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RE[4] Project

REuse and REcycling of CDW materials and structures in energy efficient pREfabricated elements for building REfurbishment and construction

D3.1 Design concept for renovation Public summary of deliverable	
Author(s)[1]:	ZRS Architekten
Date:	06/11/2019
Work package:	WP3 - Innovative concept for modular/easy installation and disassembly of eco-friendly
Distribution[2]	This document is a public summary of the confidential deliverable D3.1 of RE[4] project.
Status[3]:	**Final**
Abstract:	D3.1 reports on design concepts for renovation of existing buildings. Existing buildings often demonstrate a very poor performance with regards to thermal insulation. The work therefore developed different concepts for the thermal optimization of existing building elements, mainly the building envelope. In a first step, suitable building typologies have been identified in order to select a specific building for a case study. In a next steps different façade concepts have been developed on the basis of either prefabricated half-timber panel from waste wood or in-situ solutions that offer a great level of flexibility based on CDW mineral materials. Furthermore, existing roofs have been covered as well, as the thermal upgrade of such elements has a major impact on the final

[1] Just mention the partner(s) responsible for the Deliverable
[2] PU: Public, RE: restricted to a group specified by the consortium, CO: Confidential, only for members of the consortium; Commission services always included.
[3] Draft, Revised, Final

	impact of overall energy demand of buildings.
File Name	RE4_D3.1_Design_concept_for_renovation_Public_Summary

Version	Date	Description	Written By	Approved by
V1.0	06.11.2019	Public Summary of D5.4	ZRS Architekten	

Introduction

Deliverable 3.1 summarises the results obtained by the RE^4 team involved in *Task 3.1– Design concept for renovation,* (ZRS, Vortex) of *WP3 – Innovative concept for modular/easy installation and disassembly of eco-friendly prefabricated elements.* The work focused on the design development of prefabricated and in-situ solutions for the thermal optimisation of the building envelope. Solutions are based on the integration of timber and mineral CDW.

At first, a suitable building typology for refurbishment was defined in order to carry out a case study development and verify the developed solutions. This exercise should maximise market viability and therefore the impact of the developed solutions For this aim a brief desk study on the European building stock has been undertaken based on previous work, carried out under Task 2.2, where the European building stock has been analysed in greater depth. As findings proofed to be useful also for this task, the results have been used to base the design development for the newly developed solutions on.

The regulatory framework, that has formed the basis of the design development, was investigated and very briefly presented. As the main purpose of this task was to improve the thermal performance of existing buildings, mainly thermal requirements valid in different European countries have been collated and used for the developed solutions. Furthermore, the developed solutions have been designed in such way, that they can be adapted in a flexible way to the thermal requirements of the different countries.

In a next step the the main design criteria for the architectural concept of the single elements were outlined. Reversible connections, the integration of a high portion of CDW as well as prefabrications have been the main drivers of the newly developed solutions. Key considerations have also been undertaken to improve the thermal and environmental performance of the building to meet highest energy efficiency standards for Northern Europe, while developing durable solutions. Roofs have also been addressed and a concept for a fully reversible green roof has been developed. The different solutions are described element by element. Details regarding the integration of windows, building plinths and the attic have also been provided. To demonstrate the architectural appearance of the developed solutions full elevations and section are included in the design development as well.

Suitable building typology for refurbishment

In order to determine a suitable building typology for the refurbishment with prefabricated RE^4 elements, it was decided to analyse the European building stock with regards to building typologies, building age and respective energy efficiency standard. The main findings, relevant for the study are summarised as follows:

- building stock in European Member States is relatively heterogeneous
- residential buildings compose the majority of floor area
- portion of residential buildings varies notably between countries
- majority of residential buildings consist of single family houses
- multy residential houses offer a greater level of repetition
- the majority of buildings were erected between 1945 and 1990

- 50% of the residential building stock was built before 1970, where the first thermal regulations came into force

The analysis identified building typologies that demonstrate a poor energy efficiency standard. The assumption is that such buildings demonstrate the highest potential for either deconstruction or refurbishment, as their energy efficiency performance is the worst in comparison to all other buildings. Therefore, they have been taken also for this exercise, where RE^4 prefabricated and non-prefabricated solutions for building renovation will be elaborated.

The majority of residential buildings consist of single family houses (e.g. detached, semi-detached and terraced houses), whereas apartment blocks constitute only 36%. However, the investigation focused on multifamily houses, which makes a prefabricated production of serial elements possible and therefore economical. The main construction method in Europe for multifamily houses is a solid construction with a single or a double leaf masonry wall and concrete floors.

Legal Requirements

Thermal Requirements

The new energy efficiency guideline, effective since December 2012, defines the framework for energy efficiency measures throughout Europe and determines the maximum energy in 2020 within the Union.

Maximum primary energy demand: 1483 million tons raw oil units
Maximum end energy demand: 1086 million tons raw oil units

The Energy Performance of Building Directive (EPBD), foresees that EU Member States shall take the necessary measures in order to ensure that minimum energy performance requirements are established with the goal of achieving cost-optimal levels. EU Member States do have their own national building code in line with EPBD guidelines. Table 1 summarises the thermal requirements for the targeted member states

	Dwellings (refurbishment of externall walls)			Other Buildings (refurbishment of externall walls)		
Country	U- Value in W/m²*K min	U- Value in W/m²*K max	RE4 Target value	U- Value in W/m²*K min	U- Value in W/m²*K max	RE4 Target value
Germany		0,28	0,18		0,28	0,18
Italy*						
Zone A-B						
Zone C		0,34	0,34		0,34	0,34
Zone D						
Zone E						
Zone F						
Spain						
Climatic Zone A1- A4		0,94				
Climatic Zone B1- B4		0,82				
Climatic Zone C1- C4		0,73				
Climatic Zone D1- D4		0,66	0.30-0.60			
Climatic Zone E1- E4		0,57				
Sweden						
Heated area ≥ 50 m²		0,4***			0,6***	
Heated area < 50 m²		0,33***			0,33***	
Rec. external walls****		0,18			0,18	
UK						
England, Northern Ireland	0,18	0,3**	0,24	0,26	0,30**	
Scottland	0,15	0,22**		0,18	0,27**	

KEY
* Values valid from 01. January 2019 / 2021
** Limiting u-value, that considers thermal bridges, openings, etc.
*** Average counted on all enveloping surfaces incl.
**** Recommended value for external walls (excluding windows, doors etc)
Location of demonstrator

Figure 1 - **Target values defined for the building refurbishment**

Fire Protection

Although fire safety for building elements for refurbishment is not investigated and tested within the RE^4 project, legal requirements are taken into consideration. As rules and standards for fire protection differ significantly across the EU and even in countries, such regulations are defined by the federal states, Germany as a country with stringent standards, and namely Berlin and its regional building regulations has been taken as a reference for the development of the RE^4 solutions.

Structural requirements

For the static design dead loads and wind loads (DIN 1055-4) have to be taken into consideration. In certain cases also snow, ice or other additional loads (scaffolding, lighting etc.) have to be considered.

In the following cases DIN 18516-1 sets out requirements for the stability of the substructure as well as their anchorage:

- Building height > 8 m
- single size clothing > 0.4 m2
- Individual weight of façade element > 5 kg

Design Concept

The following RE^4 goals were taken into the consideration for the development of the design concepts for both solutions.

- Integration of waste wood
- Integration of CDW in concrete components
- Reversible connections
- Prefabrication

The design of the different elements follows the above mentioned standards. Both European climates, the cold and the warm climate have been covered. For the prefabricated timber element, thermal requirements applicable in Germany have been considered, whereas for the development of the solution based on mineral CDW, Italian standards were taken into account. Additionally, certain aspects regarding the durability of building elements or occupants comfort have been further elaborated as they are considered as important.
In addition, the following design criteria were taken into consideration:

- Thermal protection in Winter
- Driving rain
- Durability
- Transportation

Design Proposal Prefab Timber Façade Panel

The panel is constructed as a wood frame with studs. The frame is designed according to the panel size, which was defined according to the façade division. The frame accommodates a regular grid of studs, on a 62.5 cm grid, which derives from the standard measure for timber construction. The center distance of the studs is based on standard sizes for dry construction in Germany and ensures a speedy workflow in the prefabrication process. If the width of the panel does not fit to the grid or window frames, studs have to be accommodated and additional studs can easily be placed. In such cases the studs supporting the window have to be strengthened. Figure 1 shows the distribution and the integrated window frame of the chosen panel. Figure 2 shows the element build-up and the respective single layers in sections.

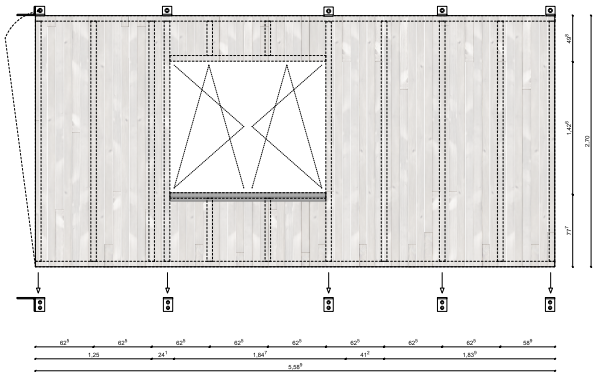


Figure 1 – **Dimensions and mounting points prefab timber façade panel**

For the mounting of the panel, the existing exterior plaster will be locally removed in order to pre-mount the metal brackets which form the support for the panel on the façade. The distribution of the angles must be carried out according to static calculation. After the positioning and fixing of the Panel on the brackets. The module will be fastened against tilting on the façade via smaller metal brackets already attached to the panel (Figure 1). In order to be individually reversible there is a vertical gap 30 cm between the panels.
After two horizontal rows of panels are fixed, the gap is filled with insulation and covered with a wood fibre board and the weather shell.

For a disassembly of one panel this filler must be removed first in order to loosen the panel from its metal brackets (Figure 2).

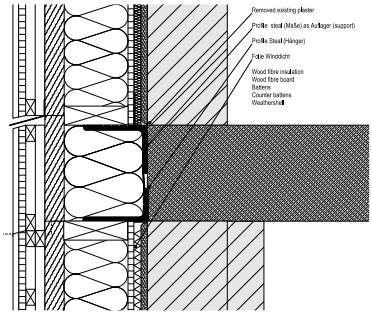


Figure 2 – **Detail drawing of vertical section through the Anchoring**

Figure 3 provides an elevation of the panel, applied on all floor levels and shows also the arrangement and fixation in plan and section.

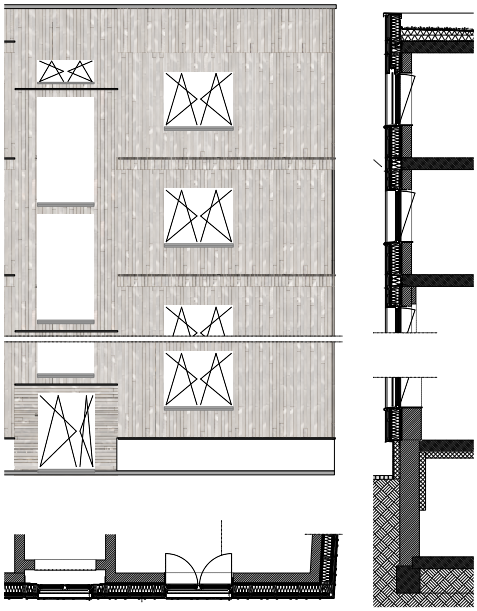
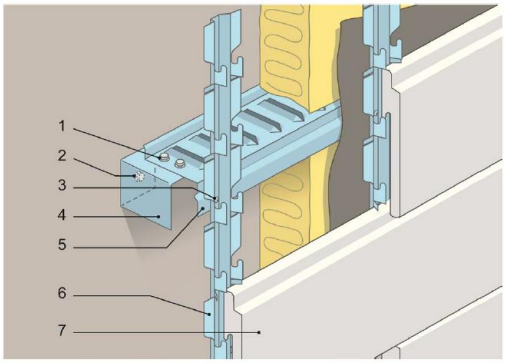


Figure 3 –**Regular wall construction of the panel**

Design Proposal Concrete-Based Façade Panels

Marmoroc® is a patented ventilated exterior wall cladding system consisting of cladding elements made of non-reinforced extruded concrete stones, installed on a metallic frame fixed to the wall.

Sweden company Marmoroc AB Box 274 SE-731 26 Köping, Sweden is the owner of the patent. The system is Type approved by Sitac (Swedish Institute for Technical Approval in Construction) in accordance with BBR sector 6:532, 5:63, 5:631 and BKR sector 2:111 (approval no. 1356/70). The Marmoroc®stones and the fixing system are classified as non-load-bearing construction elements in façades. The cladding system does not contribute to the stability of the wall on which it is installed. Any tightening material such as mortar or similar is required. The cladding system is not water tight, but capable to offer rain protection to the walls on which it is installed. The reaction to fire of the external wall cladding system Marmoroc® is Class A1 as per EN 13501-1**Error! Reference source not found.** [**Error! Bookmark not defined.**]. The Marmoroc® system has European Type approval ETA 16/0847. Figure 4 shows the typical fixing system to the substrate wall.



1 **Screws**, connect distance lath with wall distance, FZB ETA 10/0184*
2 **Screws**, connect into existing wall/construction, FZB ETA 08/0190*
3 **Screws**, connect mounting rail with distance lath, Bright galvanized ETA 10/0180*
4 **Wall distance**, hot dipped galvanized steel, S250GD + Z 275
5 **Distance lath**, hot dipped galvanized steel, S250GD + Z 275
6 **Mounting rail Nordic**, hot dipped galvanized steel, S250GD+Z275 / **Mounting rail Nordic**, hot dipped galvanized steel painted with polyester (25 µm) on the exposed surface and painted with polyester (8 µm) on the not exposed surface, S350 GD ZMA
7 **Marmoroc NORDIC**, unreinforced tiles of cement and crushed marble

* Screws where all relevant performances are equal or better may be used.

Figure 4 – **Marmoroc® fixing scheme with steel items description**

Marmoroc® cladding system thermal insulation considerations

CDW-derived stones are extruded elements based on the Marmoroc® system and with a replacement of virgin aggregates with CDW-derived aggregates.

Mix design foresees the following ratios:
w/c= 0.25
a/c= 3

Where:
w stands for water
c stands for Portland cement
a stands for aggregate.

Since Marmoroc® stones has a main aesthetic purpose, finishing surface aspect plays a fundamental role. One of the goals of the RE^4 Project was to develop eco-sustainable building components containing up to 65% by weight of CDW-derived materials; to this aim, tests carried out in WP^4 revealed that an acceptable compromise has been achieved using a 85% in weight of CDW aggregate together with a 15% in weight of fine sand (Figure 5**Error! Reference source not found.**). Stones produced only with 100% CDW-derived aggregate were not deemed to conform an acceptable quality standard (Figure 6**Error! Reference source not found.**).

Figure 5 – **Marmoroc® Baltic stones with 100% CDW replaced aggregate**

Figure 6 – **Marmoroc® Baltic stones with 75% CDW replaced aggregate.**

The mounting rails of the Marmoroc® system are attached direct to the wall with screw or nails and they are shaped in way a ventilated air space of approx. 15 mm appears between the stone and the existing wall. A special distance beam (steelstud) is used in case of added insulation needed. Marmoroc® stones are hooked to the metallic.
The final aspect of a cladded wall is as per Figure 7

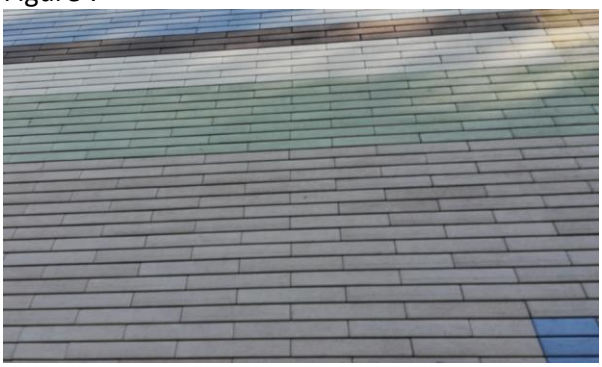


Figure 7 – **Marmoroc® façade panel**

Design Proposal Green Roof

Green roofs are an effective measure to increase the thermal insulation of a building and therefore to reduce the overall energy consumption. This is relevant for both, the Northern European but more importantly the Southern European climate. Through effective UV protection of the waterproofing level and the entire roof construction they lead to reduced maintenance and operating costs.

Furthermore, green roofs improve the microclimate climate and provide a compensation area for an occupied site and respective areas for rainwater infiltration. On a social level, they increase the residential and recreational value of buildings.

To favour the reversibility of the developed solution for the roof, the construction above existing roof consists of a vapour barrier, a reversible wood fiber board insulation mat and a seal. On top of this construction an off-shelf products on the market, which use velcro connections for the roof seal can be applied. On this layer either gravel or a green roof can be installed. By renouncing glued or sealed connections between the different materials, the reusability of the single elements increase and furthermore the unmixed disposal can be accomplished after its end of life. Figure 8 shows the design concept of a reversible roof construction including details for the attic, including the provision of a green roof.

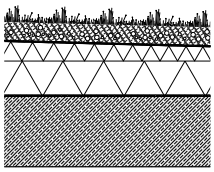


Figure 8 – **Detail reversible green roof**

Results

PREFABRICATED TIMBER PANEL

Integration of recycled waste wood

A full replacement of virgin material with CDW derived from dismantled old wood is possible and the product quality can be even better as it is anticpated that historic wood is already completely dried out. However, this assumption has to be further investigated. As mentioned before, the components manufactured within the RE^4 project enable a 100% replacement of virgin material. It is assumed that the commercial wood fibreboards can also be manufactured on the basis of 100% recycled timber, this has however to be proved.

Prefabrication

Based on an extensive analysis of the existing building with increasingly accurate measuring instruments the use of prefabricated elements brings significant advantages for the refurbishment of the existing building stock. Through very precisely calculable installation plans the assembly on site can be very fast and therefore it will have a positive impact on cost.

Ease of repair and maintenance

The prefabricated timber elements allows for an easy repair of all layers down to the core of the wall. If the weather shell, which is exposed to the ambient conditions is affected, timber slats can easily be exchanged as all connections are visibly screwed. If the substructure has to be repaired, battens and counters battens can also easily be unscrewed. If a renewal of the insulation layer is required due to e.g. water damage, repair can be arranged in the same way by unscrewing the weather shell, battens and the wood fibre board to exchange the insulation.

MARMOROC SYSTEM

The façade system proposed offers an esthetical wall cladding finishing coupled to an easy mounting-demounting installation procedure and with the chance of introducing insulating panels in the air gap between the substrate wall and Marmoroc® stones.

The system is a fairly flexible cladding system, which does not require any grouting at all. Extruded stones are hooked directly on a metallic frame screwed on the substrate wall. The system allows to put in place ventilated

façades with the possibility of adding insulating panels between the substrate wall and the finishing extruded stones layer. Single stones replacement is easy to implement as well. The stones itself demonstrate a CDW replacement of 85% in weight.
The manufacturing and assembly concepts can be transferred in full to the extruded stones produced with a partial replacement of virgin materials with CDW derived aggregate, making convenient future dismounting operations.

Conclusions

Solutions for the energetic refurbishment of the existing buildings were developed. The solutions cover the building envelope, namely the thermal upgrade of existing facades as well as existing roofs. The developed solutions look into the integration of CDW on the basis of mineral aggregate but also timber and range from prefabricated panels (timber) to a more customised system (concrete), which is suitable for more individual solutions or in cases, where architectural features make prefabrication inefficient.

Advantages of the RE^4 refurbishing method

The newly developed prefabricated RE^4 panel for refurbishment offers improvements for existing buildings regarding the following aspects:

- architectural renewal
- improvement to the buildings energy efficiency and increased living comfort
- high degree of prefabrication
- high level of repair and maintenance
- replacement of virgin material use of recycled timber materials in façade elements
- modification of façade materials and openings
- time efficient installation through prefabrication and therefore less noise and disturbance
- maintenance oriented and end-of-life design utilising LCA methods
- product endorsing an ecological lifestyle of health and sustainability