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Challenging construction industry with C&DW: opportunities and limits

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Argentine Association of Concrete Technology
IX international Congress/23th Technical Meeting
2-6 November 2020

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Global context

What to do?

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Global context

- We are living in a limited world
  - Energy
  - Raw materials
  - Space
  - Maximum capacity of resilience of nature
- Ascertainment → behaviour
- **Deposit ↔ market ?**

Global context

- We produce wastes
  - Between **3.4 to 4 billions tons/year** or from 80 to 126 tons/second!
  - Each day, human activity is contributing for more than 10 billions kg wastes
  - Annual production of recycled aggregates accounted for 202 million tons in 2015
  - *Construction area is producing more or less than 40% of CO_2*

UEPG. 2018. http://www.uepg.eu/statistics/estimates-of-production-data/data-2015

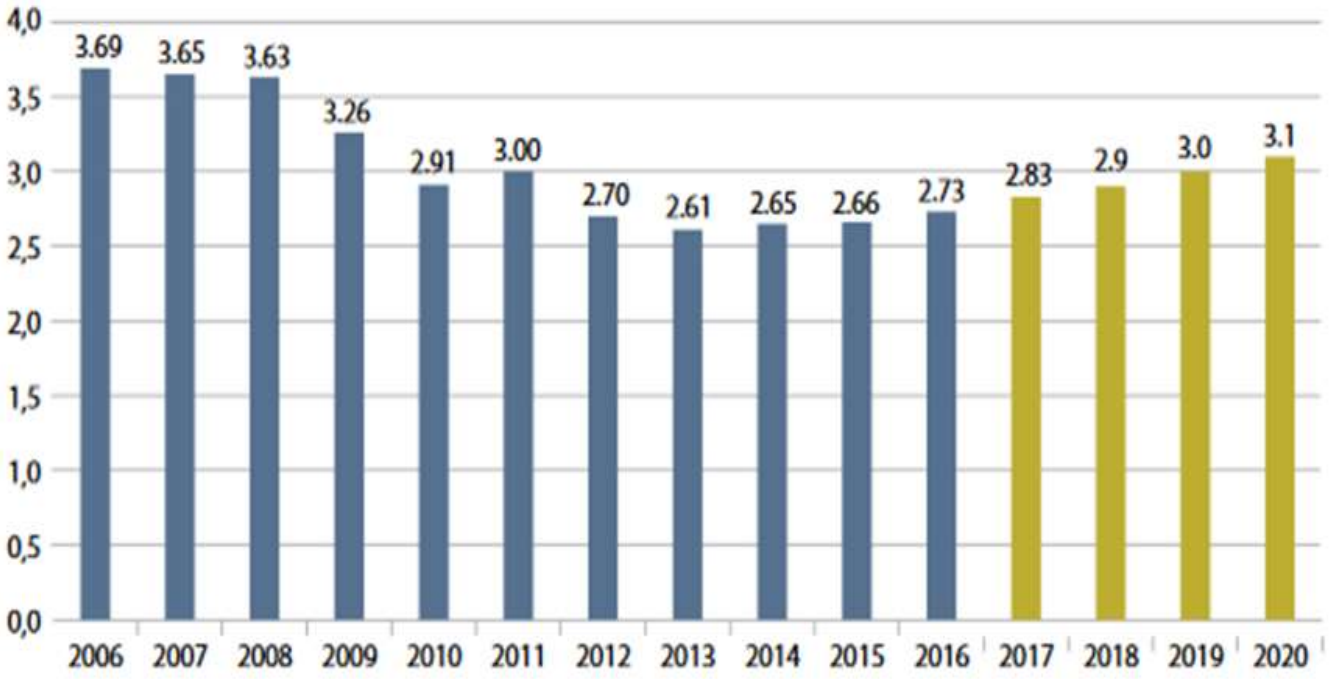
Global context

- We need construction materials
  - Cement: 4 billions tons/year (56% from China)
  - Concrete: 10 billions tons/year
  - Consumption of cement in kg/inh (2018)
    - China: 1704 kg/inh
    - EU: 309 kg/inh
    - USA: 287 kg/inh
    - BE: 550 kg/inh
    - AR: 270 kg/inh
  - Emission of CO_2 (2018): 5-8% world production

Global context

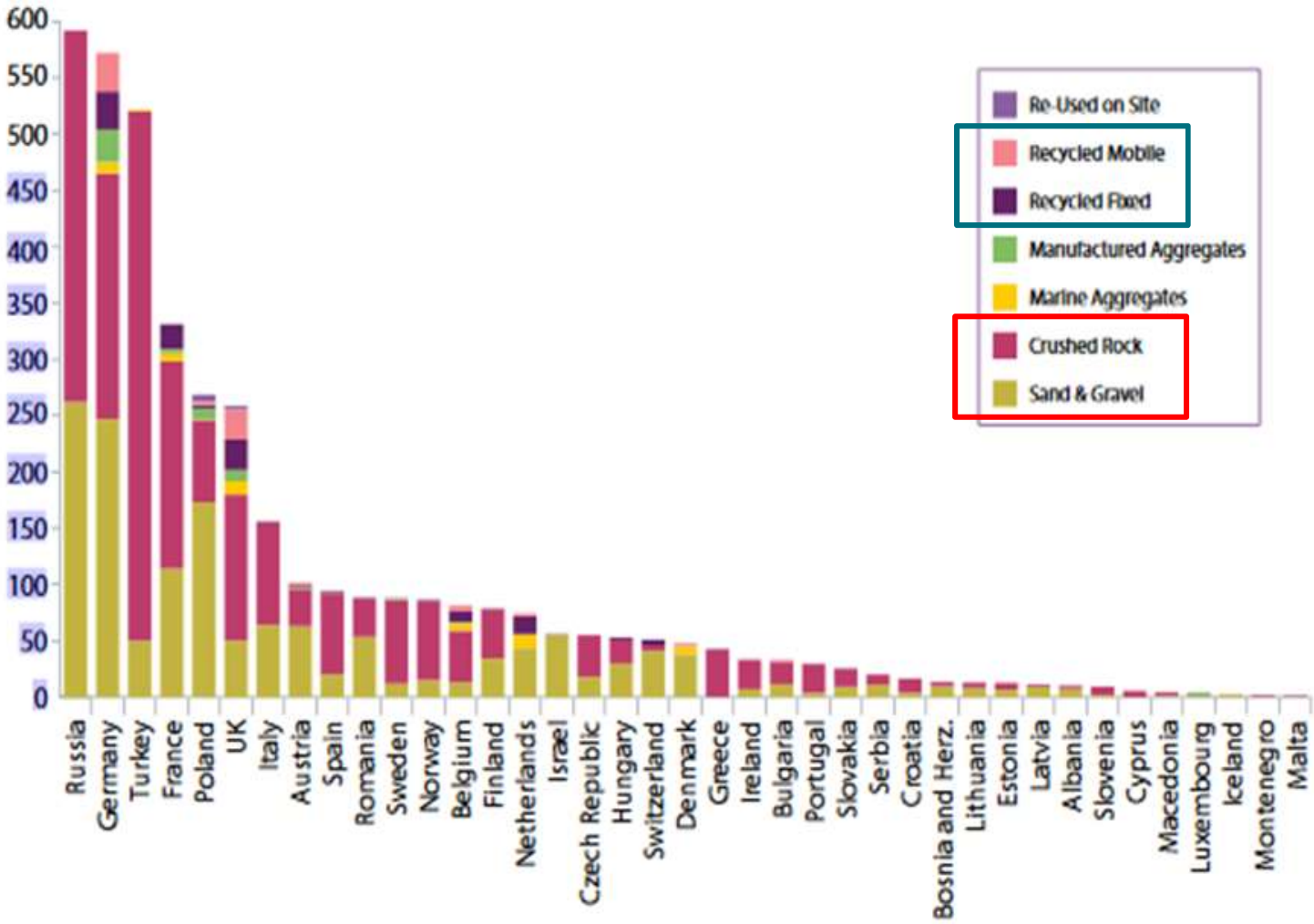
- We need construction materials
  - For the EU28 plus EFTA countries, the total 2019 **aggregates production** is estimated just on **3,00 billion tons**. The primary materials came from 26,000 quarries and pits, operated by 15,000 companies (UEPG, 2018, http://www.uepg.eu/statistics/current-trends)

Global context



Trend in total EU + EFTA Tonnages (in billions of tonnes) for the production of aggregates

Global context



2016 aggregates production in Europe in millions of tonnes by country and type

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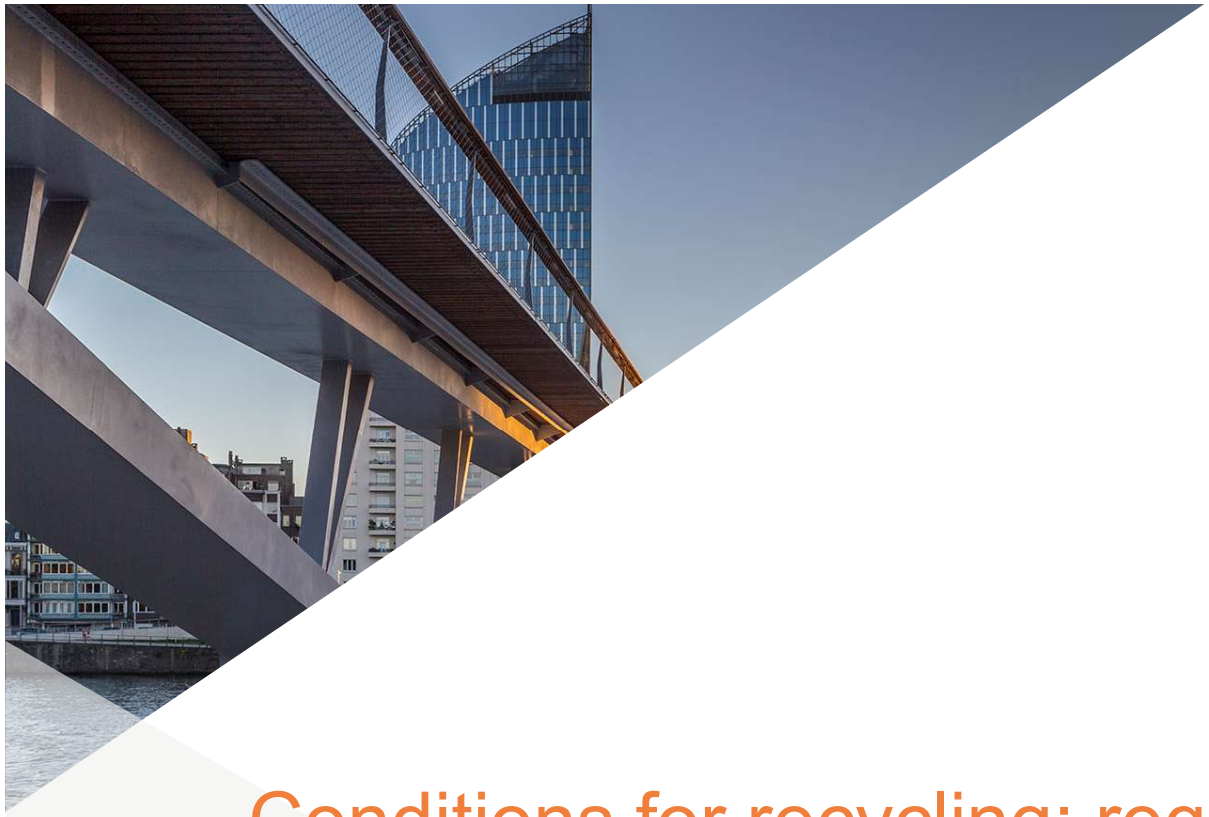
Objectives

- 3R: Reduce, Reuse and Recycle
- Using CD&W as sub-base and base material in road construction (“less noble”)
- Meeting Sustainable Development Goals: recovery targets to 70% of construction and demolition wastes (CD&W) by 2020 in European Union (**Directive 2008/98/EC**)
- Reducing use of natural aggregates (preservation of natural resources)



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Conditions for recycling: requirements, barriers, applications

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Conditions for recycling

- Possible restrictions
  - Transport
    - Transport price = f(quantity, distance)
    - Independent of the quality
    - Interesting recycling if
      - Far landfill
      - High dumping charge
      - Expensive raw materials and difficult supply
  - Standards
    - *a material has not specification because it is new and not used*
    - *a material is a few used because it is uncovered by specifications*

Conditions for recycling

- Possible applications
  - *Filling materials*: low requirements, consumed in large quantities, for embankments but transportable over short distances due to costs;
  - *Aggregates*: high quality requirements to lead to finished products of quality identical to that of traditional materials;
  - *Binders*: very precise specifications, properties must remain constant over time;
  - *Activators*: small quantities, which can cause problems of collection, storage, distribution and regularity.

Conditions for recycling

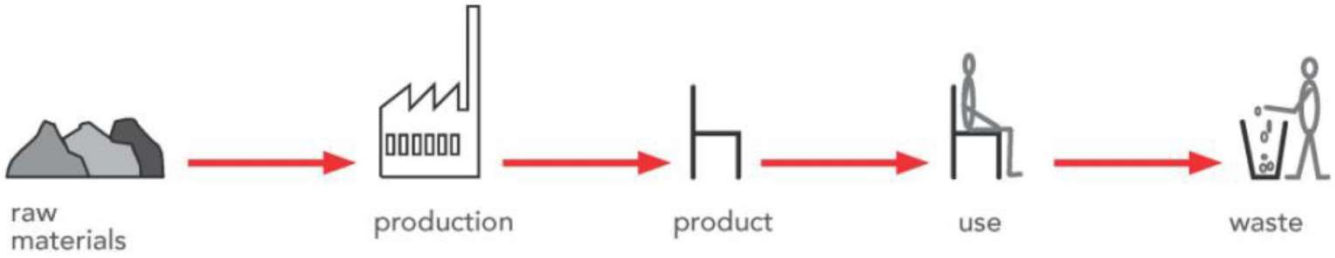
- Evaluation of the opportunity of recycling
  - Technique
    - Waste characterisation
    - Durability
    - Consistency of the properties
  - Logistic et economic
    - Deposit and transport
    - Consistency of the production
    - Conditioning
    - Localisation

Conditions for recycling

- Evaluation of the opportunity of recycling
  - Environmental et economic
    - Decrease of the quantities in landfill
    - Regulatory obligation to eliminate
    - Taxation

We don’t recycle …
anything,
anyhow,
at any price.

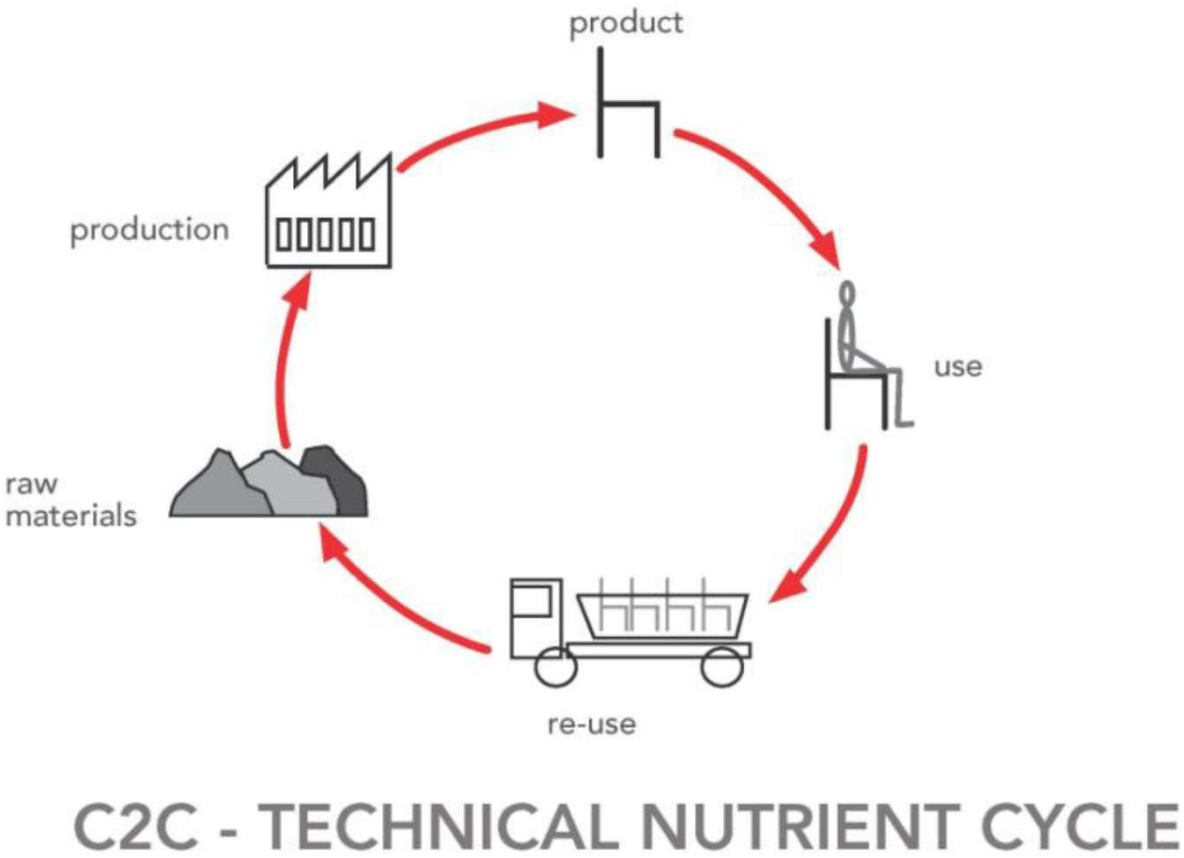
Conditions for recycling



OLD LINEAR ECONOMY - is about ownership

SOURCE: S. BECKERS (d'après M. BRAUNGART –EPEA, Cradle to Cradle)

Conditions for recycling

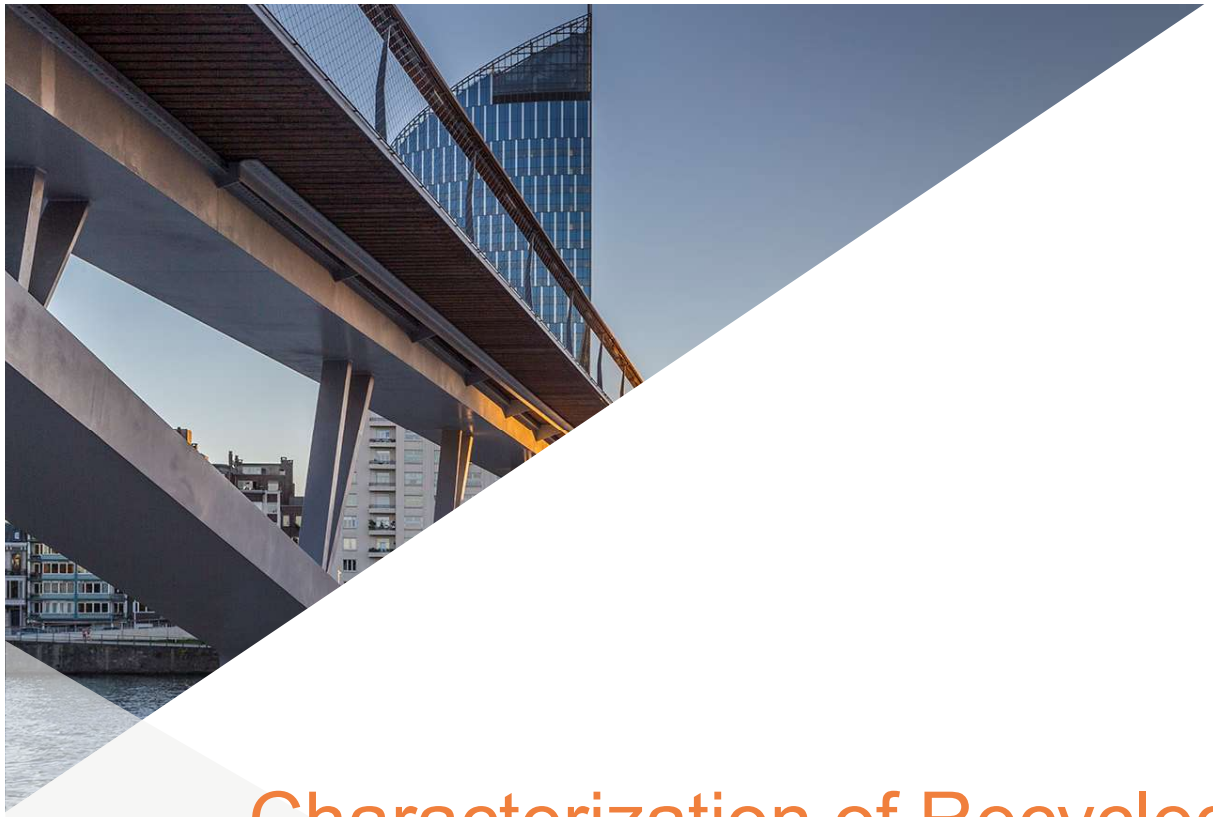


SOURCE: S. BECKERS (d'après M. BRAUNGART –EPEA, Cradle to Cradle)

Most significative challenges

- the lack of incentive to design for the end-of-life issues for construction products
- the low value of products at end-of-life (economic challenge)
- the construction industry's structure (fragmented supply chain)

- *a better recovery of material by means of viable take-back schemes*
- *higher value markets*
- *assurance schemes for reused materials*



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Characterization of Recycled Concrete Aggregates

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C&DW recycling

- Transforming wastes …

C&DW recycling

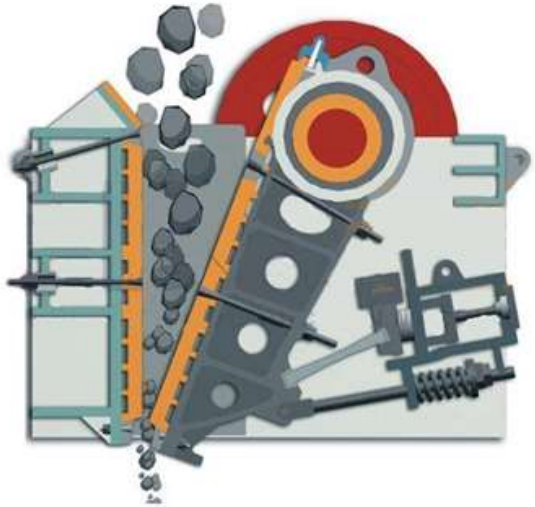
- … into secondary ressources

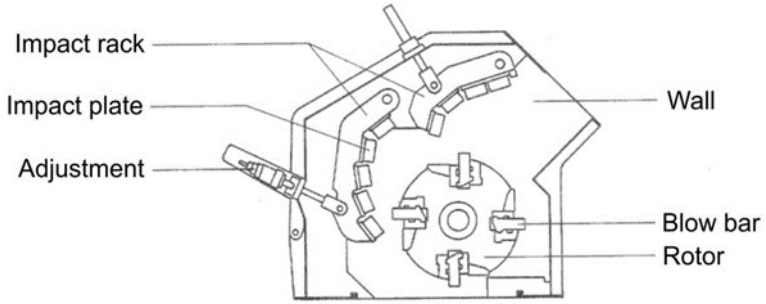
Flow sheet for material processing

Flow sheet for material processing

Material processing

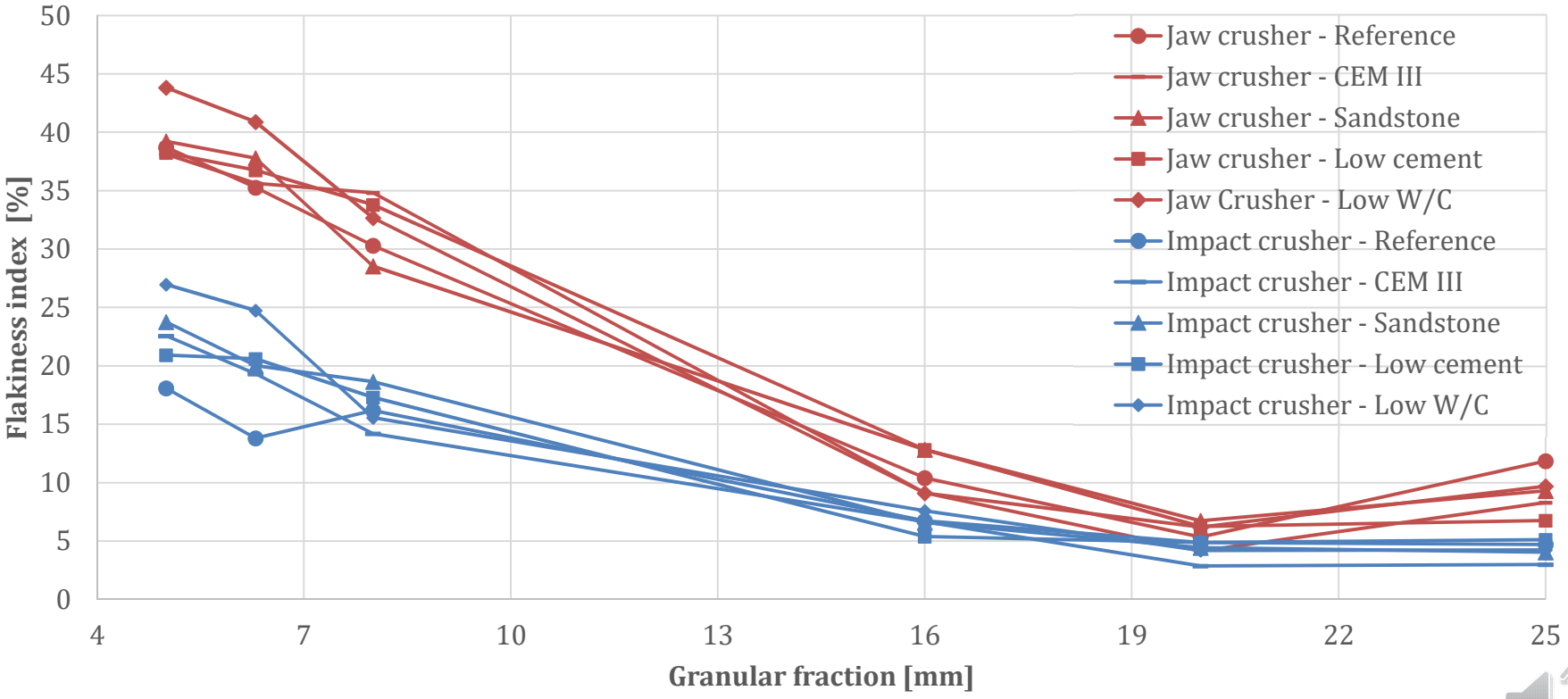
- Jaw crusher
  - allows producing very fine fractions
  - induces the biggest wear
  - limited by the primary size of waste to be treated
- Impact crusher
  - to treat bulky waste like concrete slabs
  - does not allow to produce very fine particles
  - generally requires a secondary crushing





Material processing

- The flakiness index decreases with increasing granular fraction and the jaw crusher produces flakier aggregates
- No influence of the concrete composition

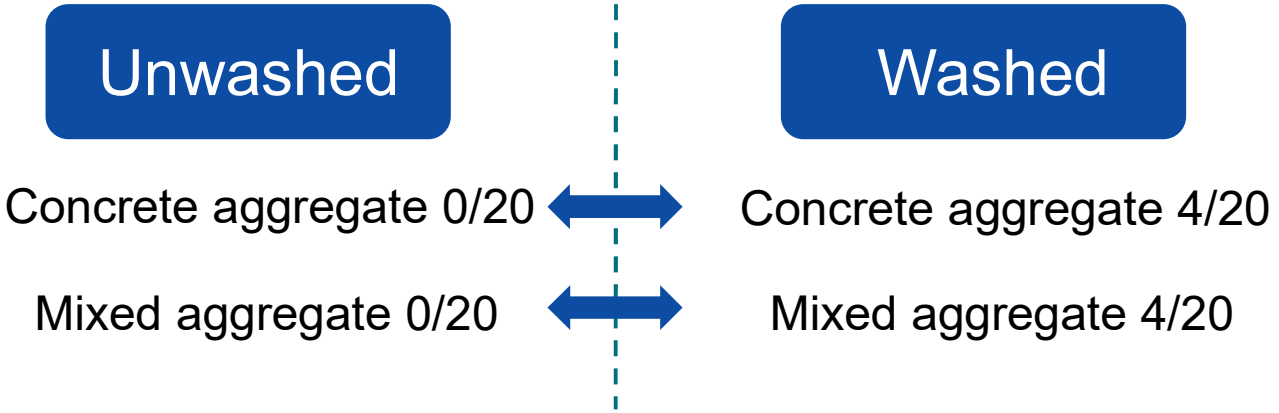


Effect of washing

Expectations of washing aggregates:

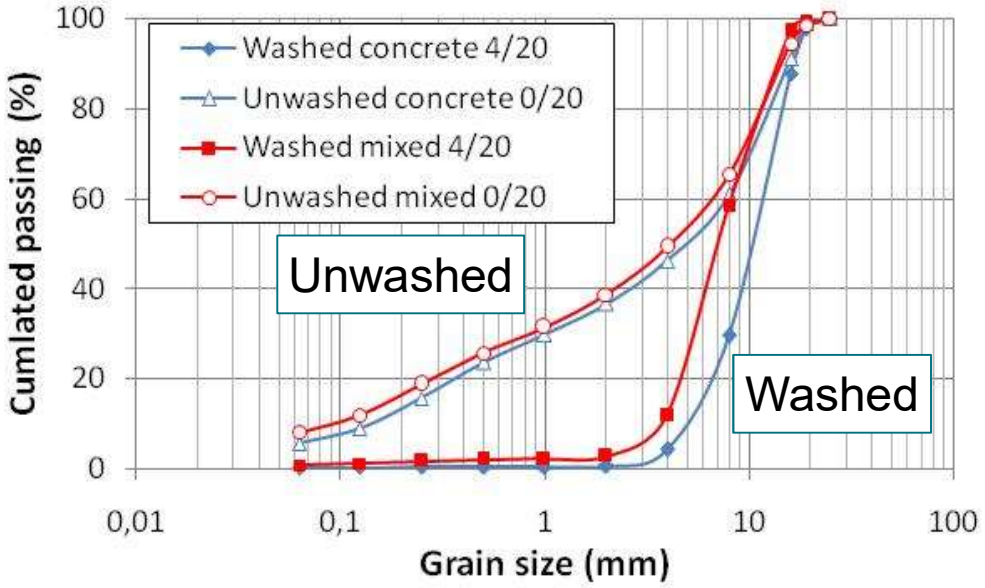
- Constrain grain size distribution
- Decrease fine content
- Decrease the quantity of unwished components (floating, clay, plaster...)
- Increase resistance to fragmentation

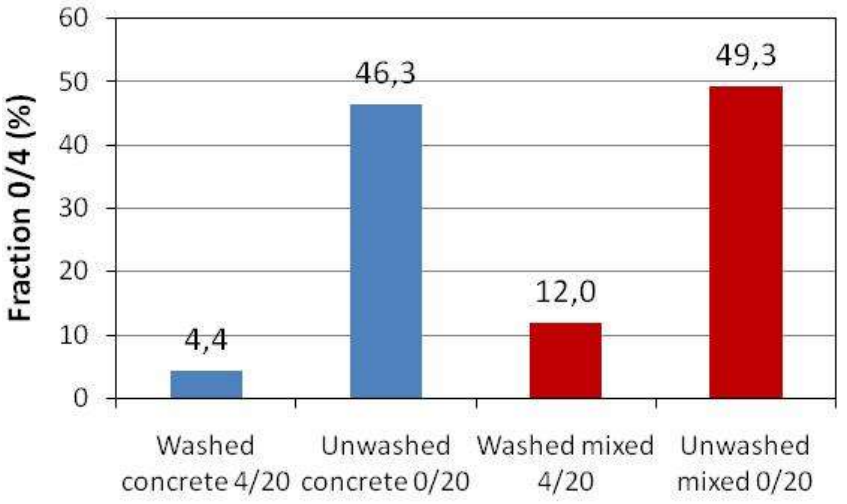
Methodology



Grain size distribution - aggregates

- 0/4 fraction comprises nearly 50% of the unwashed aggregates composition
- 0/4 fraction a bit higher in mixed aggregates
- Washing significantly reduces the sand fraction of the aggregates





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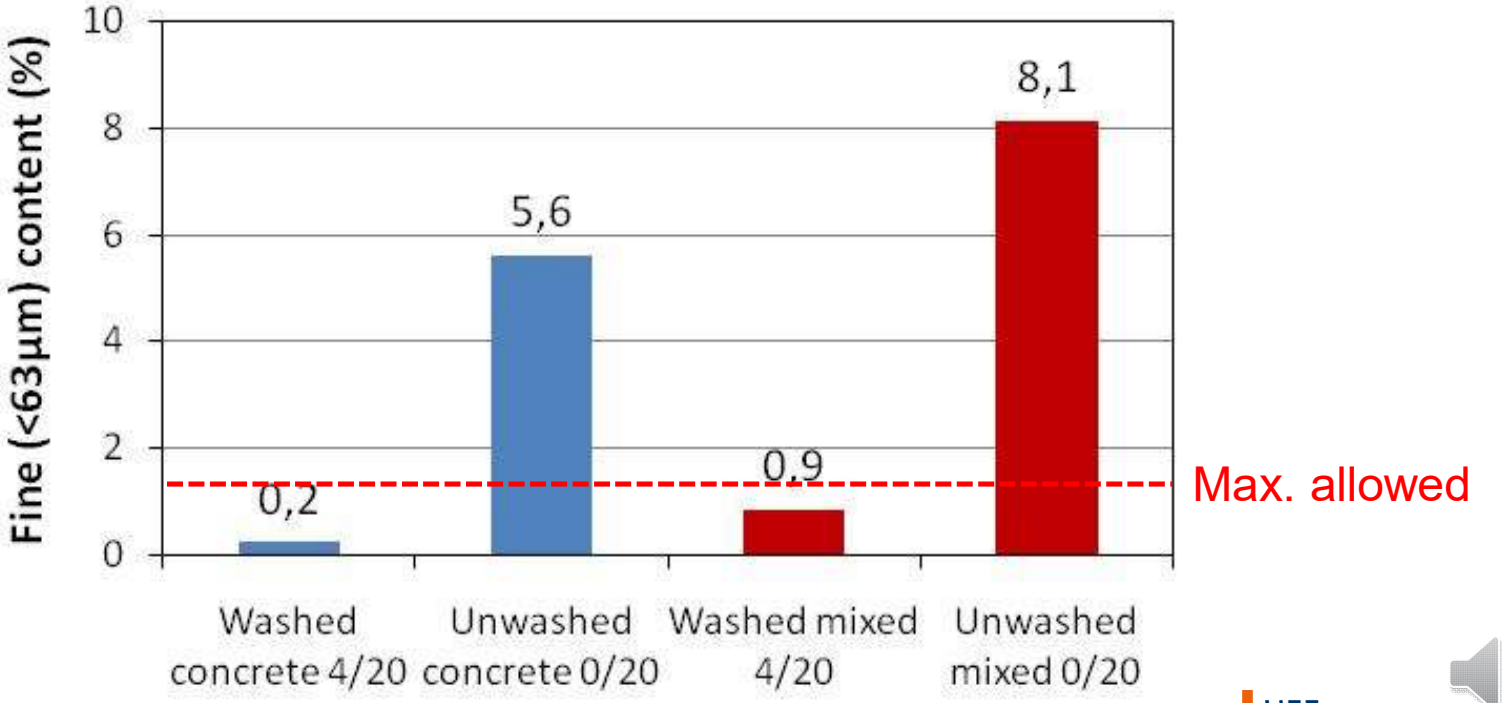
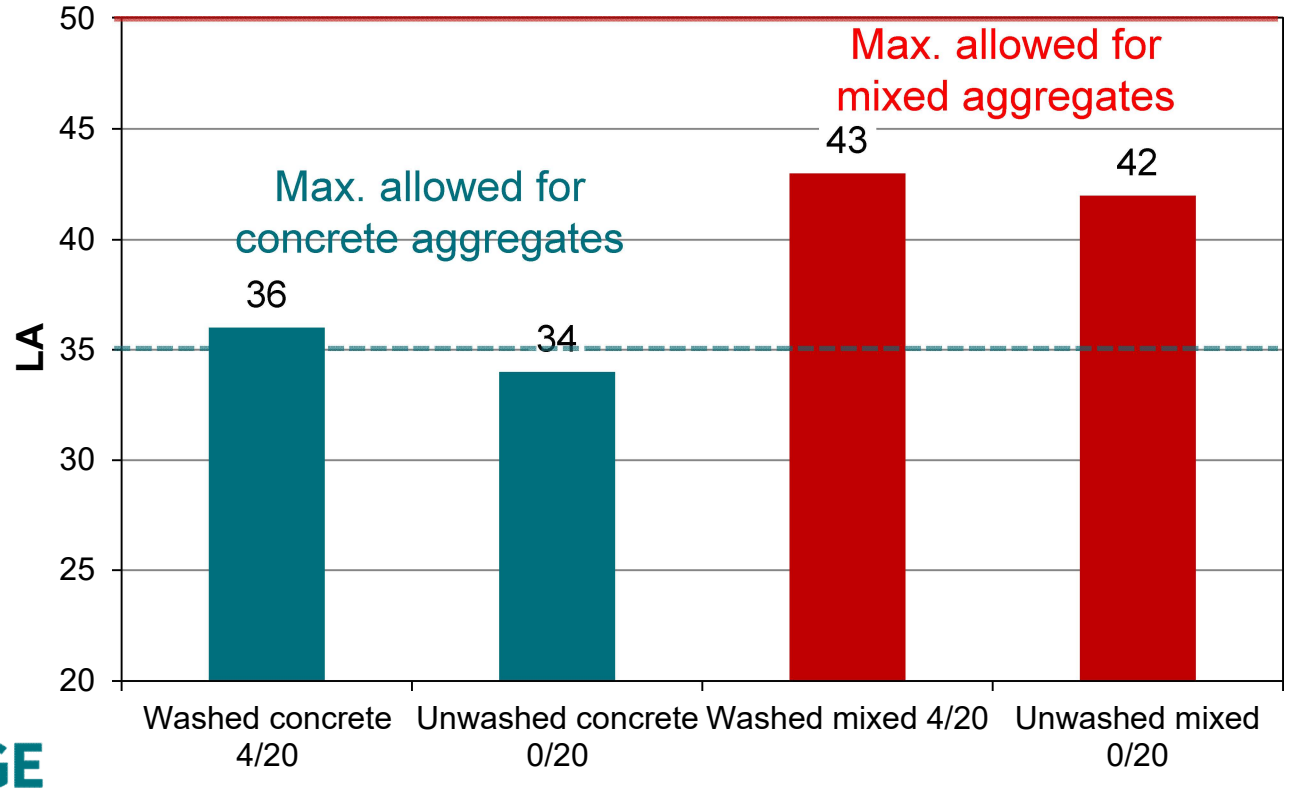
Grain size distribution - aggregates

- Fine content (< 63µm) higher in mixed aggregates and significantly reduced by washing
- Fine fraction higher in mixed aggregates
- Washed aggregates respect regulations in all considered countries



Resistance to fragmentation

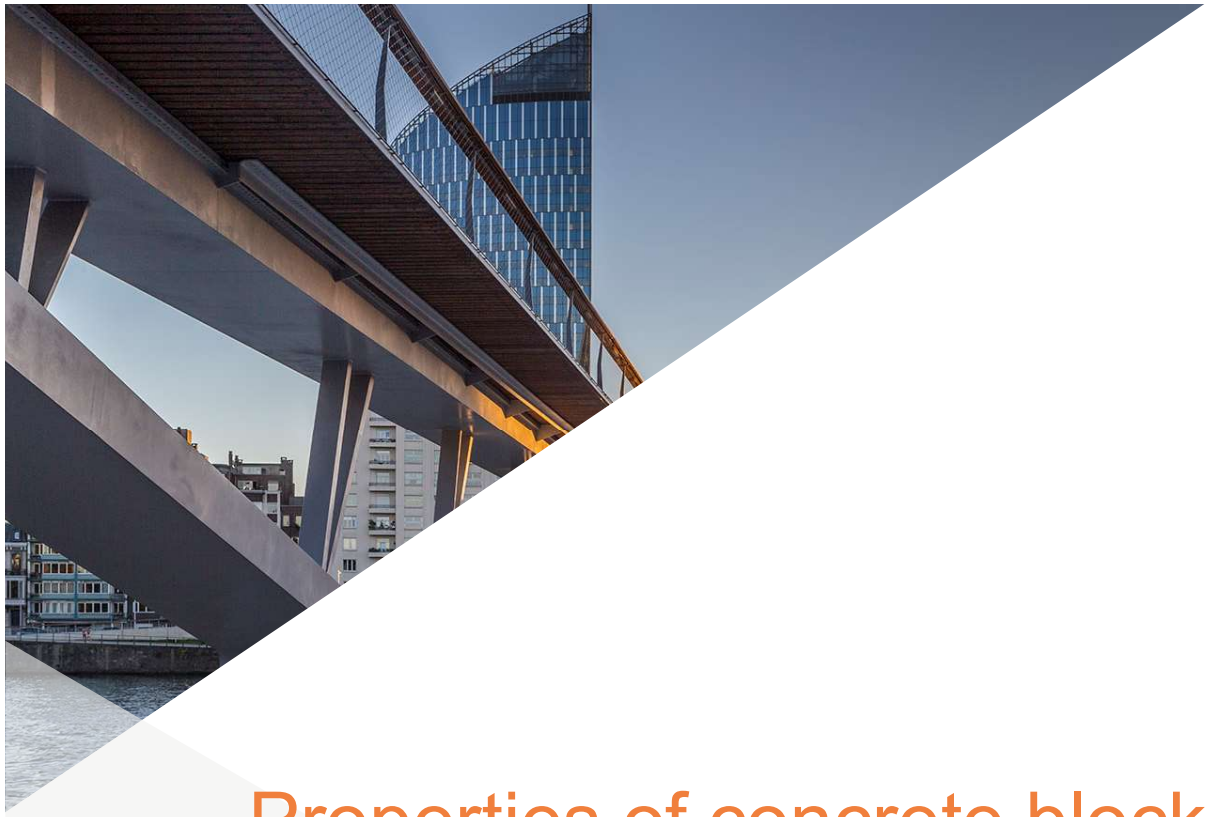
- Concrete recycled aggregates have better resistance to fragmentation than mixed aggregates
- No effect of washing



Conclusions

Expectations of washing aggregates:

- Constrain grain size distribution ☑
- Decrease fine conten ☑
- Decrease the quantity of unwished components (floating, clay, plaster ☑
- Increase resistance to fragmentation ☒



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Properties of concrete blocks made with recycled concrete aggregates: from block wastes to new blocks

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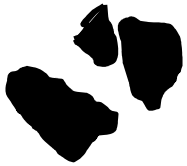
Materials

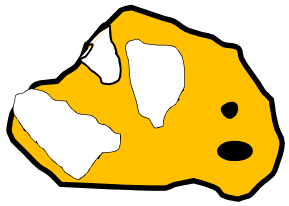
- RCA manufactured in laboratory
  - Old concrete from block wastes (C8/10 from Prefer Company)
  - Crushing (jaw crusher in laboratory, opening ≈10mm)
  - Separation of RCA by sieving (0/20mm)
    - Four granular classes: 0/2 - 2/6.3 - 6.3/14 - 14/20

Properties of RCA

- Hardened Cement Paste Content (CPC) of RCA
  - Principal soluble and insoluble phases in salicylic acid and methanol dissolution *(Zhao et al., 2013. Journal of Sustainable Cement-Based Materials **2**,186-203)*



Quartz, Dolomite, Calcite
Insoluble in salicylic acid

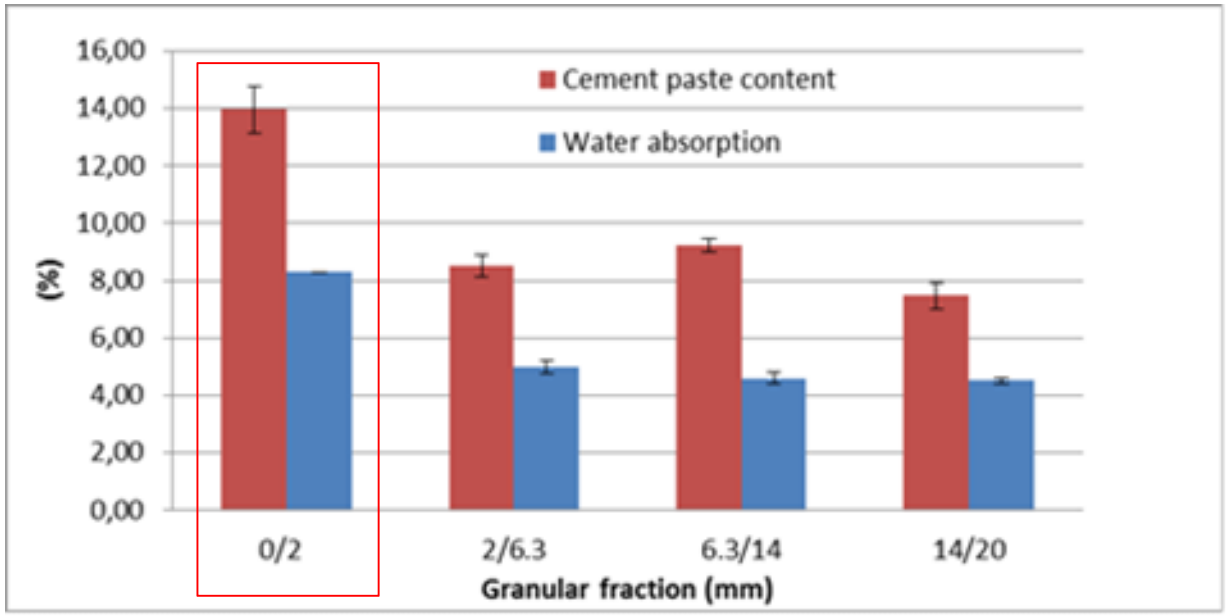


C_2S, C_3S, $Ca(OH)_2$, C-S-H, Ettringite
Soluble in salicylic acid

Insoluble in salicylic acid
C_4AF, AFm ⟶ CEM I
Calcite, Slag… ⟶ CEM II, III

Properties of RCA

- Water absorption W_A (EN 1097-6)



  - CPC and W_A of 0/2mm fraction larger than three coarse fractions
  - Recycled sand presents higher CPC and W_A than CRCA

Materials

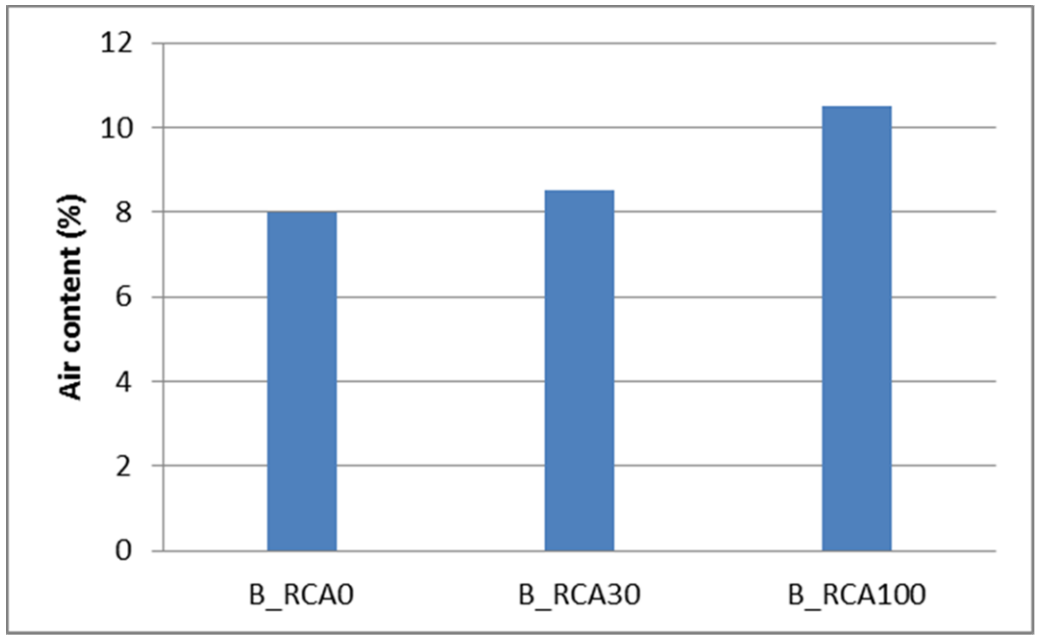
- Mix design

	B_RCA0	*B_RCA30*	*B_RCA100*
NA 2/7 (kg)	1080	754	0
RCA 2/6.3 (kg)	0	302	1008
NS 0/2 (kg)	825	825	825
Cement (kg)	150	150	150
Efficient water (kg)	105	105	105
Absorbed water (kg)	13.12	26.00	56.20
W_{eff}/C	0.70	0.70	0.70

  - Different substitution rates of NA 2/7 by the same volume RCA 2/6.3 (0, 30, 100%)
  - Same W_{eff}/C ratio - cement CEM III/A 42.5
  - Pre-saturation of aggregates in the mixer **5 min** before the addition of cement by half of total water

Properties

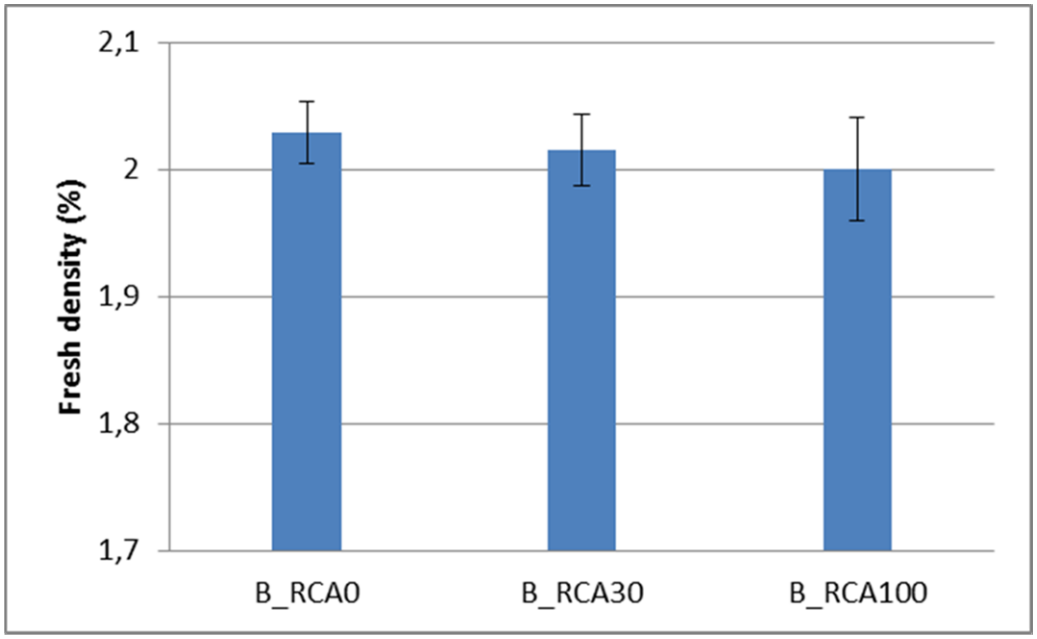
- Fresh properties of concrete (zero slump)



  - The air content of concrete increases when the substitution of recycled aggregates increases

Properties

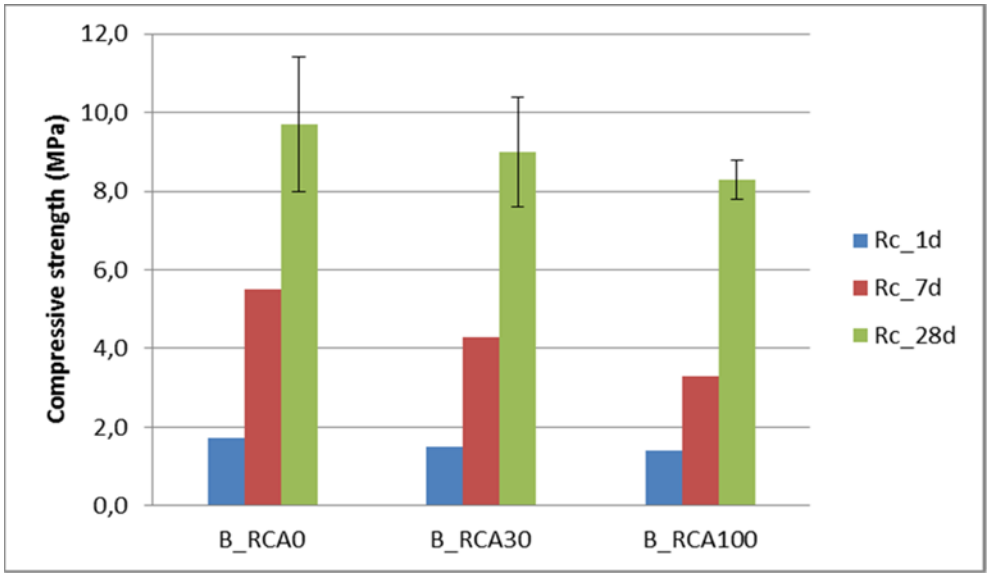
- Density of fresh concrete



  - The density of fresh concrete slightly decreases when the substitution of RCA increases

Properties

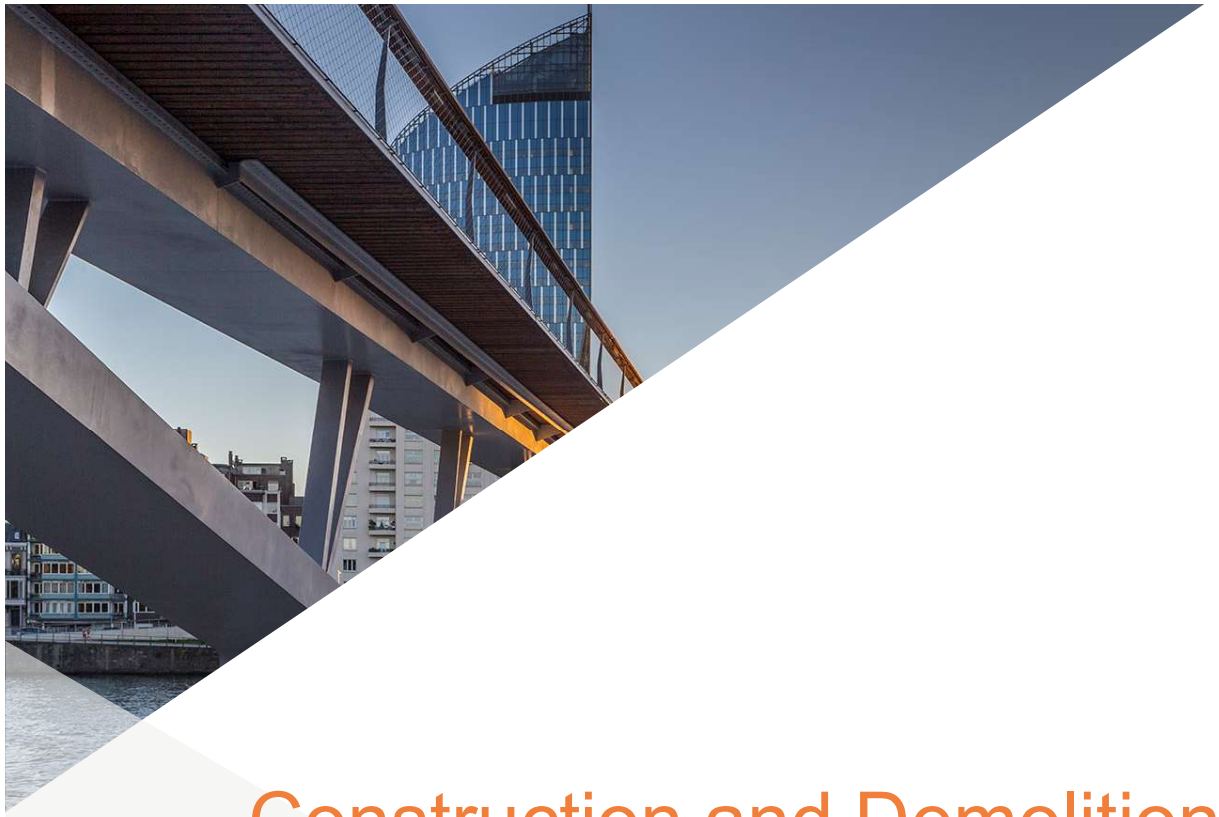
- Compressive strength



  - Compressive strengths of concretes with RCA are slightly lower than those of concrete with natural aggregate
  - Compressive strength of concrete made with 100% RCA at 28 days is 8 MPa (14.4% decrease)

Conclusions

- Feasibility of using RCA obtained from old concrete block wastes in the new concrete blocks
  - Recycled sand possesses significantly higher cement paste content and higher water absorption than coarse RCA
  - Compressive strength of concrete blocks slightly decreases as the substitution of RCA increases;
  - Rc of B_RCA100 could reach 8 MPa after 28 days without increasing the cement content of the concrete mix



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Construction and Demolition Waste: SeRaMCo project

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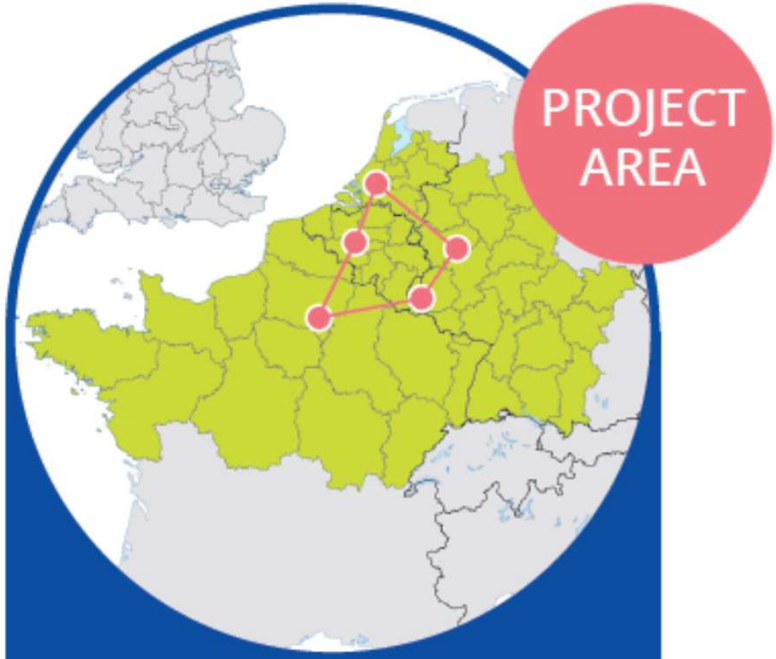
Interreg
EUROPEAN UNION
North-West Europe
SeRaMCo
European Regional Development Fund



Duration
March 2017 - September 2020

Budget
Total: € 7.28 million
EU funding: € 4.37 million

Partnership:
11 Partners
3 Sub-Partners
3 Associated Partners

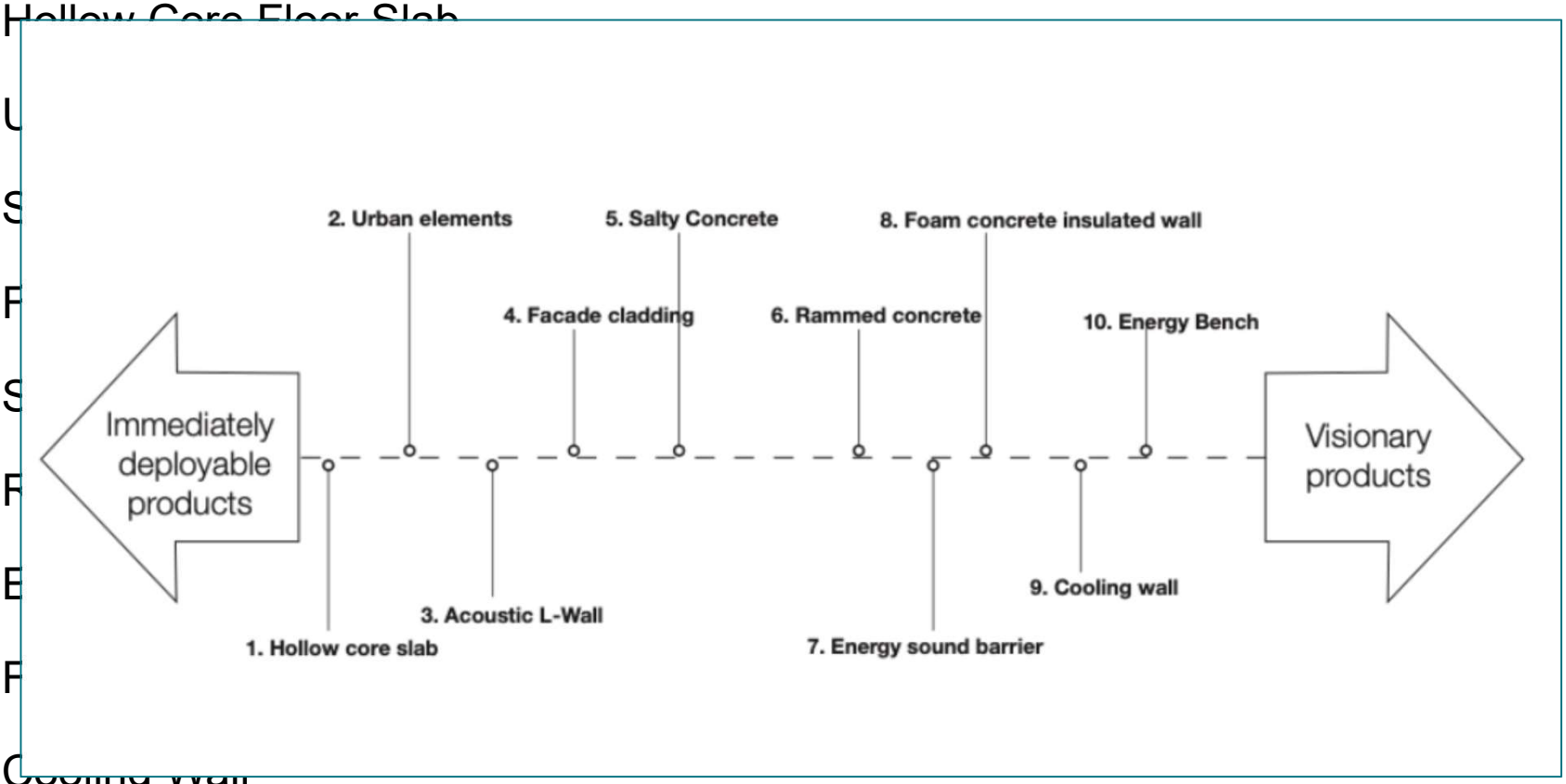
17 Partners from 5 EU countries (Germany, France, Netherlands, Belgium, Luxemburg)

10 Product designs

1. Hollow Core Floor Slab
2. Urban SeRaMCo Elements
3. Sound Absorbing L-Wall
4. Façade Cladding
5. Salty Concrete
6. Rammed Concrete
7. Energy Sound Barrier
8. Foam Concrete Insulated Wall
9. Cooling Wall
10. Energy Bench

10 Product designs

1. H
2. U
3. S
4. F
5. S
6. F
7. E
8. F
9. C
10. Energy Bench



10 Product designs

1. **Hollow Core Floor Slab**
2. **Urban SeRaMCo Elements**
3. **Sound Absorbing L-Wall**
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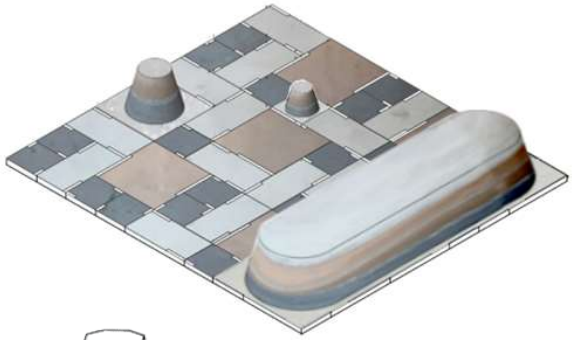

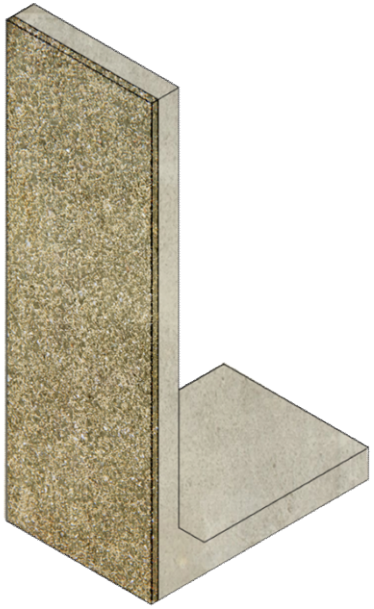

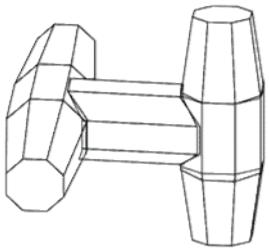

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10 Product designs

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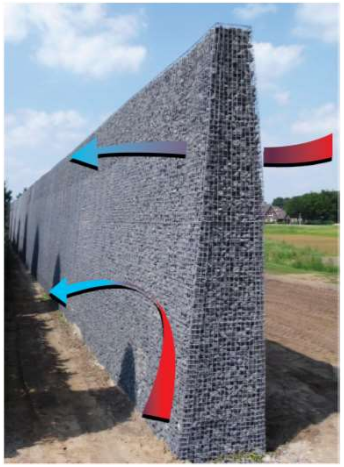

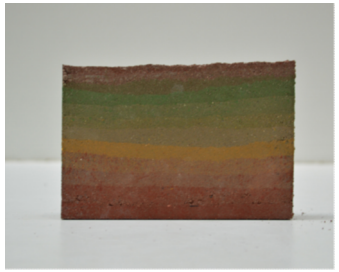

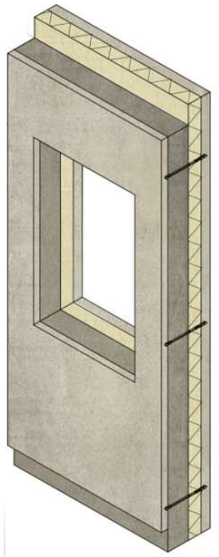

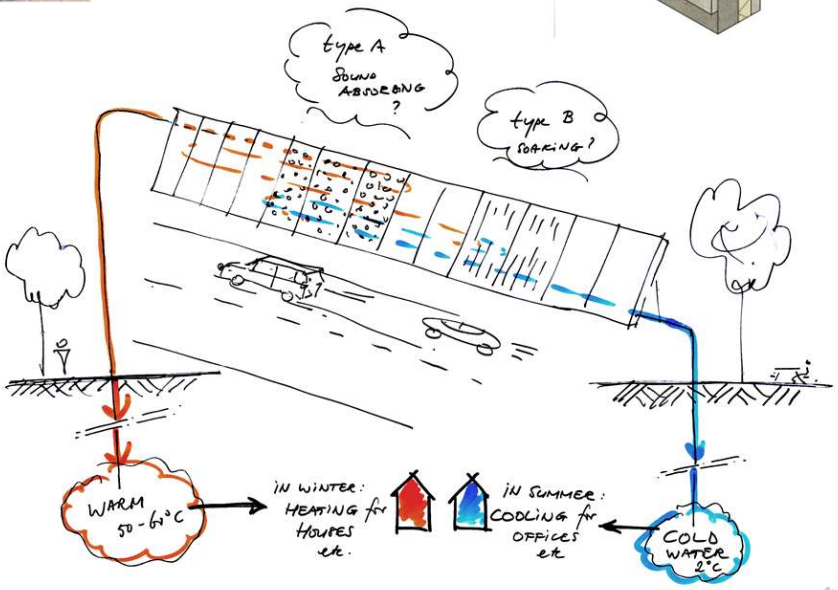

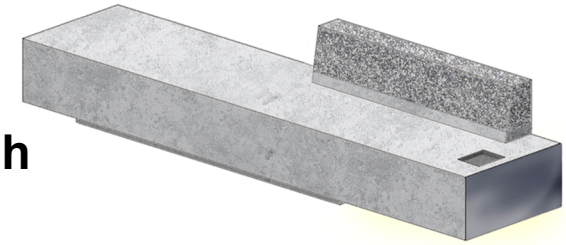

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Parkour Parc

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Recommendations

- Enhance public procurement through the introduction of **mandatory percentages** of recycled aggregates in large civil engineering projects;
- Develop reuse/reclaimed products programme of **support and promotion** (e.g. reuse percentage target);
- Introduce end-of-waste criteria for recycled products;
- **Develop standards for recycled materials** for various utilization for waste that did not meet end-of-waste criteria;
- Facilitate material content **traceability**;
- Introduce applications for recycled non-aggregates;
- Encourage the construction products and materials supply chain to have **much greater provision** for taking back and incorporating recycled materials into new products;
- Deploy **financial incentive** to use recycled aggregates.

Acknowledgment

- VALDEM INTERREG FWVL research project
  - “Integrative solutions for the valorization of CDW for transborder circular economy” - *http://www.valdem-interreg.eu*
- SeRaMCo INTERREG NWE research project
  - “Secondary Raw Materials for Concrete Precast Products (introducing new products, applying the circular economy)” - *http://www.nweurope.eu/seramco*
- Wallonia Brussels International