METABUILDING 1st GROW / HARVEST CALL : MEET THE WINNERS !

DeConStRACtion

Towards Next-generation Deconstructable Concrete Structures made of Recycled Aggregates from Construction & Demolition Waste (CDW)

SECTORS INVOLVED : Construction · Circularity & Recycling

ITALY

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SWITZERLAND

"The project aims to define a concept for 'deconstructable' buildings made by prefabricated concrete elements incorporating Recycled Aggregates from construction and demolition waste."

Dr. Marco Pepe
CEO · TESIS

"The project will allow our company re-fer AG to expand our product and application range by developing reusable concrete elements from recycled aggregate material and an innovative and recyclable iron-based shape memory alloy for prestressing."

Dr. Julien Michels
Dipl. Bauing. EPF SIA, MBA-HSG
re-fer · Managing Director

metabuilding

SECTOR INVOLVED: #Construction #Circularity & Recycling

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DeConStRACtion

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Introduction

Introduction

Motivation: use of Construction & Demolition Waste

The increase in urbanization has led to an **unprecedented generation of CDW**, as it is considered as **one of the most relevant issues due to its environmental, economic and social impacts**.

There is a **growing trend in the consumption of aggregates in construction** since global demand is expected to increase from 45 (in 2017) to 66 (by 2025) billion tons.

RAs from CDW are still significantly under-exploited and, without a clear entry point into the circular economy model, the comprehensive set of EU policies cannot be achieved.

CDW recycling is an opportunity to extract economic and environmental benefits from waste and is therefore a business activity in which it is worth investing.

Introduction

Motivation: modular structures

In recent years, many authors have investigated the role of innovative cement-based structural systems in reducing the dead loads, increasing durability and extending the building lifespan through using advanced materials such as ultra-high or very-high-performance cementitious composites, allowing the minimization of the concrete volume.

On the other hand, very limited attempts to reuse concrete building elements are documented in the literature: current trends, in fact, produce structures devised to maximize the construction speed, ignoring future deconstruction, transformation capacity and reuse.

This clearly collides with the evidence that, with reference to concrete bearing members, 75 to 95% of the whole environmental impact is generated in the production phase.

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Consortium

Consortium

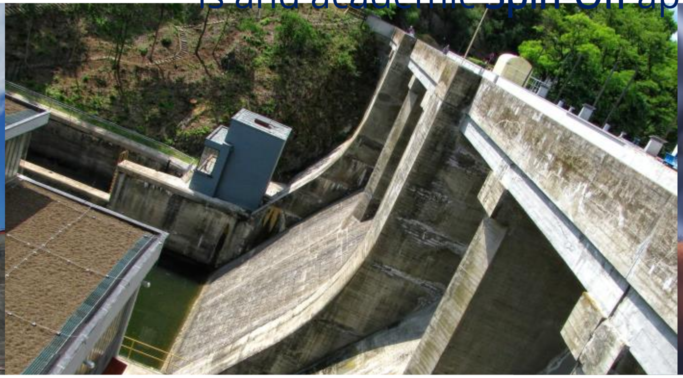
The project combines the expertise of SMEs working on concrete sustainability (**TESIS srl**) and innovative prestressing systems (**re-fer GA**) and will benefit of the support of a relevant academic institution (**Politecnico di Milano**) traditionally close to the precast concrete industry.

Consortium

TESIS srl - IT

***TESIS** (**T**ecnologie **E**mergenti a **S**ervizio dell'**I**ngegneria **S**trutturale) s.r.l.*

is and academic **Spin-Off** approved by the **University of Salerno**.



The main objective of TESIS s.r.l. is to promote the use of **innovative and sustainable cement materials** also through the implementation of **emerging methodologies for diagnostics and structural monitoring** and supported by **advanced simulation tools**.

The activities of TESIS s.r.l are organised in the following operating sectors:

- Materials
- Diagnostic and monitoring
- Modelling

Consortium

metabuilding

TESIS srl - IT

Materials: development of innovative procedures, techniques and technologies for the "formulation« of cement-based composites, also based on the use of recycled constituents, so that they for meeting the several requirements for structural applications.



SERVICES & PRODUCTS

- **Mixture proportioning of "green" concrete mixtures** both cast in situ and for the realization of prefabricated elements, also in light of the new Italian Technical Standards for Construction 2018 and the European Directive 98 of 2008 aimed at promoting the use of construction and demolition waste (up to 70%, by weight by 2020) with the dual objective of reducing the demand of natural resources and minimizing the landfills disposal of these waste.
- **Formulation** and **prediction** of **mechanical properties** and **durability** of cementitious matrix composites with **unconventional reinforcement** (fibers / fabrics).

Consortium

re-fer AG - CH

Milestones

2012 – Creation of the company as an Empa spinoff
2014 – First industrial production of memory®-steel
2017 – Pilot application on-site
2020 – Creation of first franchisees outside Switzerland

Currently 5 employees (structural engineers, commercial assistants, technical specialist)

Our vision

We are aiming for global market leadership in memory®-steel prestressing techniques. Our proximity to the customer worldwide, plus our technical expertise and practical experience, enable us to combine research and development with best practice on-site. memory®-steel is 100% recyclable and contributes positively to sustainability. Through continuous development and patents, we intend to secure the long-term competitiveness of re-fer.

Our mission

By increasing the service life and strengthening of existing built infrastructure, we are adding value for our customers. Upgrading and repurposing of existing structures also helps to protect the environment more than with new constructions. Prestressing new concrete floor/deck slabs can also eliminate the need for downstand beams. We provide designers with better reinforcing solutions for the producing filigree concrete elements.

Consortium

re-fer AG - CH

Retrofitting system supplier and technical consultancy

Innovation in structural maintenance due a novel iron-based shape memory alloy, the «memory®-steel» - **self-prestressing steel upon heating**

Externalls end-anchored re-plate

Ripped re-bar in sprayed mortar

Smooth re-bar R18 with mechanical anchorage

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re-fer AG - CH

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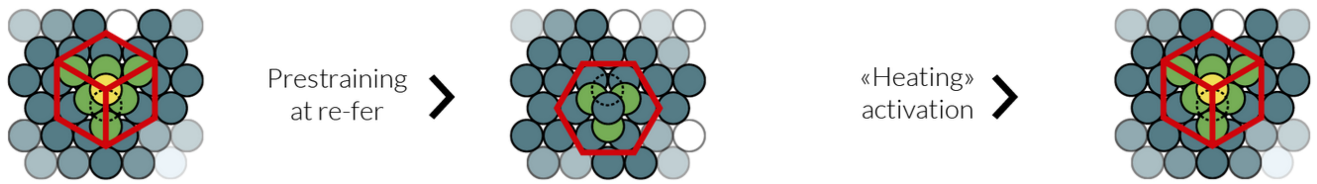
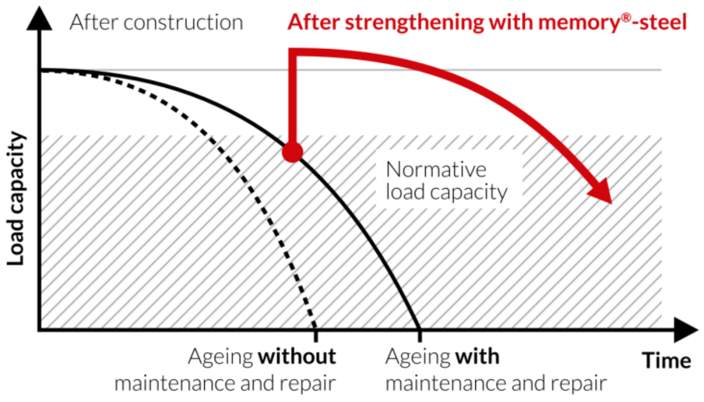
Austenite		Martensite		Austenite

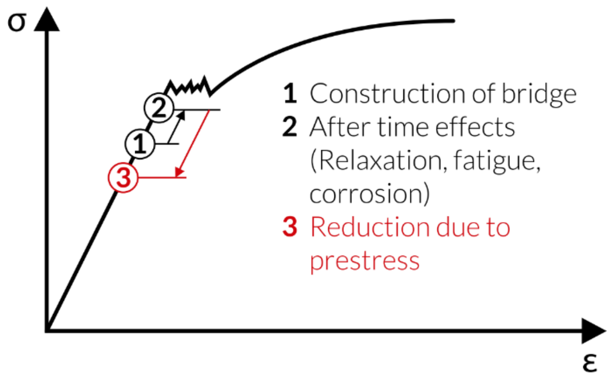


Initial alloy at steel plant	Delivery and installation on site	Reconversion in the structure: **Prestressing when shape recovery is prevented**

Service life:



Stress in existing reinforcement:



1 Construction of bridge
2 After time effects (Relaxation, fatigue, corrosion)
3 Reduction due to prestress

Consortium

Service provider: PoliMI

The Politecnico di Milano – Department of Civil and Environmental Engineering (DICA) ranks first among Italian universities and 7th worldwide in Subject "Civil and Structure Engineering". The DICA has a strong expertise in the **research field of prefabricated concrete structures** and, enhancing the transversely among the disciplines characterizing the civil and environmental engineering is one of the main aims of the Department, so that the problems of the sector can be dealt with using an integrated approach.
The DICA also works in the field of **mechanical characterization of construction materials and structures** and is equipped with laboratories devoted to the mechanical characterization of traditional and advanced cementitious materials, both in standard and extreme conditions and on the experimental testing of full-scale load-bearing members.

Innovation Mentoring - Support in the conception and the **prototyping of innovative cement-based materials and structures**: support in the conception of innovative thin-walled structural components made with recycled aggregates;

Technical Analysis and Assistance - Experimental validation of construction materials and full-scale structural components, through the support of the testing infrastructures available at the Politecnico di Milano: prototyping and **experimental validation of 4 full-scale structural components** made with ordinary concrete or concrete with recycled aggregates.

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Aims & Scope

Aims & Scope

Objectives

Making the **construction sector greener** is one of the main global challenges and, one of the most promising actions is based on recycling **Construction and Demolition Waste** (CDW) for being re-used within the same sector.

The construction sustainability can be further amplified through the **production optimization, assembly and deconstruction/reuse procedures and the service life maximization**.

This project explores the possibility to define a concept for **deconstructable buildings made by prefabricated concrete elements incorporating Recycled Aggregates (RAs) from CDW**. The concept is based on assembling duly sized and designed prefabricated blocks by means of an **innovative memory®-steel prestressing techniques** on site.

The target building typology is that of highly **modular structures**, demanding high construction speed and the possibility of reconversion of internal spaces.

This collaborative innovation project receives funding in the framework of the METABUILDING project funded through the H2020-INNOSUP programme directed by the European Innovation Council and SMEs Executive Agency (EISMEA)

Ams & Scope

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Objectives

Several issues will be targeted to achieve the project goal:

- A detailed characterization of **Recycled Aggregates** from CDW
- Proper **mixture proportioning** will lead to durable Recycled Aggregate Concrete members;
- The most appropriate **structural configuration** will be considered for achieving deconstruction capabilities;
- **A proof of concept** will be designed, produced and tested.

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Implementation

Implementation

Work Plan

Task 1: Selection of prefabricated elements typology

Task 2: Processing of CDW and production of structural RACs

Task 3: Thin & high-performance prefabricated elements: design for disassembling

Task 4: Life-Cycle and Cost analysis approach

Task 5: Experimental tests on prototypes

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Task 1: Selection of prefabricated elements typology

Phase 1 – Best practices in precast concrete production (buildings)

Precast concrete production aims at optimizing time flows on site as well as reducing required material consumption. Element geometry in building construction typically ranges from hollow core (left), partial slab elements (to be complemented with concrete on site – middle) and beam elements (right)

The project investigations use hollow-core slabs (left) to assess new deconstructable erection methods

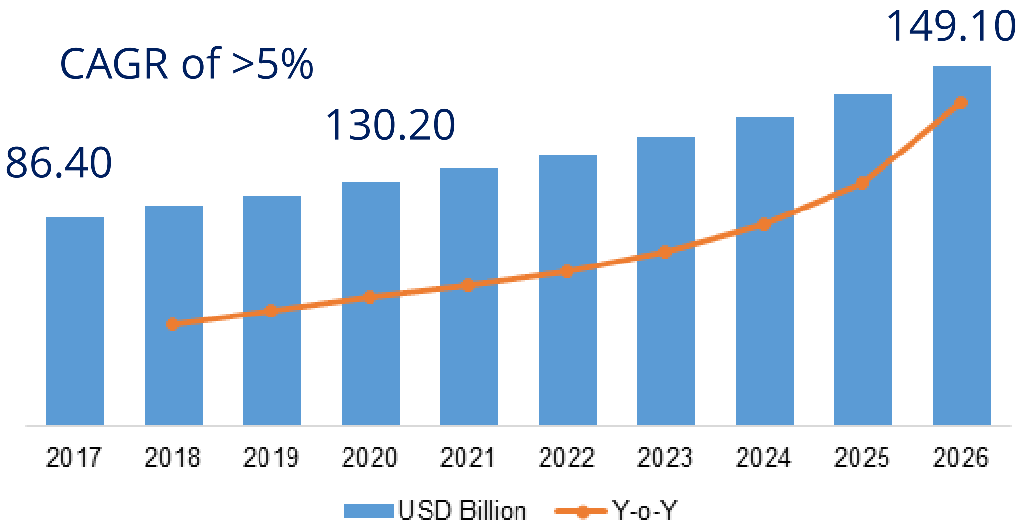
The aim is to combine positive aspects from current precast technology and to eliminate drawbacks via an improvement for deconstructable elements

Implementation

Task 1: Selection of prefabricated elements typology

Phase 2 – Market size

Precast market is continuously increasing – a large part comes from permanent modular buildings (>60% are used for residential and commercial buildings, strongly used in Asia)



Goal of the project is to ensure a transfer from permanent to non-permanent / re-erectable modular building systems

Implementation

Task 2: Processing of CDW and production of structural RACs

Phase 1 – Protocol processing procedure for RAs from CDW

Compound	***Recycled aggregate type***	
	A	***B***
Concrete debris	> 90 %	> 50 %
Natural aggregates + Concrete debris	> 95 %	> 70 %
Masonry	< 10 %	< 30 %
Bituminous materials	< 1 %	< 5 %
Floating stone materials	< 2%	< 2 %
Deleterious materials, cohesive materials, plastics, rubber, ferrous and non-ferrous metals, putrescible materials, glass	< 1%	< 2 %

EN 206:2016 - Definition of Recycled Aggregates

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Task 2: Processing of CDW and production of structural RACs

Phase 1 – Protocol processing procedure for RAs from CDW

CDW processing

Centrifugated Reinforced Concrete poles

Demolition

Processing

Recycled Concrete Aggregate

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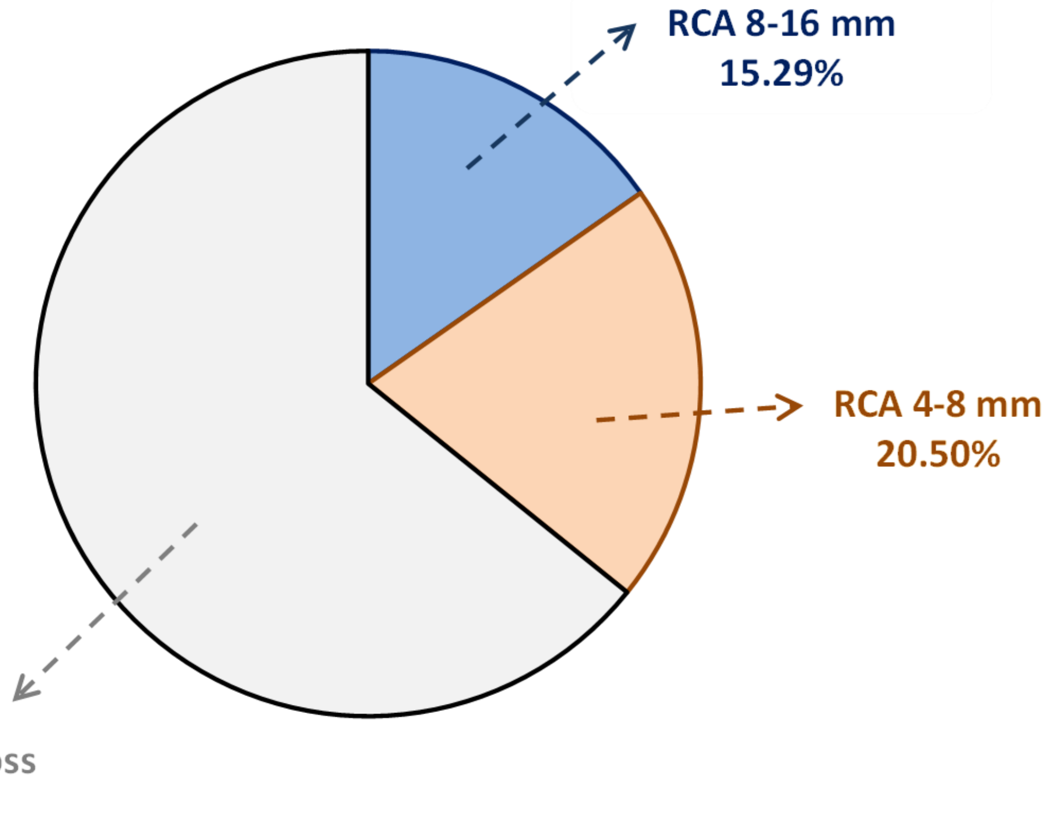
Task 2: Processing of CDW and production of structural RACs

Phase 1 – Protocol processing procedure for RAs from CDW

CDW processing

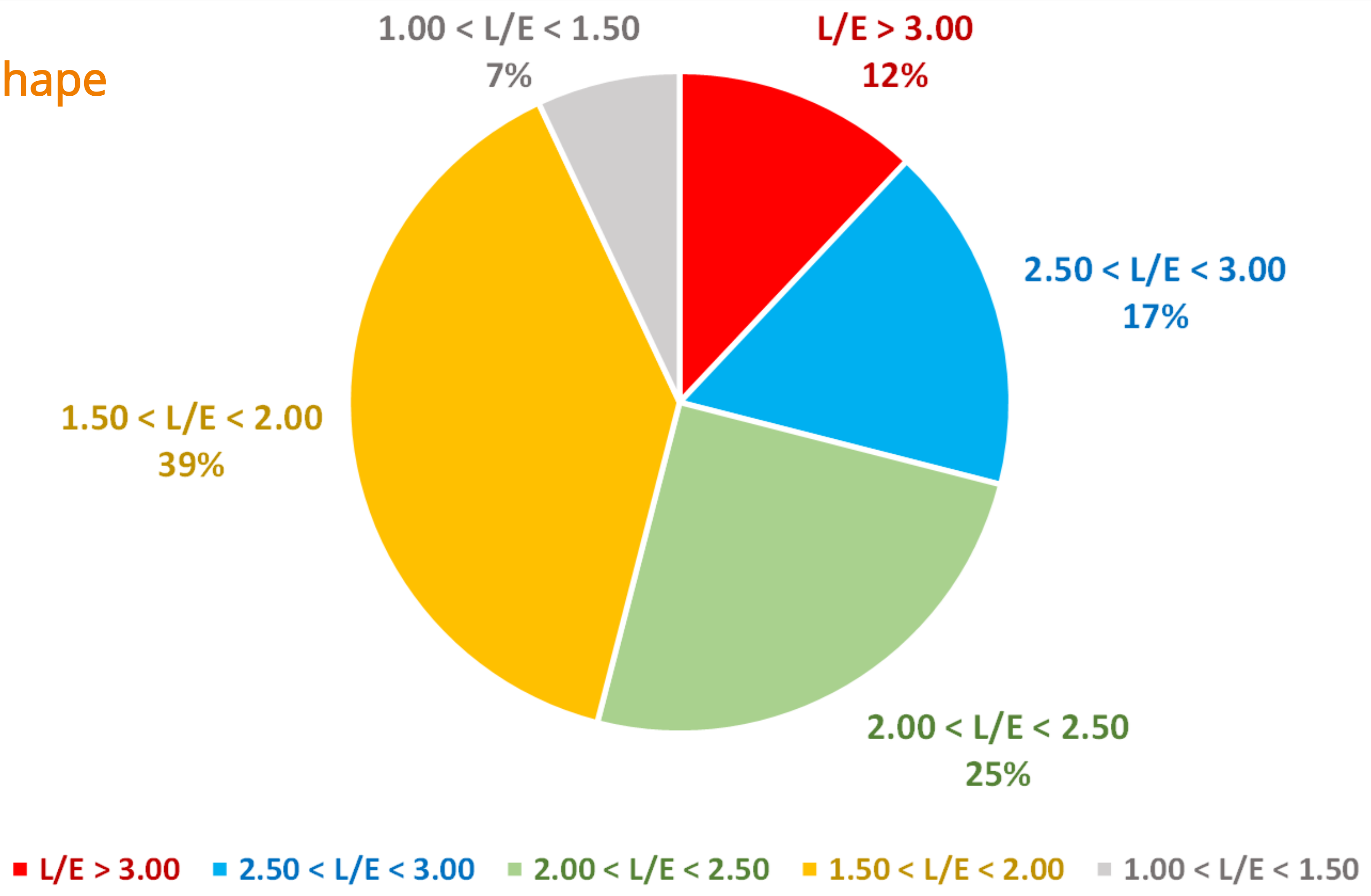
RCAs processing - Total



Task 2: Processing of CDW and production of structural RACs

Phase 1 – Protocol processing procedure for RAs from CDW

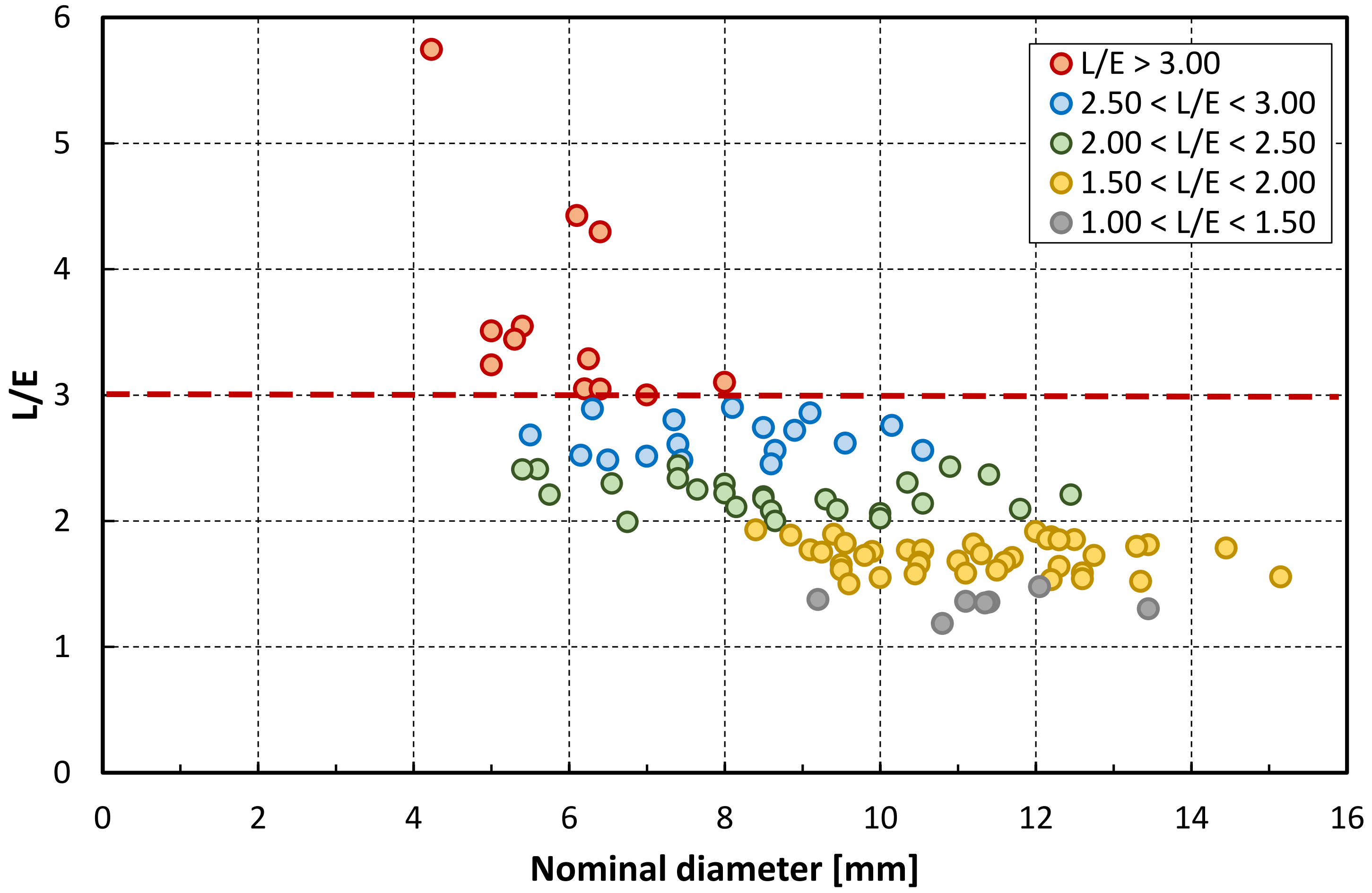
Particles' shape



Implementation

Task 2: Processing of CDW and production of structural RACs

Phase 1 – Protocol processing procedure for RAs from CDW

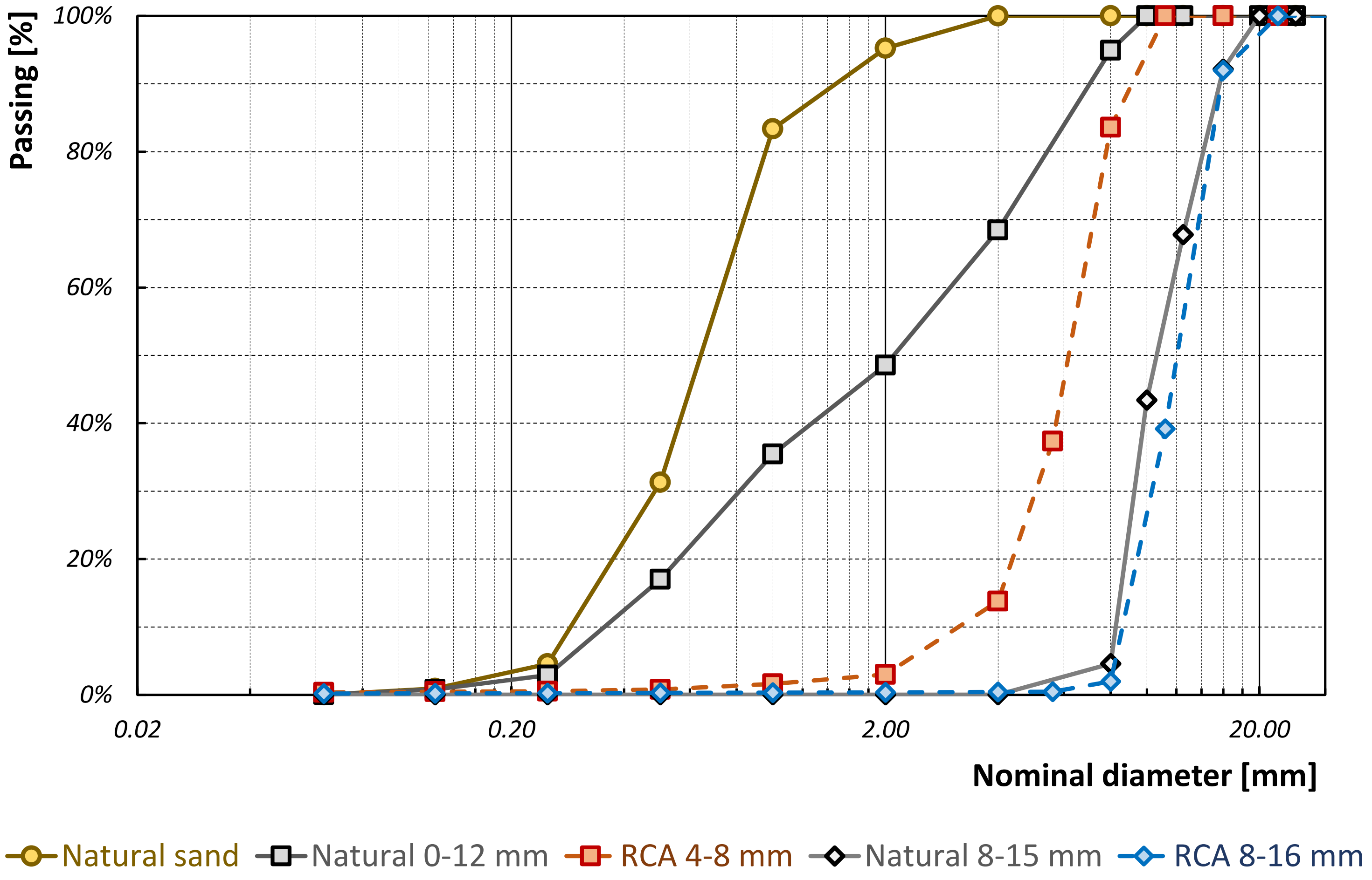


Particles' shape

Implementation

Task 2: Processing of CDW and production of structural RACs

Phase 1 – Protocol processing procedure for RAs from CDW



Grain-size distribution

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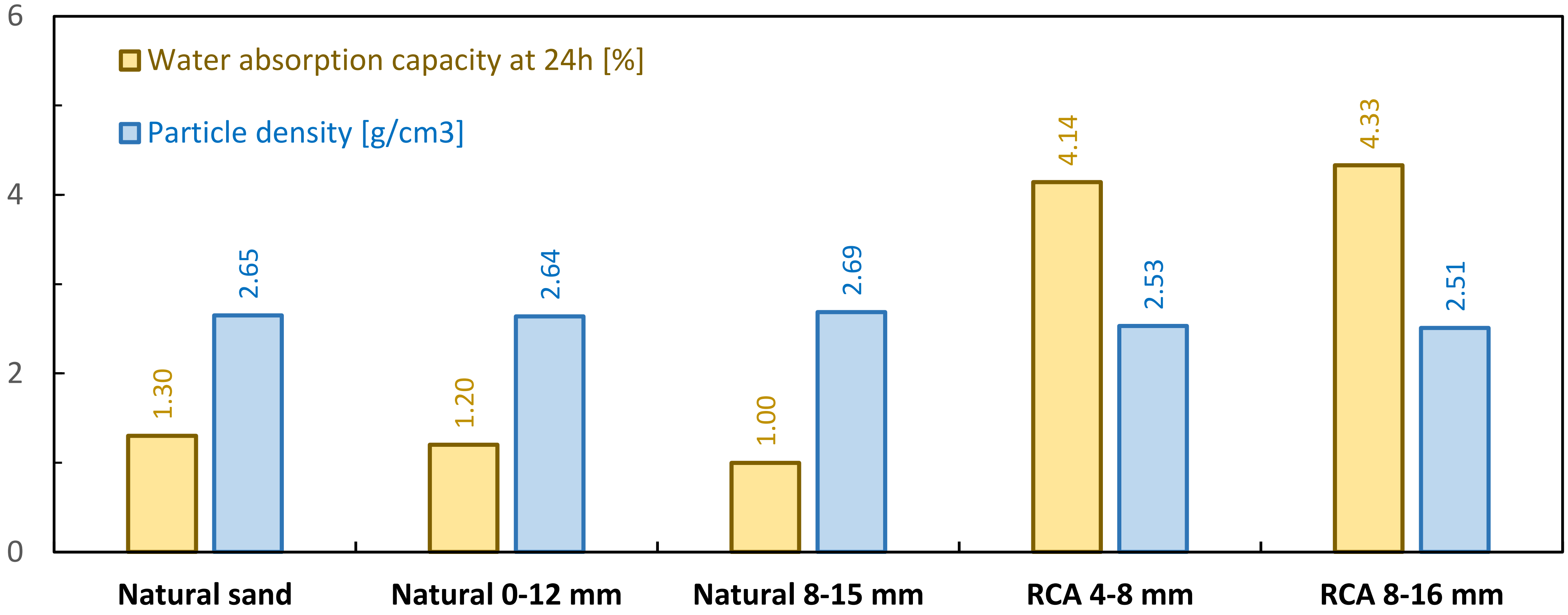
Task 2: Processing of CDW and production of structural RACs

Phase 1 – Protocol processing procedure for RAs from CDW



Physical properties

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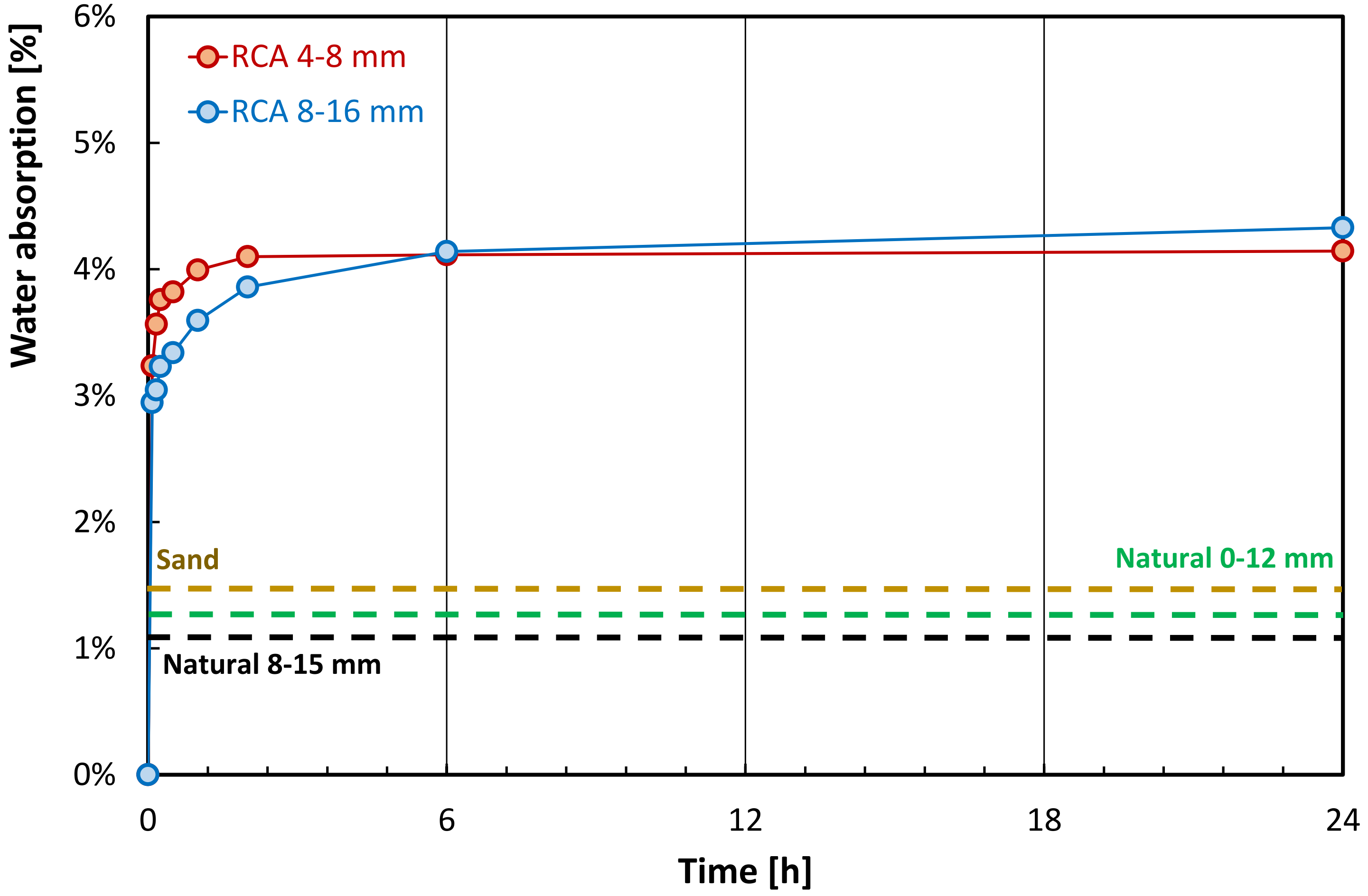
Task 2: Processing of CDW and production of structural RACs

Phase 1 – Protocol processing procedure for RAs from CDW

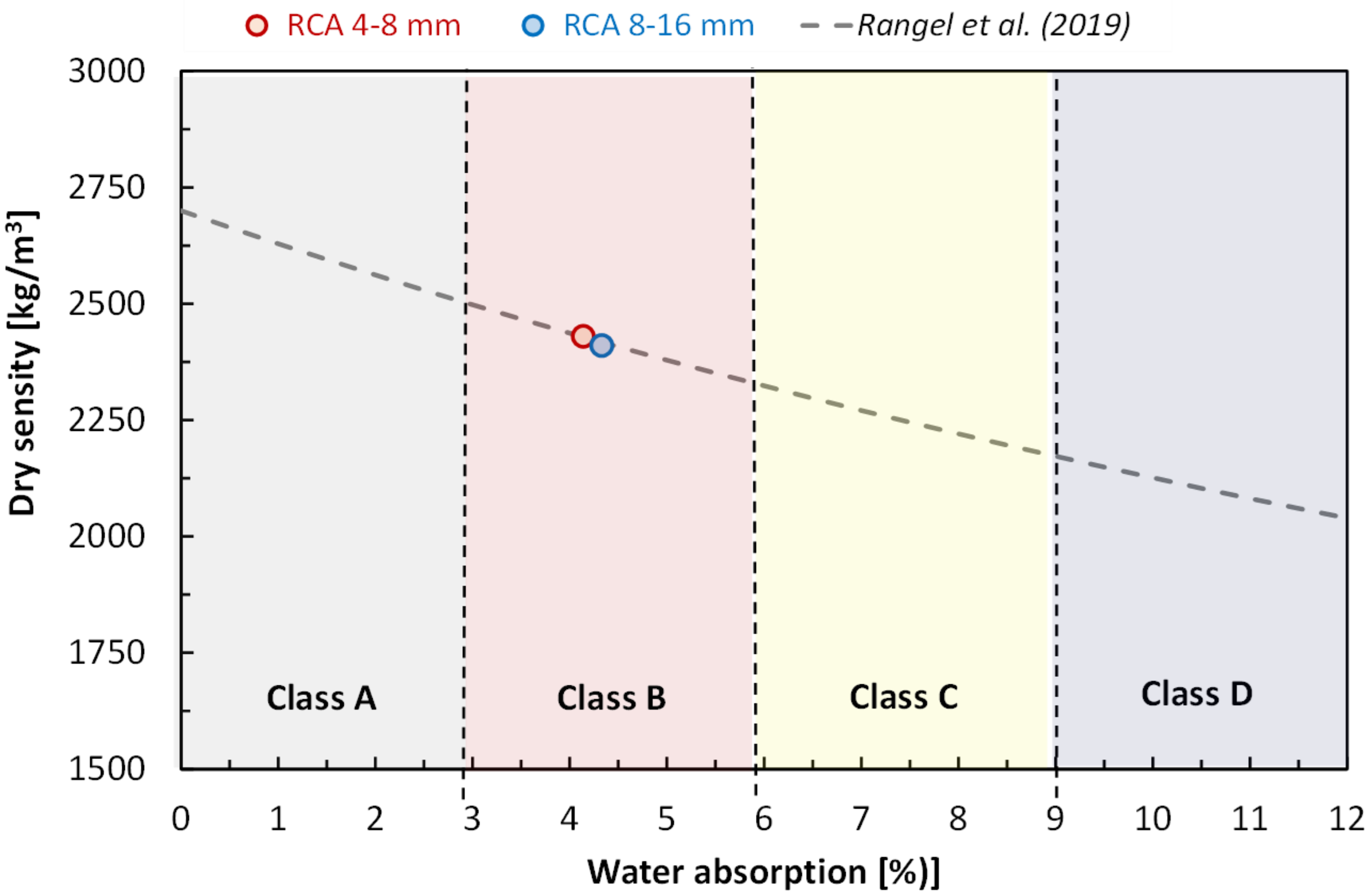


Water absorption capacity

Implementation

Task 2: Processing of CDW and production of structural RACs

Phase 1 – Protocol processing procedure for RAs from CDW



Classification of Recycled Aggregates

Implementation

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Task 2: Processing of CDW and production of structural RACs

Phase 2 – Mixture-proportioning method

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A novel mix design methodology for Recycled Aggregate Concrete

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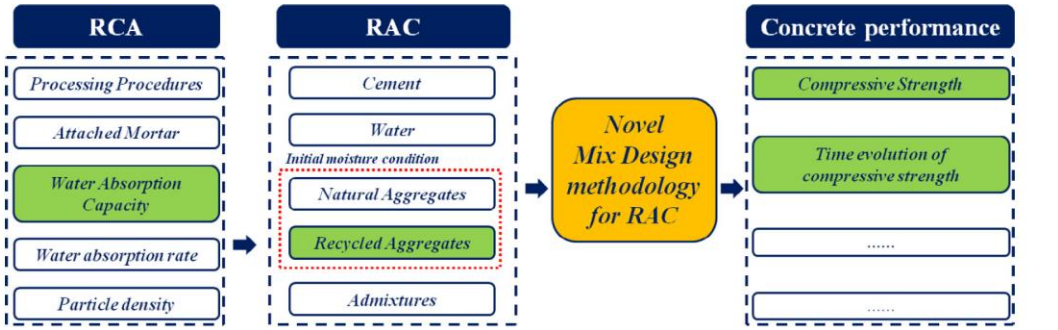

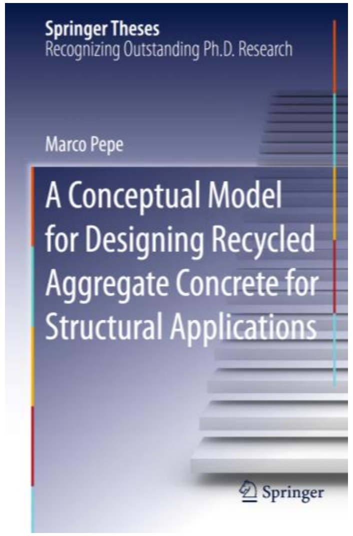

Ministero dello Sviluppo Economico

Ricevuta di presentazione

per

Brevetto per invenzione industriale

Domanda numero: 102020000031412

Data di presentazione: 18/12/2020

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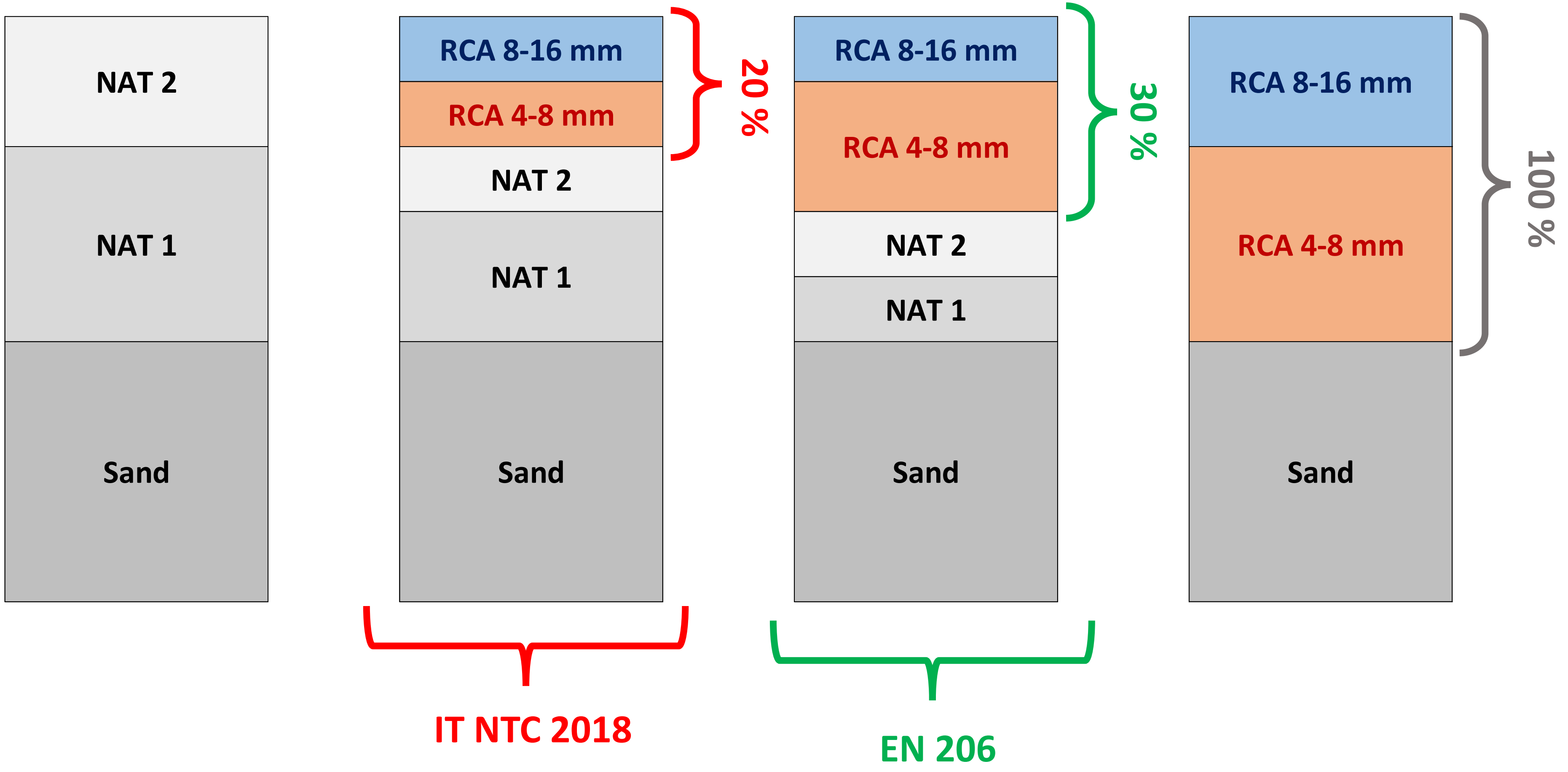
Implementation

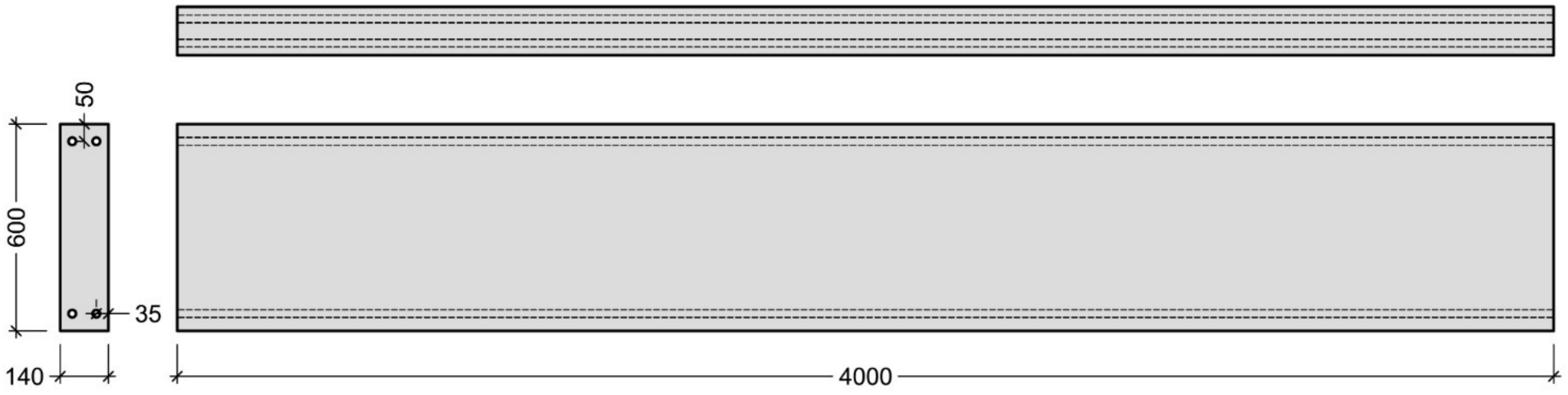
Task 2: Processing of CDW and production of structural RACs

Phase 2 – Mixture-proportioning method

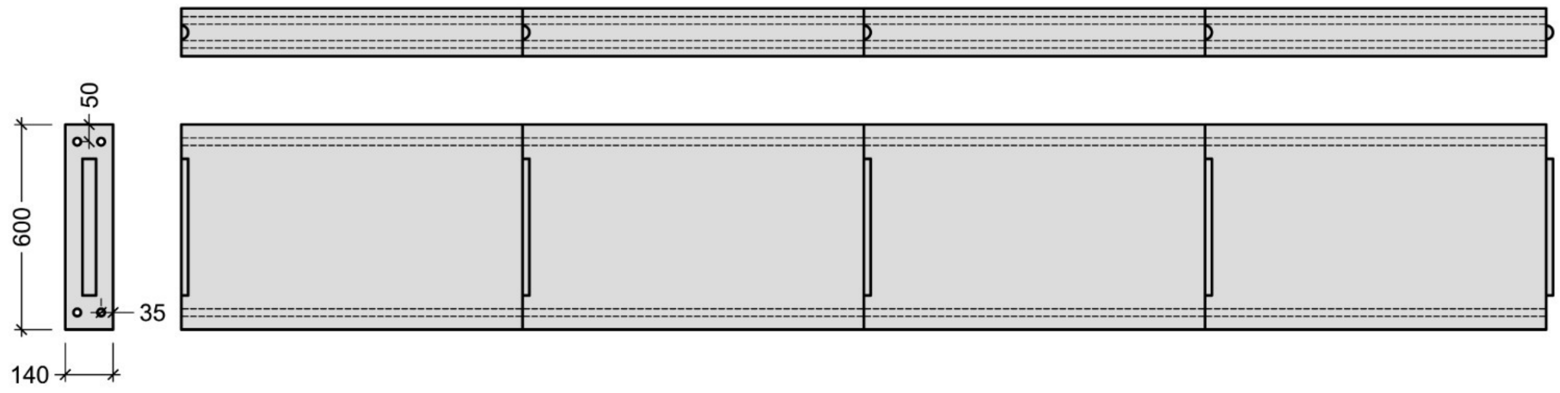


Task 3: Thin & high-performance prefabricated elements: design for disassembling

Reference concrete elements



Modular Recycled Aggregate Concrete elements



Implementation

Task 3: Thin & high-performance prefabricated elements: design for disassembling

Reinforcing method with re-bar R18

Existing product for a new application!

Repair of existing steel structures ➔ Modular erecting of concrete constructions

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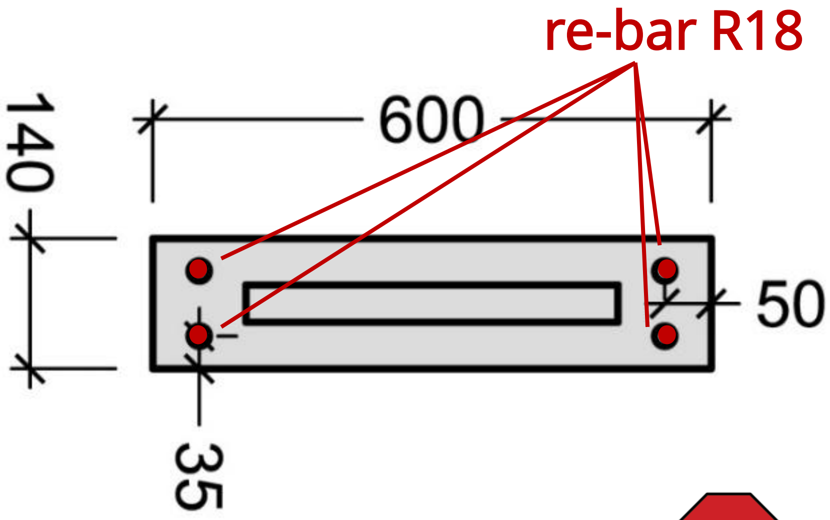
Task 3: Thin & high-performance prefabricated elements: design for disassembling

Reinforcing method – technique and method principle

memory®-steel allows for a simple and fast prestressing and reinforcing procedure. Prestressing is generated upon activation at high temperatures (in this case by resistive heating (electricity) to 300°C) Smooth re-bar R18 with threads at each end are used to couple and reinforce the different precast concrete blocks.



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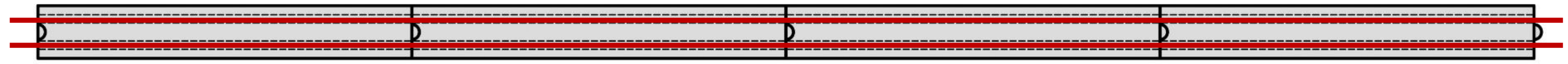
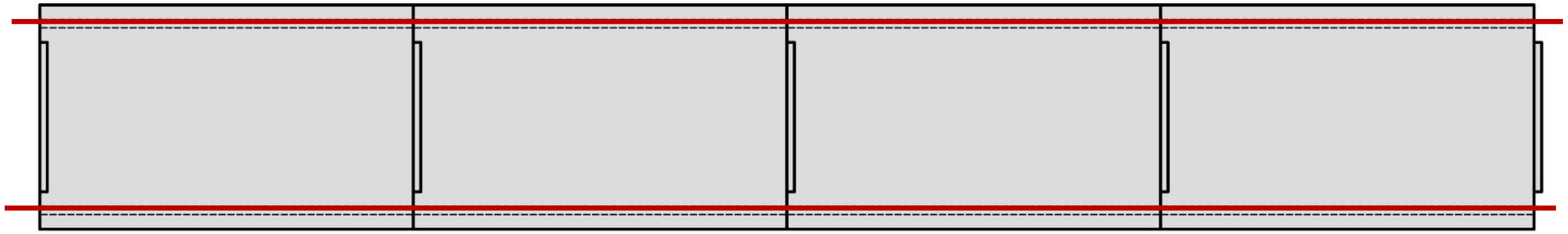
Implementation

Task 3: Thin & high-performance prefabricated elements: design for disassembling

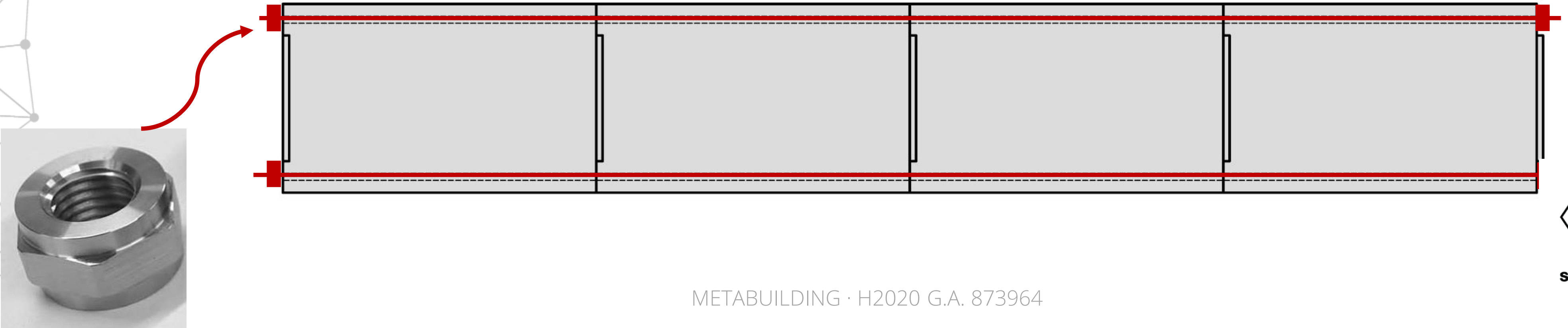
Reinforcing method – installation and prestressing procedure

Blocks are connected and re-bar R18 inserted (4x) in preinstalled voids





re-bar R18 is end-anchored with nut at each end over the thread (rigid connection)



Implementation

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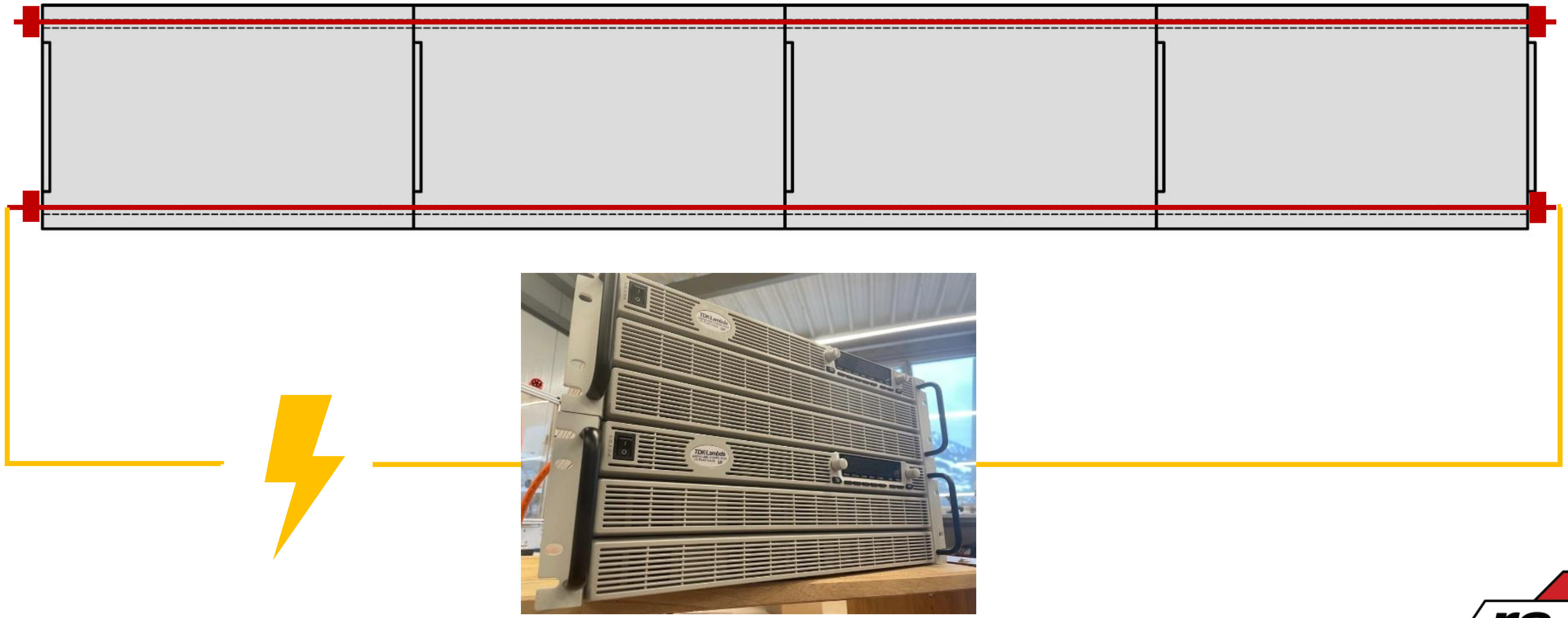
Task 3: Thin & high-performance prefabricated elements: design for disassembling

Reinforcing method – installation and prestressing procedure

re-bar R18 is activated by resistive heating
(special power source for electricity by re-fer AG)



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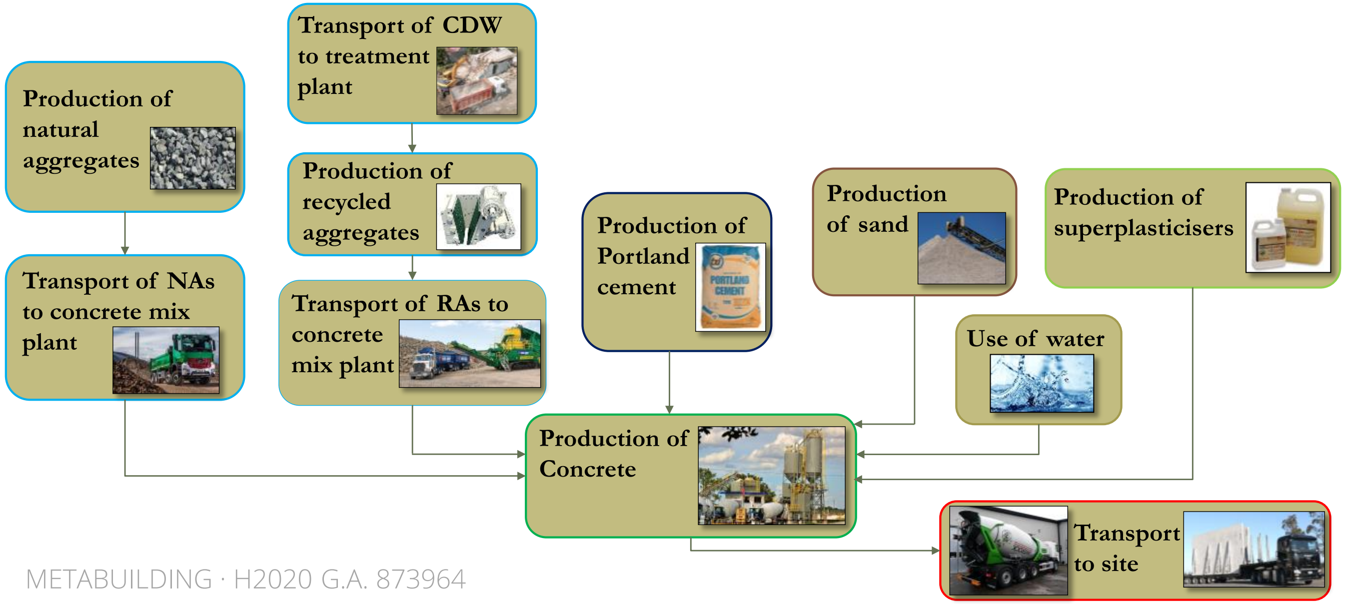
Implementation

Task 4: Life-Cycle and Cost analysis approach

Possible type of LCA:

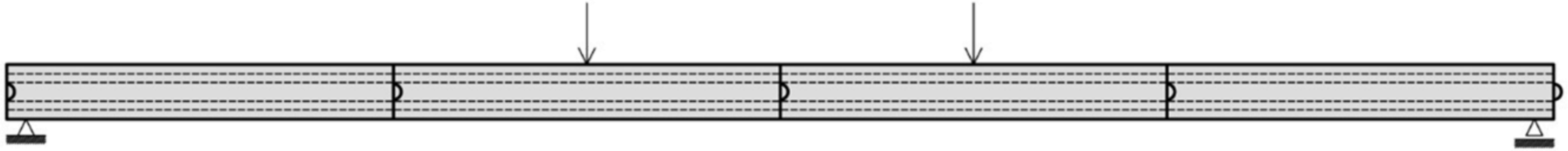
- Gate-to-gate
- Cradle-to-gate
- Cradle-to-grave
- Cradle-to-cradle

Product Stage			Construction Stage		Use Stage							End of Life Stage				Benefits beyond system boundary
Raw Material Supply	Transport	Manufacturing	Transport to Site	On Site Processes	Use	Maintenance	Repair	Replacement	Refurbishment	Operational Energy Use	Operational Water Use	Deconstruction / demolition	Transport	Waste Processing	Disposal	Reuse / Recovery / Recycling Potential
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D



Implementation

Task 5: Experimental tests on prototypes



Experimental validation of 4 full-scale structural components
made with ordinary concrete or concrete with recycled aggregates

Expected impanct

Expected impact

Impact of the proposed solution

The project is expected to primarily impact the microeconomic environment, through the development of a next-generation construction system able to meet multiple requirements and open to various applications.

The knowledge and the technical advancements acquired in the project could also foster a general growth of the construction engineering sector, oriented towards greater standards of:

(i) Sustainability: thanks to use of CDW recycled products and the reduction of material consumption through the topological optimization of the bearing members;

(ii) Cost containment: since the reduction of structural weights leads, in turn, to economic advantages associated to the improved handling, transportation, assembly and deconstruction phases;

(iii) Structural safety: thanks to the improved material durability;

(iv) Innovativeness: entailed by the multi-scale development approach, in which reuse principles are declined from the material scale to the entire life-cycle of the structural elements.

Expected impact

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Impact of the proposed solution

The project innovation can also reverberate on the **social environment**, thanks to macroeconomic effects including consumer confidence levels, employment rates and saving rates.

Structural elements conceived for disassembly and reuse, in fact, can counteract the tendency of building materials to get more and more expensive over time, as widely documented in the literature.

In terms of social impact, it is also worth mentioning the reduced demand of raw materials for the production of new structures and, referring to prefabrication, the mitigation of the interruptions resulting from cast-in-place activities and demolition processes.

In addition to this, **the use of environmentally friendly materials in construction positively impacts on wellbeing and has been proven to increase productivity up to 10%.**

Expected impact

Estimation of key performance indicators

Technological improvement

	after project completion	1 year after project completion	3 years after project completion
New or improved products or processes developed	1	1	2
New software-based marketing methods	-	1	1
New organisational methods	-	1	1

Environmental improvement

	State of performance at submission [current value]	after project completion [% of reduction]	1 year after project completion [% of reduction]	3 years after project completion [% of reduction]
Water consumption	-	-	-	-
Greenhouse gas emissions	200 kg-eq CO^2/m^3	5	8	12
Energy consumption	150 MJ-eq/m3	3	5	10
Building material waste	-	20	25	30
Noise pollution	-	-	-	-

Economic improvement of SME

	State of performance at submission [current value]	after project completion [%]	1 year after project completion [%]	3 years after project completion [%]
Increase of turnover	€ 50.000,00	10	20	25
Increase profit	€ 10.000,00	15	20	25
Increase yearly productivity	€ 20.000,00	15	25	30
Reduction of expenses	€ 20.000,00	20	25	30

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Conclusion

Conclusion

"The project explores the possibility to define a concept for deconstructable buildings made by prefabricated concrete elements incorporating Recycled Aggregates from CDW. It is expected to also impact the economic environment, through the development of a next-generation construction system able to meet multiple requirements and open to various applications."

Dr. Marco PEPE, TESIS srl
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"The METABUILDING investigation will allow our company re-fer AG to expand our product an application range by developing reusable concrete elements from recycled aggregate material and an innovative and recyclable iron-based shape memory alloy for prestressing"

Dr. Julien MICHELS, re-fer AG
jmichels@re-fer.eu

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Thank you for your kind attention

www.metabuilding.com

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