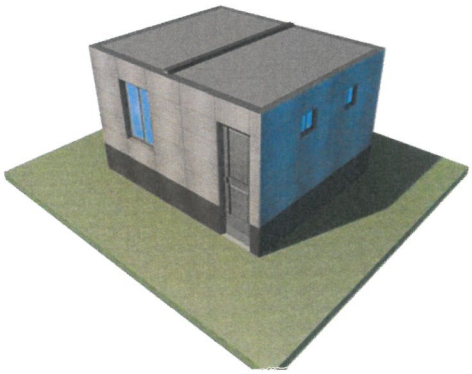


Figure 5 Façade finishing

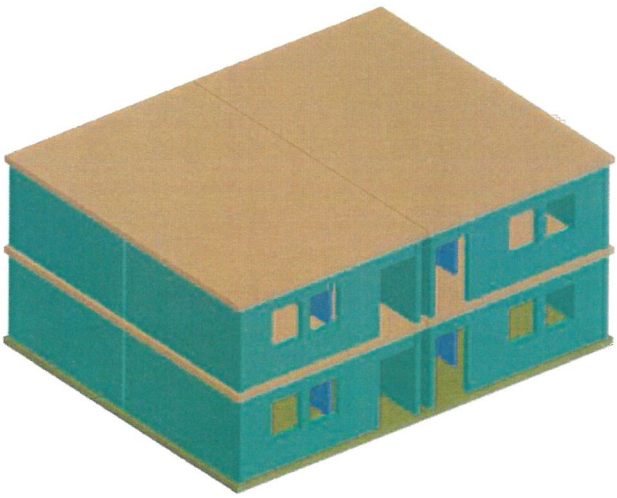


Figure 6 Modified RC living unit in slab construction

The concrete mix for the respective construction element was also to be analysed along with the extent to which recycling material can be used. The non-pollutant use of recycled aggregate (RC-AG) was to be evidenced and the proportion and delivery type of RC-AG to be optimised in the concrete, the proportion limits of RC-AG in the concrete being ascertained.

The RC-AG of the delivery types 1 and 2 especially produced for this project were:

- in the permissible proportions according to DAfStb directive "Concrete according to DIN EN 206-1 and DIN 1045-2 with recycled aggregate according to DIN EN 12620" and
- above and beyond this, used and tested 100% in the concrete.

The concrete mixes and material spatial model were developed into a natural AG substitute taking into account the use of different proportions according to the exposure class and the load-dependent loading.

Figure 7 Sampling of aggregate material 0/16 concrete chips on the site of the company Heim Deponie & Recycling GmbH

Apart from the above-mentioned directive the following standards found application:

- DIN EN 206-1:2001-07+A1:2004+A2:2005 "Concrete – Specification, properties, production and conformity" and
- DIN 1045-2:2008-08 "Concrete, reinforced and prestressed concrete structures – Part 2: Concrete – Specification, properties, production and conformity application rules for DIN EN 206".

Tested was the use of different cement types and quantities to achieve the required strength classes as well as the workability (consistency) of the concrete.
The fresh concrete and hardened concrete properties were characterised by means of the following parameters:

- Fresh concrete raw density in accordance with DIN EN 12350-6,
- Flow table test in accordance with DIN EN 12350-5,
- Air pore content in accordance with DIN EN 12350-7,
- Compressive strength after 28 days in accordance with DIN EN 12390-3,
- Density of hardened concrete in accordance with DIN EN 12390-7 and
- Water penetration depth in accordance with DIN EN 12390-8 (solely for the RC components of the foundation module).

Hardened concrete testing was effected on sample bodies in accordance with DIN EN 12390-2. Reliance was placed on the experience gleaned in previous research projects.

The RC components are to be constructively developed and designed in accordance with the dimensions drawn up in the project REMOMAB for flexible systems of the recycling living units (RC-LU). Nubs are arranged on the upper side of the wall design and pockets/recesses on the underside in order to facilitate the interlocking of the RC components without formworking the concrete. This enabled not only the stability of the wall design to be assured, but also the dismountability of the components.
To ensure custom adaptation of the LU, the development and dimensioning of suitable modules (blocks) for foundations and walls as well as suitable slabs for ceilings and walls (alternative) were undertaken.
The optimised solution of the developed module (prototype) is then produced by the concrete works Mattig & Lindner in Forst and then assembled on site. In the process, the results of the research were tested under practical conditions and thus the feasibility and usability verified.

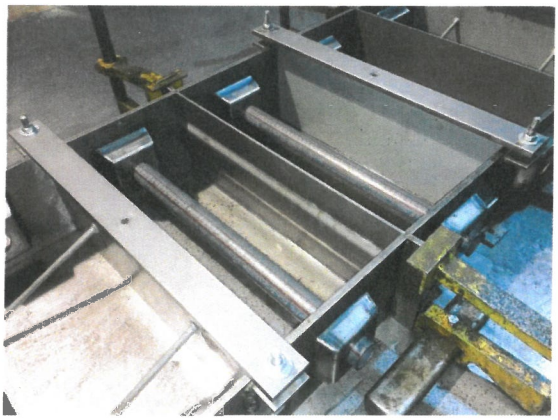


Figure 8 Formwork for the RC concrete half-sized stones

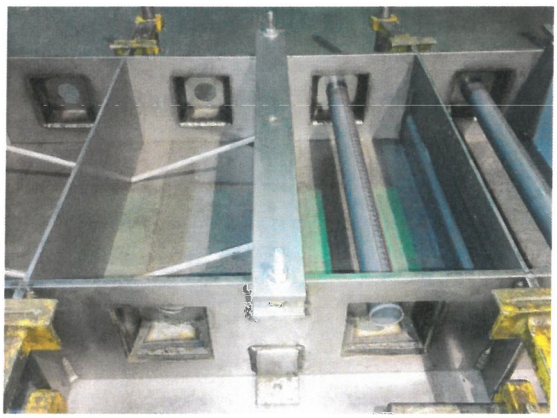


Figure 9 Formwork principle for half-sized stones

Figure 10 RC beams, concreting process

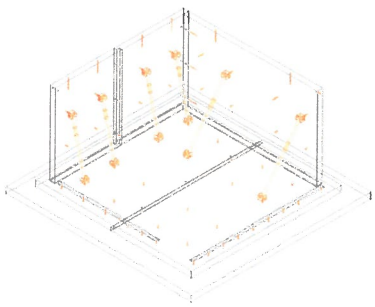
Figure 11 RC-beam, filling the RC beam

The process of series production can be based on the results of the individual manufacture to ensure the efficient production of the RC components and elements. Also required are the development of an efficient metering technique and the adaptation of the arrangement of the boxes for the secondary output materials, taking into account the local conditions of the production site. A mould is required for the individual stones that ensures better dimensioning, in particular for the half-sized stones (e.g. in battery form).

Figure 12 RC ceiling slab 1, formwork, connection technique

Figure 13 RC-ceiling slab 1, concreting

The assembly of the wall slabs is effected using the standard tools and equipment Figure 14



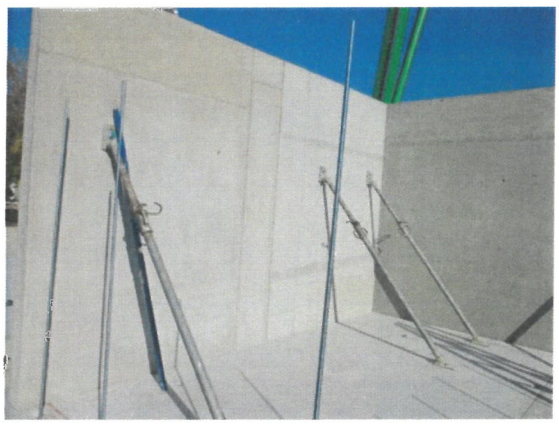


Figure 14 Assembly of the wall slabs by means of assembly supports

The wall stones are introduced using standard lifting and moving gear via the vertical armature bars. The vertical tensioning is effected at ceiling level, around the level of the window parapet).

The final project stage tested dismountability and the recyclability. The building was set up in Forst, stored and then transported to a new location, where it was rebuilt. This was effected in unfavourable weather conditions. However, it was demonstrated that the new building method was advantageous even under these conditions.

In the design and implementation of the building, the composite principle was entirely dispensed with. This was the only way to ensure a clean dismantling and reuse. The tension peaks arising due to the low tolerance can be absorbed easily by concrete components made of RC concrete.

Figure 15 Dismantling of a RC concrete stone with the angled pincers

Figure 16 Reassembly at the new location. Sealing against rising moisture on the concrete slab (left) – wall assembly (right)

Figure 17 Completely re-assembled module at the new location

Conclusion

The research project demonstrated that recycling concrete is suitable for use as load-bearing constructions that can provide living space whilst dispensing with the application of the composite principle. The hitherto permissible limits of RC granulation can be increased considerably upwards and this greatly contributes to the husbanding of resources and improvement in sustainability.
In the modular design of the draft of a home, the assembly as well as the dismantling of a solid building was assured. Thus, a decisive contribution can be made to reducing rubble and building waste. The expenditure of energy for dismantling can, in comparison to the margins usually found today, be reduced to an absolute minimum. However, it is still possible to move a building during its life cycle to respond to a change in requirements.

Core data

Brief title: Complete dismountable living units from resource-husbanding concrete - RCWE

Researcher / project management:

TU Dresden, Faculty for Architecture, Structural Planning,
o. Prof. Dr.-Ing. Wolfram Jäger (project management)
Dipl.-Ing. Hassan Youssef

Researcher for recycling concrete and its application:

BTU Cottbus- Senftenberg,
Faculty of Environment and Natural Sciences
Field of work – Building recycling
Siemens-Halske-Ring 8
03046 Cottbus
apl. Prof. Dr.-Ing. habil. Angelika Mettke
Dipl.-Ing. Stephanie Schmidt,
Dipl.-Ing. Viktoria Arnold

Project partners and sponsors

Mattig & Lindner GmbH C.-A.-Groeschke-Str. 15 03149 Forst	**mCon GmbH** In der Schlade 1 57258 Freudenberg
Ecosoil Umwelt GmbH Laugfeld 29	**DYWIDAG-Systems International GmbH**

01968 Senftenberg	Germanenstraße 8 86343 Königsbrunn

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