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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

D5.2 Development of prefabricated components Public summary of deliverable	
Author(s)[1]:	QUB, CETMA, VORTEX, ZRSA
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Work package:	WP5 - Development of precast components and elements from CDW
Distribution[2]	This document is a public summary of the confidential deliverable D5.2 of RE^4 project.
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Abstract:	D5.2 summarises the results obtained by the RE^4 team involved in Task 5.2 – *Development of prefabricated components*. The work in this task focused on the development of prefabricated components (building blocks, reconstituted tiles, timber beams and columns and insulation panels) made of different sorted CDW fractions, delivered by CDE from recycling centres in Southern and Northern Europe.
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[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*

Introduction

Deliverable D5.2 summarises the results obtained by the RE4 team involved in Task 5.2 – *Development of prefabricated components* (QUB, CETMA, VORTEX & ZRSA).

Several types of prefabricated elements and components were developed using building materials either developed in Task 5.1 – *Development of materials incorporating CDW, Portland cement and alkali activated binders* (CETMA, RISE, CBI, QUB, ZRSA, ACCIONA & NTUST) or specifically developed in Task 5.2 (e.g. Portland cement semi-dry mix). These building materials were in turn, based on the CDW sorted fractions (i.e. mineral fractions, lightweight fractions and large pieces of timber) analysed and characterised as part of Task 4.2 – *Characterisation of CDW-derived materials* (QUB, RISE, CETMA, VORTEX & ZRSA), Task 4.3 – *Variability of the chemical-physical features of CDW-derived materials and effect on technological properties of developed products* (QUB, RISE & CETMA) and Task 4.4 – *Definition of quality classes for utilisation in different applications* (RISE, QUB, ACCIONA, CREAGH, CETMA, VORTEX & ZRSA). More specifically, the following types of prefabricated elements and components were developed:

- Building blocks
- Reconstituted tiles
- Timber beams, columns & weatherboarding
- Insulation panels

Building blocks (QUB) are intended for non-structural elements (e.g. internal partitions and external non-load bearing walls) and were developed using a Portland cement semi-dry mix based on a combination of CDW sorted mineral fractions (0/2, 2/8 & 8/16 mm). Compressive strength and wet density were used as performance indicators. Partial replacement of virgin aggregate by the above CDW sorted mineral fractions was achieved, while complying with compressive strength and fresh density requirements.

Reconstituted tiles (CETMA & VORTEX) were developed using two different production methods: moulding by casting and extrusion. Moulded tiles are intended for floors and walls and were developed using 100% ceramics (bricks & tiles) fine aggregate (0/4 mm) coming from unsorted CDW and bound by a suitable resin. Density, water absorption, flexural and compressive strength were used as performance indicators.

Extruded tiles, on the other hand, are intended for roofs and were developed using virgin sand (0/2 mm), CDW sorted mineral aggregate fraction 0/2 mm and Portland limestone cement. Flexural strength and water permeability were used as performance indicators. Full replacement of virgin sand by CDW sorted mineral fraction 0/2 mm was achieved.

Timber beams, columns & weatherboarding (ZRSA) were developed using large timber pieces obtained from four different deconstruction sites in Berlin. In-situ testing and chemical analysis were performed to assess the condition of timber. In addition, assessments related to decay and defects such as location and extent of cracks and branches as well as direction of grains were performed. Based on the above results, timber pieces were cleaned by removing any foreign objects and impurities and then reprocessed in order to obtain lamellas. The lamellas were then joined together using either glue or glueless connections for getting beams, columns and weatherboarding of specified dimensions.

Insulation panels (CETMA) were developed by using two different types of lightweight fractions: wood fibres or rigid plastic (RP) particles.

Performed research work

Building blocks

CDW sorted mineral aggregate fractions (0/2, 2/8 & 8/16 mm) were used to fully or partially replace virgin aggregate in a Portland cement semi-dry mix for making building blocks (Figure 1). The aims of the above investigation can be summarised as follows:

- Assess the impact of recycled aggregate on building block mix.
- Design a building block which is able to achieve a compressive strength of at least 7.3 MPa at 28 days.
- Target recycled aggregate content of 100%.

Initially, control blocks were prepared using several types of virgin aggregate (VA) obtained from different sources. Next, blocks were prepared using 100% recycled aggregate (sorted mineral fractions) coming from N-EU and S-EU, so as to assess the effect of different sources on strength. Finally, a third set of blocks was prepared by replacing 50% of virgin aggregate by N-EU and S-EU recycled aggregate. In addition, different levels of vibro-compaction leading to different percentages of air voids and hence wet density values were investigated. Replacement of virgin by recycled aggregate was done on a volumentric basis.

Figure 1: Building blocks made using a semi-dry mix

Reconstituted tiles

Unsorted ceramic CDW materials (e.g. bricks, tiles) and CDW mineral aggregate of different sizes (i.e. from fine sand up to 5/6 mm) were used in order to develop reconstituted tiles for different applications, such as floor, wall and roof tiles. Two different production processes were investigated: (a) moulding by casting and (b) extrusion.

Moulding by casting process (Figure 2) was optimized for the production of reconstituted tiles from CDW, bound by resin, to be used as floor or wall tiles. Different percentages of CDW in the mix were tested, in order to maximize their recycling rate while at the same time, ensuring suitable mechanical performance.

Fine CDW mineral fraction (0/2 mm) was used to replace up to 100% of virgin sand.

Figure 3: Extrusion process

The physical and mechanical properties of moulded by casting tiles were determined according to EU standards (Table 1). Next, a correlation between their mechanical properties and the size of unsorted CDW materials was investigated.

In the case of tiles obtained by extrusion, their mechanical properties were assessed according to EU standards reported in Table 1 and then compared against the values obtained for control samples made using 100% virgin aggregate.

Table 1: Types of physical and mechanical tests performed on tiles

Property	Standard	RE4 partner
Moulding by casting process		
Density & adsorption	EN 14617-1	CETMA
Flexural strength	EN 14617-2	CETMA
Compressive strength	EN 14617-15	CETMA
Extrusion process		
Flexural strength	EN 490-491	VORTEX
Permeability	EN 490-491	VORTEX
Freeze and Thaw	EN 490-491	VORTEX

Figure 2: Moulding by casting process

Extrusion process (Figure 3) was optimized for the production of reconstituted tiles bound by Portland cement paste to be used as roof tiles.

Timber beams, columns & weatherboarding

As CDW timber provided by RE4 partner CDE mainly consisted of low quality small pieces, large CDW timber pieces were directly obtained from four different deconstruction sites in Berlin. In-situ assessment was used to determine wood species and moisture content. Next, a chemical analysis was performed by an accredited laboratory to determine the presence of any chemical treatments. Finally, further assessments related to decay and defects such as location and extent of cracks and branches (Figure 4) as well as direction of grains were performed. Based on the above results, timber pieces were cleaned and then reprocessed in order to obtain lamellas (Figure 5). The lamellas were then joined together to obtain beams, columns and weatherboarding (Figure 6) of specified dimensions.

Figure 4: Assessment of branches

Figure 5: Lamella production for making timber beams

Figure 6: Examples of weatherboard made of CDW timber

Insulation panels

Wood fibres and plastic scraps from CDW were used in order to develop wood fibre and composite plastic panels, respectively. Wood fibre panels were developed using a moulding under pressure process, whereas composite plastic panels were developed by mixing RP particles with polyurethane (PU) foam.

The moulding under pressure process was optimized for the manufacturing of wood-based insulation panels (Figure 7). Bulk densities were optimized by testing different sizes of wood fibres, in order to achieve the desired insulation performance. Physical and mechanical properties of the produced wood–based panels were also investigated. In addition, mineralization of wood was performed in order to improve its fire resistance.

Figure 7: Insulation panel made of CDW wood fibres

CDW RP particles were used for the manufacturing of insulation panels by foaming a resin using a blowing agent (Figure 8). The production process was adjusted in terms of resin content (to maximize the content of rigid plastic waste from CDW).

Figure 8: Insulation panel made of CDW rigid plastics

The physical and mechanical properties of wood fibre and RP insulation panels were assessed according to EU standards as shown in Table 2.

Table 2: Types of physical and mechanical tests performed on insulation panels

Property	Standard	RE^4 partner
Wood based panels		
Density	EN 13171	CETMA
Compressive stress at 10% strain	EN 826	CETMA
Design thermal conductivity	EN ISO 10456	CETMA
Rigid plastic based panels		
Density	EN 1602	CETMA
Thermal conductivity	EN 12667	CETMA
Compressive stress at 10% strain	EN 826	CETMA

Conclusions

Building blocks

- Replacing 100% of virgin aggregate by N-EU and S-EU recycled aggregate lead to a significant reduction in strength. As such, building blocks made using 100% recycled aggregate failed to satisfy the requirement for strength.
- Partial replacement of virgin aggregate by N-EU and S-EU recycled aggregate lead to a relatively small decrease in strength. However, it should be noted that up to a certain replacement level, building blocks were able to satisfy the requirement for strength without increasing the cement content or reducing the percentage of air voids.

Reconstituted tiles

- Results showed that it is possible to manufacture moulded by casting reconstituted tiles by using CDW ceramic (bricks & tiles) particles.

- The properties of reconstituted tiles obtained using a moulding process are influenced by the following parameters (a) ceramic aggregate size and (b) aggregate/binder ratio.
- Results showed that it is possible to manufacture extruded tiles by fully replacing virgin sand with CDW mineral fine aggregate.

Timber beams, columns & weatherboarding

- Results showed that recycling rates for making beams and columns from CDW timber are close to 100%.
- For weatherboards durability tests are still ongoing. The results of these tests will show how well the lifespan of weatherboards made of CDW timber compares against weatherboards made of virgin timber.

Insulation panels

- Results showed that it is possible to manufacture wood fibre insulation panels from CDW by moulding under pressure. The manufacturing process and properties of the final product are highly influenced by temperature and duration of moulding under pressure.
- Results showed that mineralisation of wood fibres improved their fire resistance.
- Results showed that it is possible to manufacture insulation panels using CDW RP particles mixed with polyurethane (PU) foam. The properties of the final product are highly influenced by the volume ratio of rigid particles to that of PU foam.