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Recycling Construction and Demolition Waste: lessons based on research project results

Luc Courard, University of Liège
A. Fanara, S. Grigoletto, J. Hubert, R. Libert, J. Troquay, Z. Zhao

Hanoï, December 9th, 2025

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Global context

What to do?

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Global context

- 3R: Reduce, Reuse and Recycle
- 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)

Global context

- 3R: Reduce, Reuse and Recycle
  - Mean recycling of C&DW in EU27 is 87% (7% backfilling and 80% recycling) + 7% landfilling and 6% energy recovery
  - 25 (out of 27) member states comply with the target!
  - In 7 (out of 25 states complying), compliance is only with backfilling
- Using CD&W as sub-base and base material in road construction ("less noble") → upcycling ("upscaling")

Use of recycled aggregates in concrete – opportunities for upscaling in Europe. J. N. Pacheco, J. de Brito, M. L. Tornaghi, 2023 (JRC Science for policy report (ISSN 1831-9424)

Materials and environment

- Transforming wastes …

Materials and environment

- … into secondary ressources

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Research and innovation

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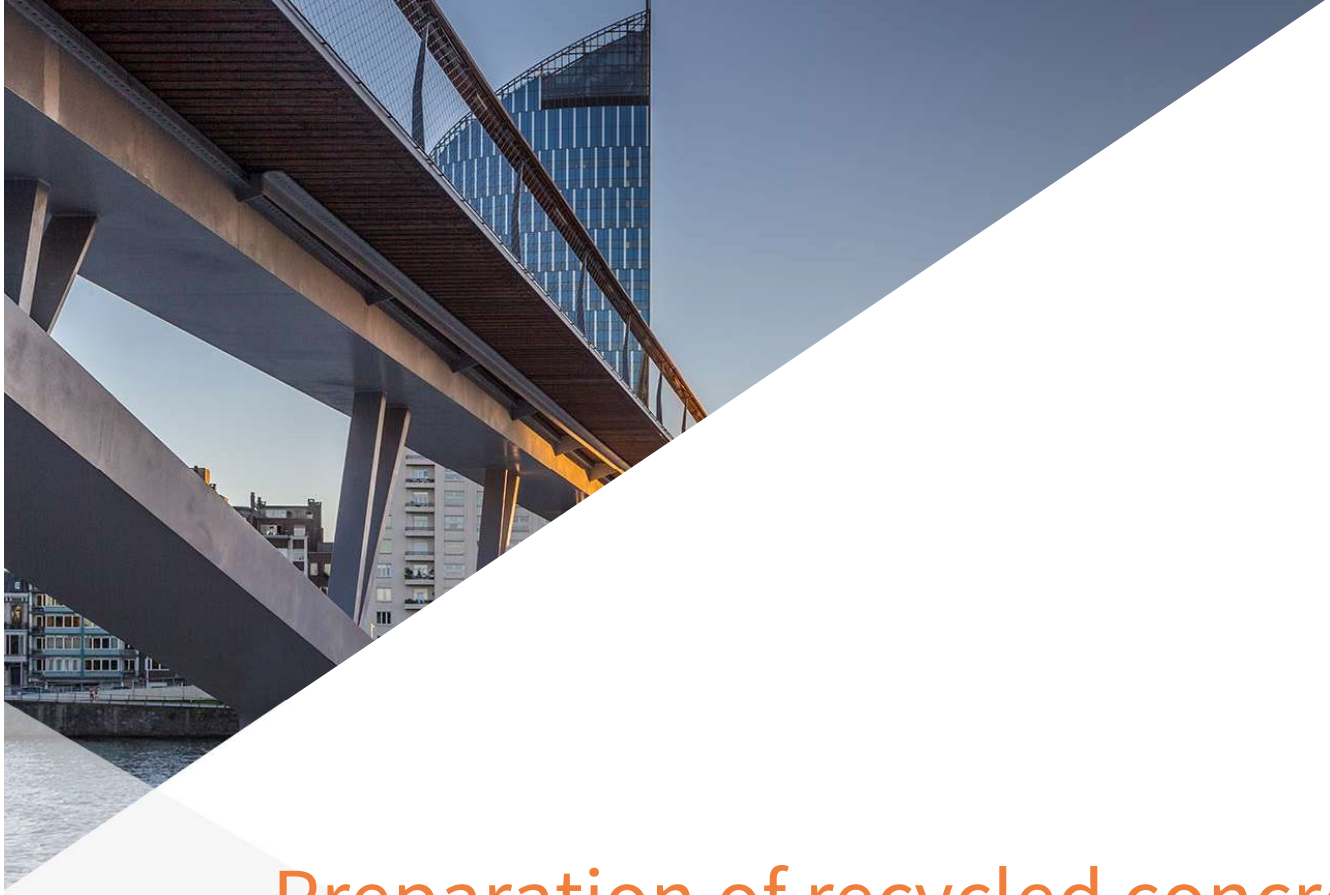
Research and innovation

- Research and innovation in improved methods for reuse and recycling

Research and innovation

- Research and innovation in improved methods for reuse and recycling
  - Preparation of recycled concrete aggregates: materials processing
  - Recycling production waste for concrete blocks
  - RAC for prefab elements
  - Valorization of fine bricks
  - Use of recycled aggregates for cladding
  - Production of compressed blocks



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Preparation of recycled concrete aggregates: materials processing

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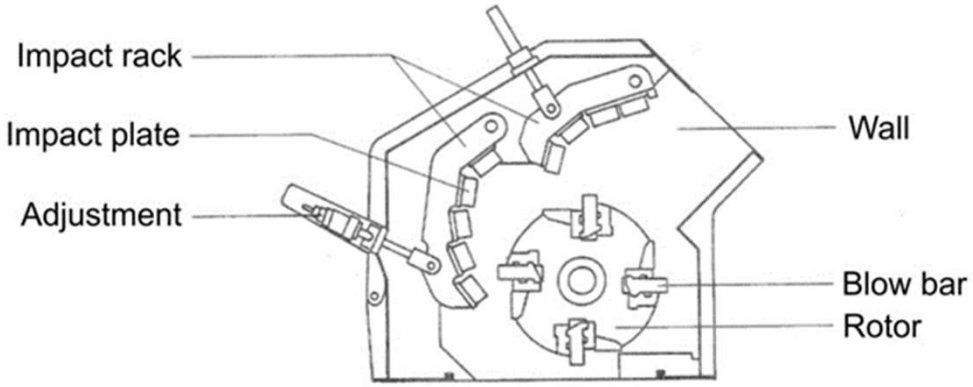
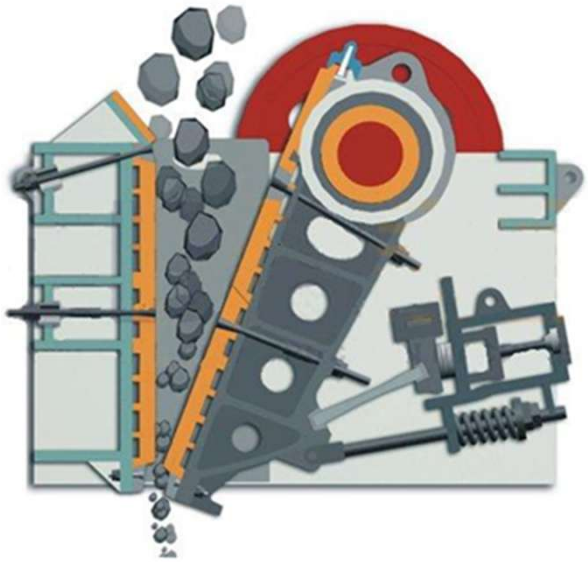
Material processing

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





Effects of crushing method on the properties of produced recycled concrete aggregates. J. Hubert, Z. Zhao, F. Michel, L. Courard. Buildings 2023, 13, 2217 (https://doi.org//10.3390/buildings13092217)

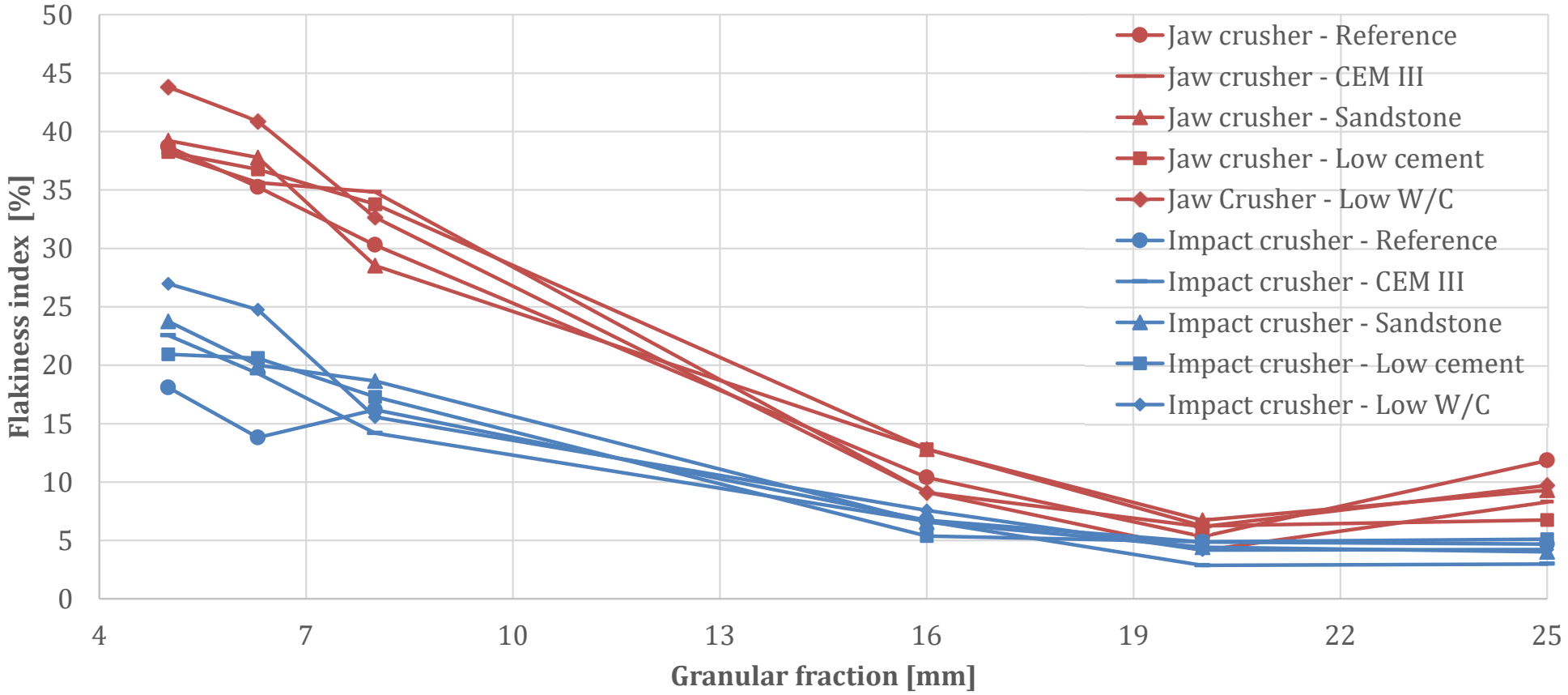
Material processing

- Experimental mixes

Name	Reference	CEM III	Sandstone	Low cement	Low W/C
Aggregates nature	Limestone	Limestone	**Sandstone**	Limestone	Limestone
Aggregates 2/7 mm (kg/m³)	368.8	368.8	368.8	405.1	367.1
Aggregates 7/14 mm (kg/m³)	345	345	345	379	343.4
Aggregates 14/20 mm (kg/m³)	433.5	433.5	433.5	476.2	431.5
Sand 0/4 mm (kg/m³)	604.9	604.9	604.9	664.4	602.1
Cement type	CEM I 52.5	**CEM III 52.5**	CEM I 52.5	CEM I 52.5	CEM I 52.5
Cement quantity (kg/m³)	400	400	400	**320**	452
Cement paste volume (dm³/m³)	351	358	351	282	351
Efficient water (kg)	224.2	224.2	224.2	180.6	207.1
W/C ratio	0.56	0.56	0.56	0.56	**0.46**
Superplasticizer (g/kg cement)	0	0	0	6.8	3.3

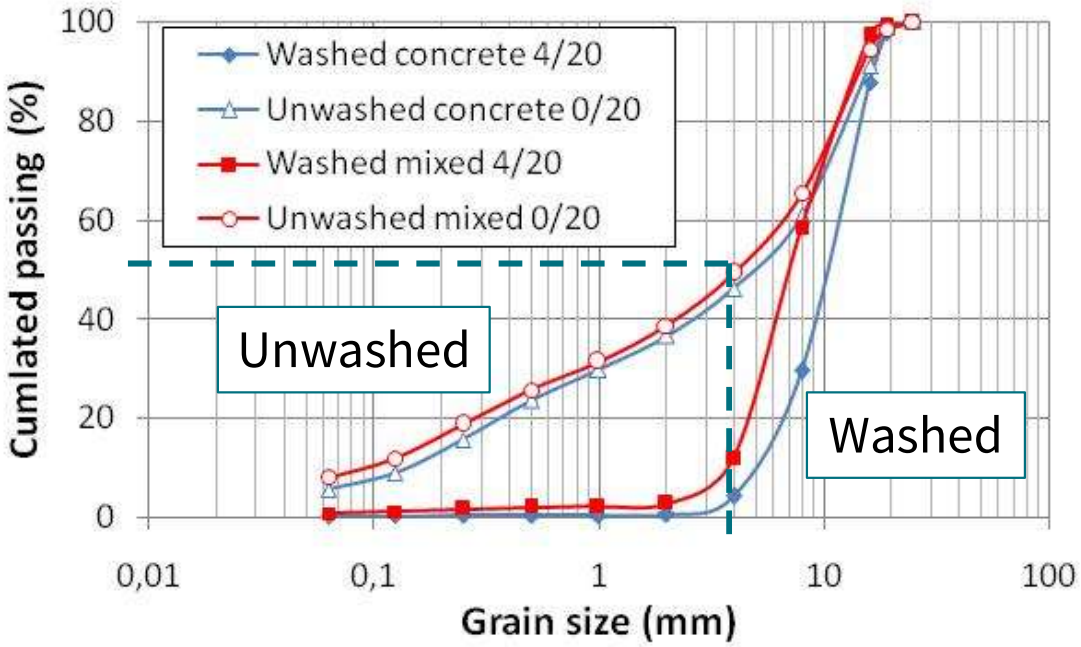
Material processing

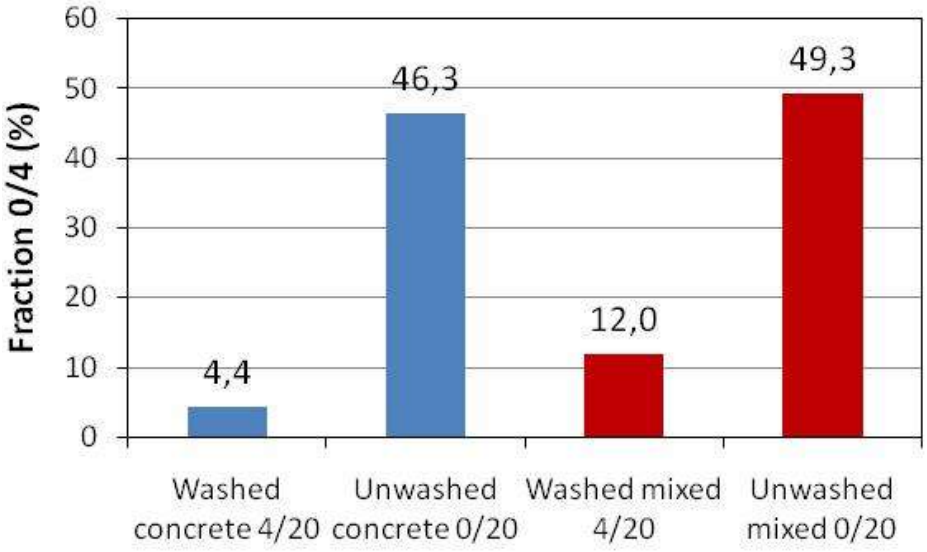
- The **flakiness** index decreases with **increasing granular fraction**
- The **jaw crusher** produces **flakier** aggregates
- No influence of the concrete composition



Materials processing: washing

- **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





Washing process for enhancing performances of coarse recycled aggregates. J. Hubert, Z. Zhao, F. Michel, L. Courard. Journal of Minerals and Materials Characterization and Engineering, 13(4),156-169 2025 (https://doi.org/10.4236/jmmce.2025.134010)

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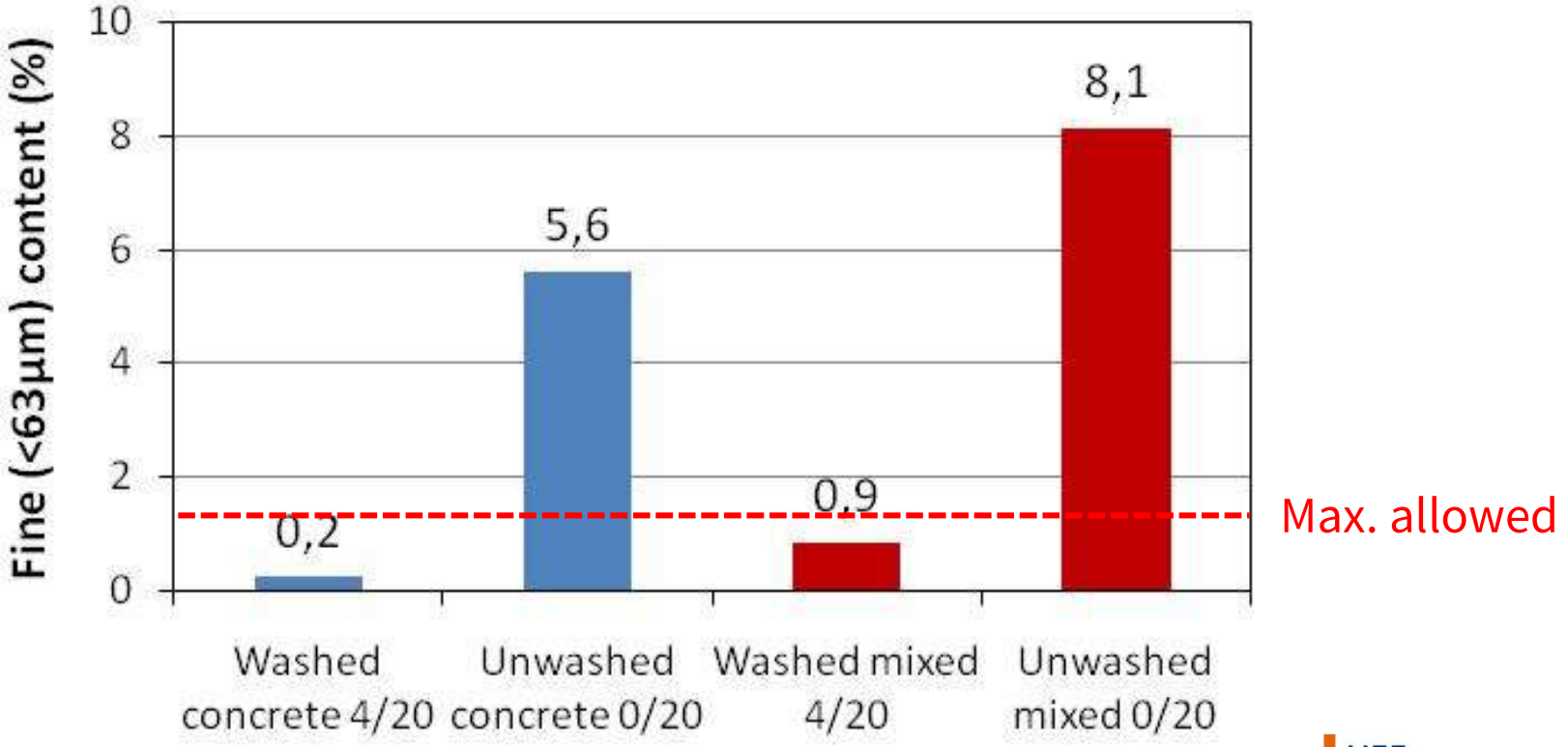
Materials processing: washing

- **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



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Recycling production waste from and for concrete blocks

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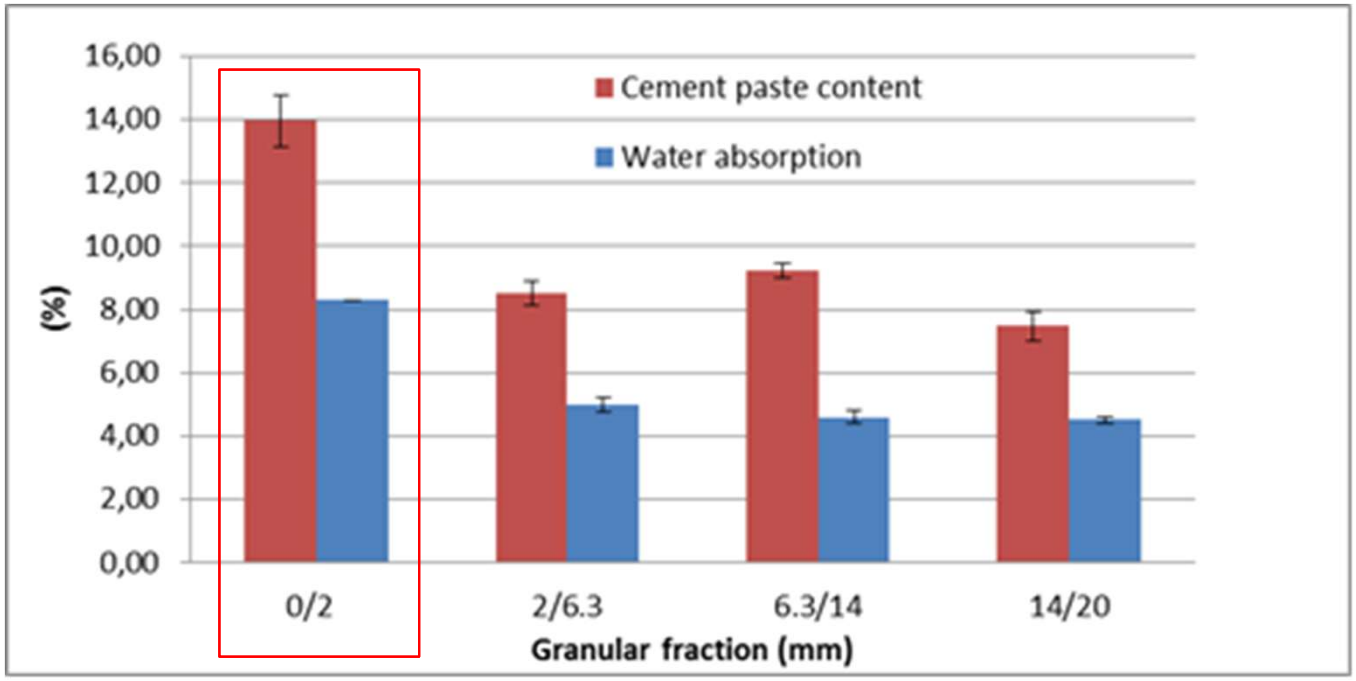
Using wastes

- RCA manufactured in laboratory
  - Old concrete from block wastes (C8/10 concrete)
  - 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

Use of RCA from precast blocks for the production of new concrete building blocks: an industrial scale study. Z. Zhao, L. Courard, S. Groslambert, Th. Jehin, A. Léonard, J. Xiao. Resources, Conservation & Recycling 157 (2020) 1-13 (https://authors.elsevier.com/a/1ahbs3HVLKiAuJ)(http://hdl.handle.net/2268/246444)

Using wastes

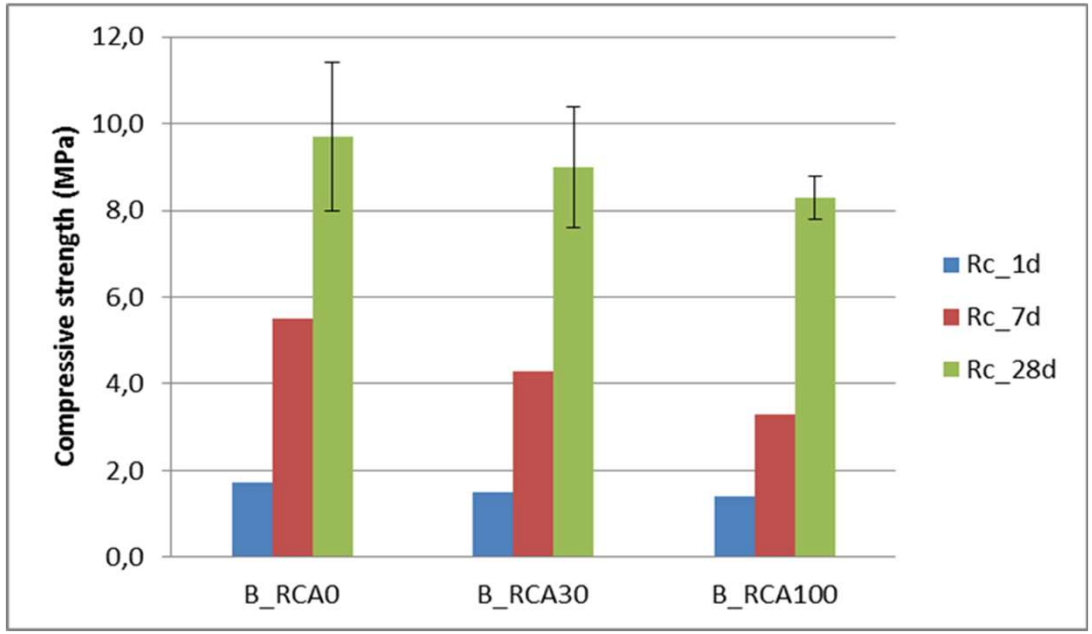
- Water absorption W_A (EN 1097-6)

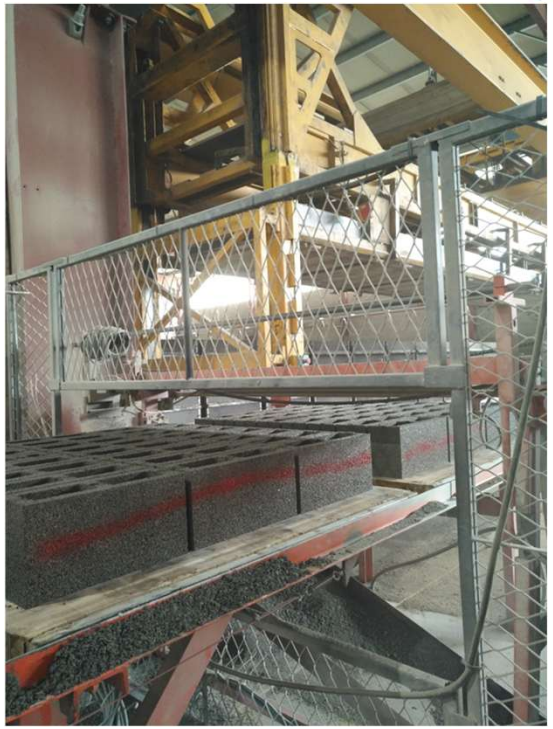


  - Cement Paste Content and W_A of 0/2mm fraction larger than three coarse fractions

Using wastes

- 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)

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Recycled Aggregates Concrete for prefab elements

Funded by the European Union
NextGenerationEU

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North-West Europe
SeRaMCo
European Regional Development Fund

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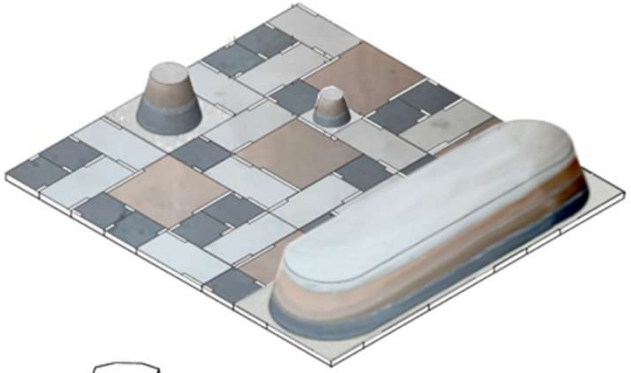
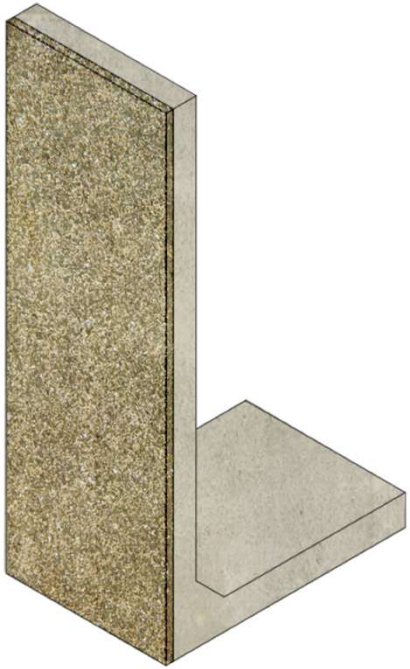
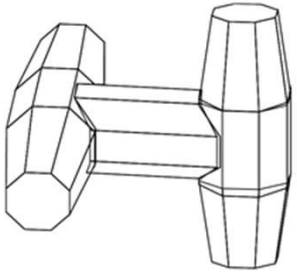
Prefab products

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







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Prefab products

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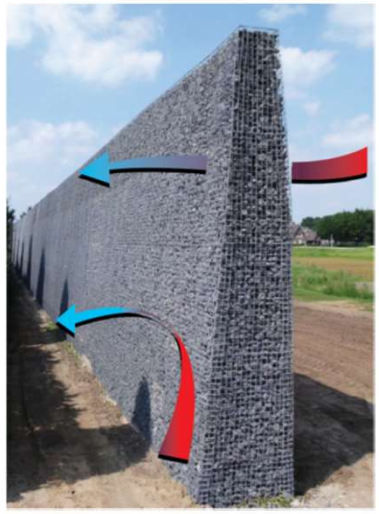

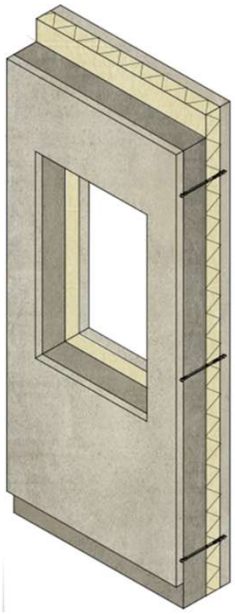

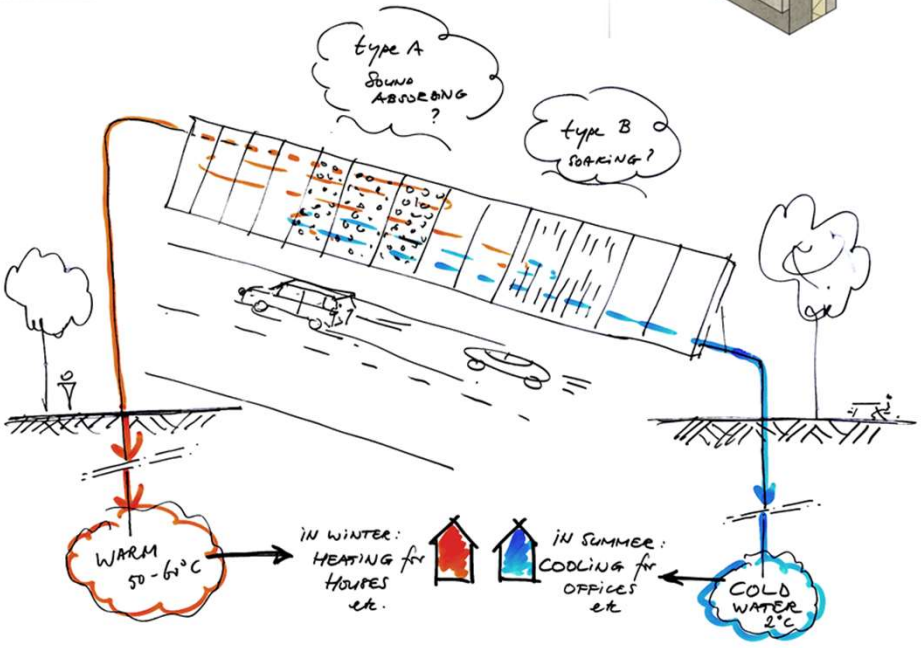

Prefab products: Parkour Park

Cement produced with recycled fines

Recycled concrete aggregates

Natural sand

Rc : 50-55 MPa
W/C <= 0.45
Cement >= 340 kg/m³
WAI <= 6.5%

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Valorization of brick fines

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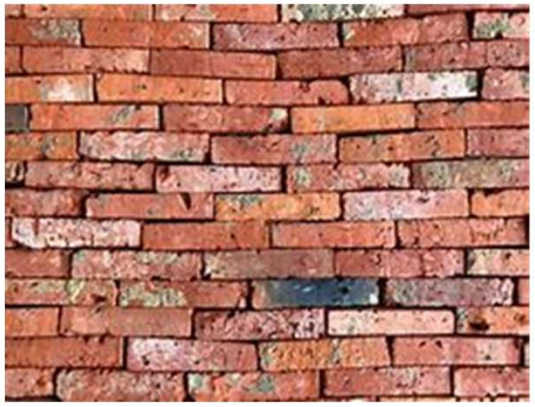
Fine bricks

- Flow of brick waste: 1-2% of C&DW in BE/North of France
- Valorization
  - Reuse of bricks
  - Aggregates: landfilling/recycling for backfilling
  - Brick fine particles



Recycled brick fines for new alkali activated binder. A. Grellier, D. Bulteel, L. Courard. 17th International Congress on Polymers in Concrete ICPIC 2023, Sept. 17-20th, Warsaw.

Fine bricks

- Brick fine particles
  - 3 types of granulometry
    - B1: d_{50} = 3.3 µm (*with supplementary cyclogrinding*)
    - B2: d_{50} = 20 µm
    - B3: d_{50} = 190 µm
- Mineralogy

Oxides (%)	CaO	SiO_2	Al_2O_3	Fe_2O_3	K_2O	Na_2O	MgO	TiO_2	Total
Brick fine	1.7	62.8	10.4	16.3	2.1	0.6	2.2	2.4	99.3
GGBFS	42.9	38	10.8	0.5	0.3	-	6.5	0.7	99.5

Alternative hydraulic binder development based on brick fines: influence of particle size and substitution rate. A. Grellier, D. Bulteel, Z. Zhao, S. Remond, L. Courard. Journal of Building Engineering 102263 (2021). (https://doi.org/10.1016/j.jobe.2021.102263)(http://hdl.handle.net/2268/252191)

Fine bricks

- Alcali Activated Material production

Brick fine particles
B2

GGBFS

Alcali-Activating Solution

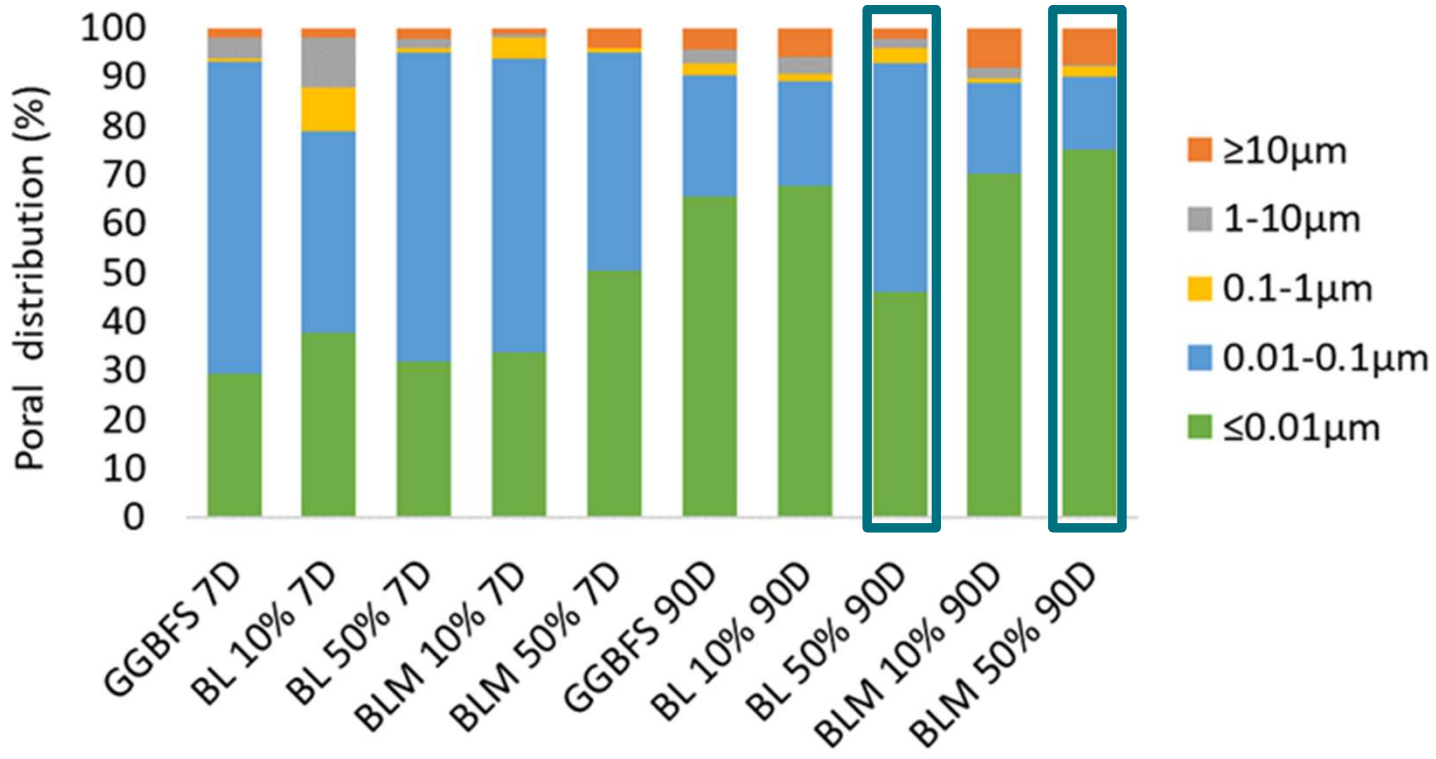
Soda (NaOH)
Sodium Silicates (Na_2SiO_3)
(SiO_2/Na_2O: 1.45)

Substitution
10, 20, 30 and 50 %

Characterization at
7 and 90 days

Fine bricks

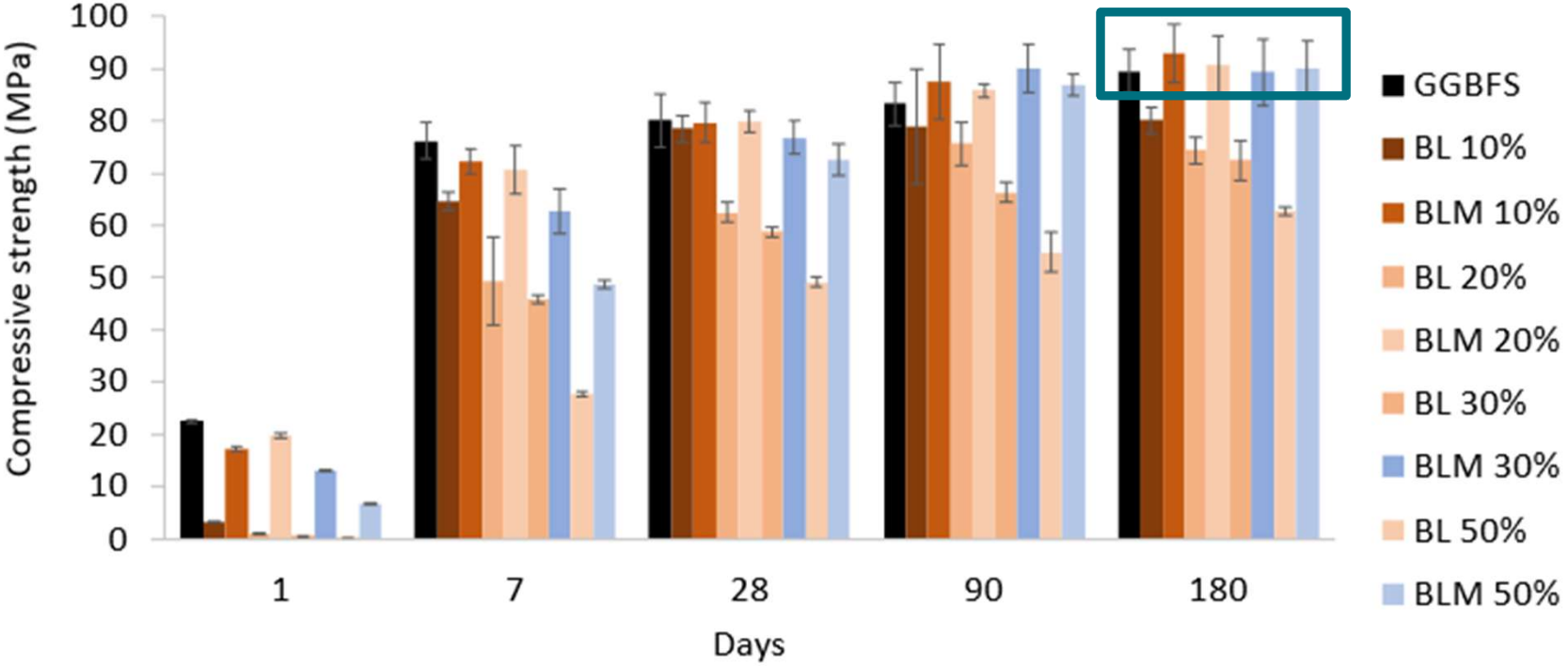
- Poral distribution



  - Finer porosity with time for all the mixes
  - Finer porosity with BLM 50% than BL 50%

Fine bricks

- Mechanical strength



  - BL: slower kinetics – Rc ↓ when [brick fines] ↑
  - BLM: quicklier kinetics - **Rc ≥ GGBFS from 90 days**
  - Brick fines can act as a *precursor*

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Compressed recycled fines blocks

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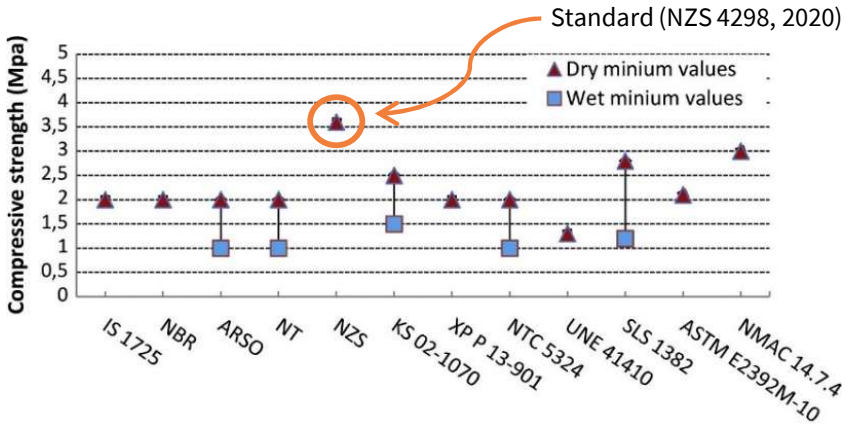
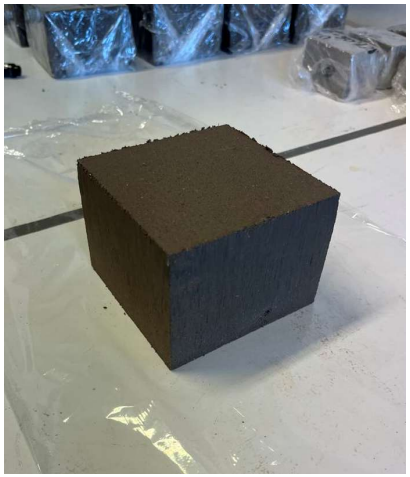
- Optimizing the **compressive strength** of the bricks while minimizing their **environmental impact** (< 10% cement) and **comparing** them to existing construction bricks/blocks.



Compressive strength standards for BTCs by country (1)



Compressed brick

Manual press TESTARAM

- Minimum required : 3,5 MPa
- Target objective : 6 MPa (2)

Applications :
Interior/Exterior walls and partitions

(1) Cid-Falceto et al. (2012). Assessment of compressed earth blocks made in Spain: International durability tests. Construction and building materials.
(2) (2) XP P13-901 (2022). Catégorie RC6 de briques et blocs de terre crue pour murs et cloisons selon les normes européennes.

Materials

- Unwashed mixed recycled sand (MRS 0/2)
- Soil fines (< 63 µm)
- CEM III/B 32,5 N

Fabrication process

- Mixing components
- Manufacturing bricks by compaction → 15 tons
- Curing under protective film for 28 days (23°C and 60% R.H.)

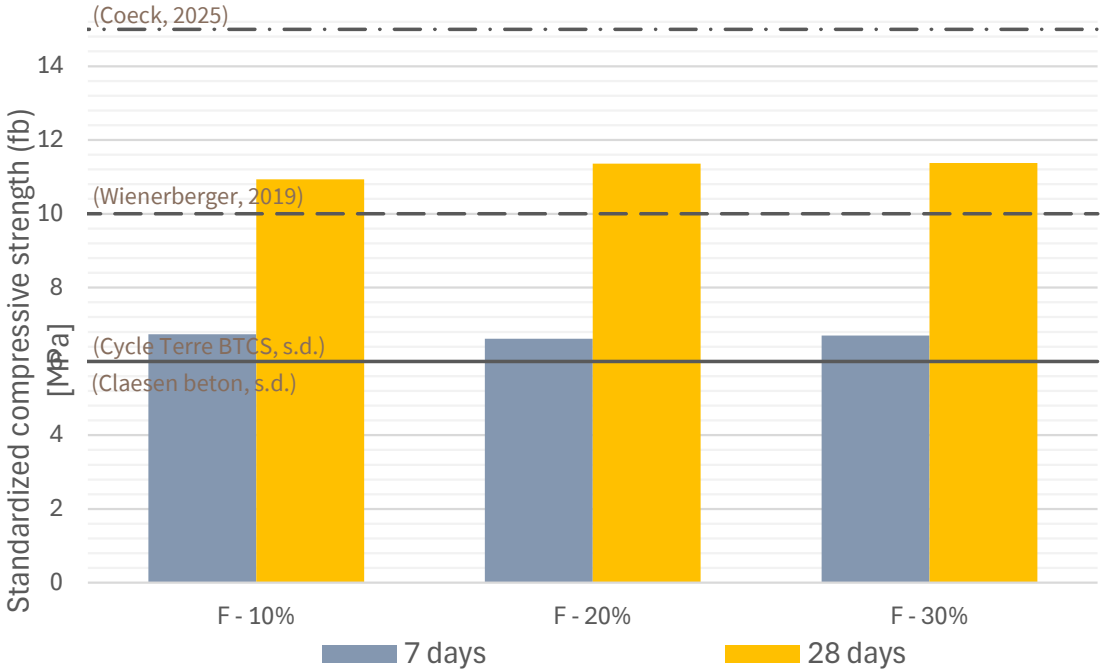
Bricks characterization

- Effective water content of fresh mixes
- Density after 28 days
- Compressive strength after 28 days
- Water absorption

Reuse of fines particles from concrete recycling (< 63 µm) for the manufacture of compressed bricks. R. Libert, J. Troquay, F. Michel, L. Courard. 2nd International Conference on Net-Zero Built Environment: Innovations in Materials, Structures, and Management, November 05 - 07, 2025 | Cape Town, South Africa.

- Results optimized mixes (10%, 20% & 30% of fines)

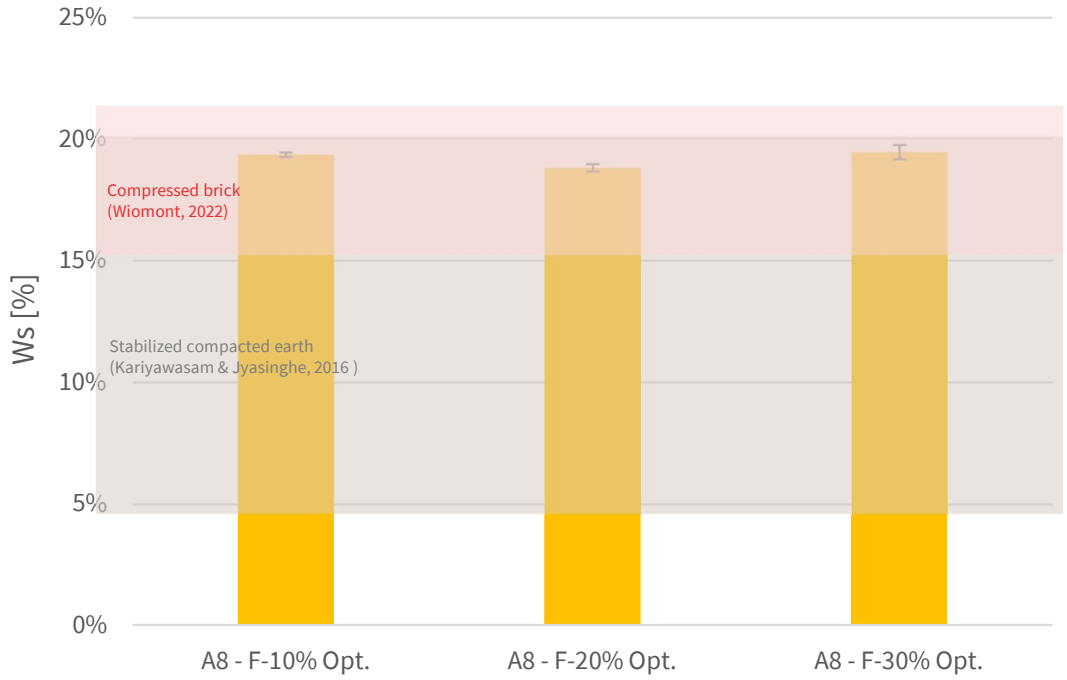
  - Compressive strength at 28 days (cement content : 180 kg/m³)



Type of brick/block	f_b (MPa)
AAC block	2 -> 5
CEB	4
CSEB & expanded clay	6
Clay brick	10
Compressed brick	±11
Traditional concrete block	15
Slag and silicate calcium brick	> 20

- Results optimized mixes (10%, 20% & 30% of fines)

  - Water absorption at 28 days (cement content = 180 kg/m³)



- Main limitation of the material
- Compressed bricks absorb ≈19% water
- Suitable for indoor use or dry climates

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Use of recycled aggregates for cladding

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CIBER – Precast concrete walls

- Fresh state behaviour

Concrete mixes

- Reference mix -> 100% NA
- ICM 2-A -> 50% replacement (coarse + sand)
- ICM 5 / ICM 5-A -> 75% replacement (50% coarse + 25% sand)
- ICM 6 -> 50% replacement of coarse aggregates only

- **Production requirements**

Parameter	Reference	ICM 2-A	ICM 5	ICM 5-A	ICM 6
Recycled content (%)	**0%**	**49%**	**78%**	**78%**	**53%**
Targeted strength class	C30/37				
Environment class	EE3				
Durability requirement	T (0,50)				
Minimum cement (kg/m³)	320				

- **Fresh concrete results**

Parameter	Reference	ICM 2-A	ICM 5	ICM 5-A	ICM 6
Slump (mm)	230	245	220	210	230
Air content (%)	2,2	2.8	3.6	3.1	1.6
Density (kg/m³)	2360	2270	2190	2200	2310
Effective W/C (-)	-	0.52	0.48	0.53	0.51

✓ *All mixes comply with Eurocode 2 and BENOR standards for fresh concrete*

Integration of high content of good quality recycled aggregates and sand into prefabricated concrete elements. R. Libert, Y. Muy, F. Michel, L. Courard. 2nd International Conference on Net-Zero Built Environment: Innovations in Materials, Structures, and Management, November 05 - 07, 2025 | Cape Town, South Africa.

CIBER – Precast concrete walls

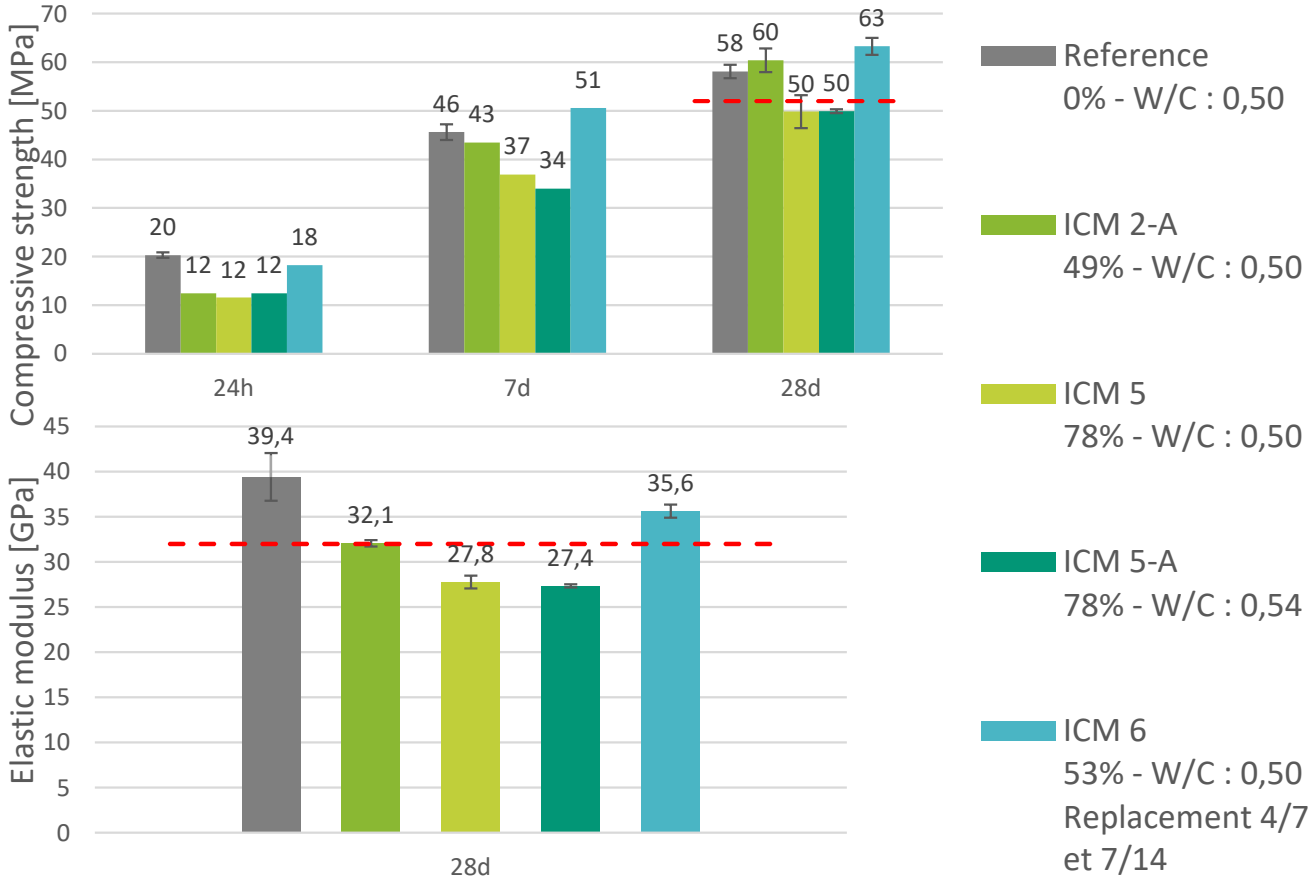
- Mechanical performance

- **Compressive strength**

  - All mixes reach or exceed **target strength** (C30/37)

- **Elastic modulus**

  - Elastic modulus also in the expected range



✓ *ICM 2-A and ICM 6 exceed the 28-day strength target (C30/37) and reach good stiffness values.*

CIBER – Precast concrete walls

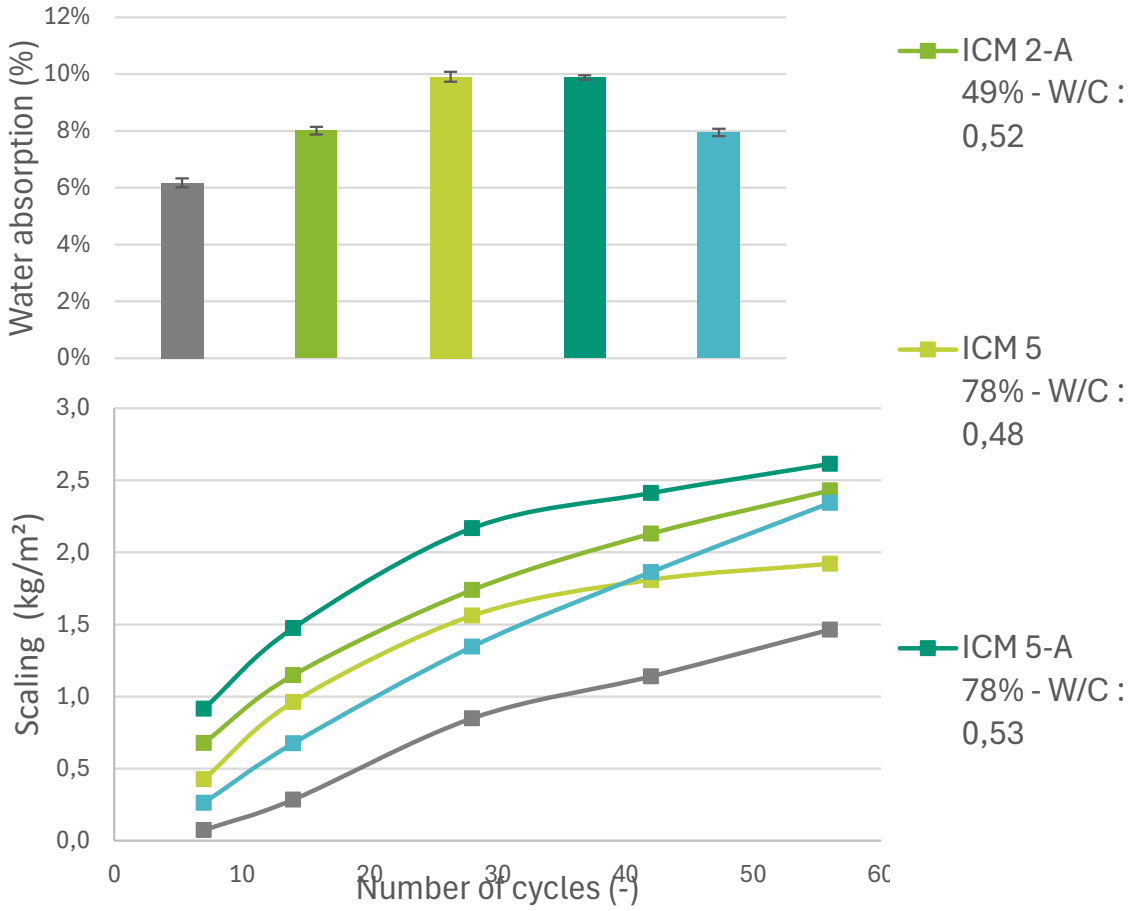
► Durability

► Water Absorption by immersion

- Water absorption **increases with recycled content**
- This is linked to **higher porosity** of recycled aggregates

► Slab test (frezze-thaw cycles)

- All mixes show **higher scaling** than the reference
- Results are **below standard limits**
- The influence comes from both the **amount of recycled aggregates** and **W/C**

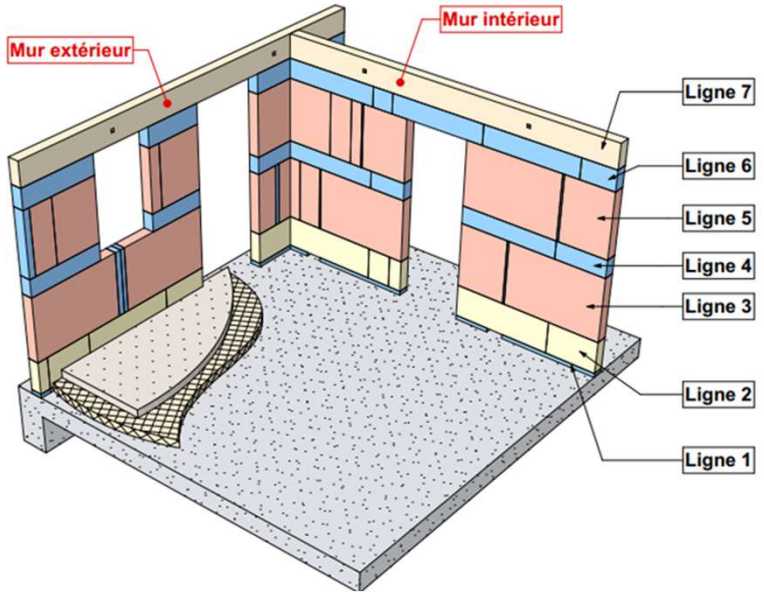


CIBER – Precast concrete blocks

- Results

  - **Block and wall performance**
  - Blocks : ≈ 12 MPa compressive strength at 28 days
  - Walls (with mortars) : > 9MPa
    - Walls behave like precast concrete panels, stronger than traditional masonry walls
    - Fire resistance : 2 hours (RF 2h)
  - **Mortar performance**
  - Low adhesion with recycled mortar (≈ 3.5 MPa at 28 days
  - Designed for easy dismantling and reuse of blocks

  → Supports circular construction and waste reduction



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Conclusions

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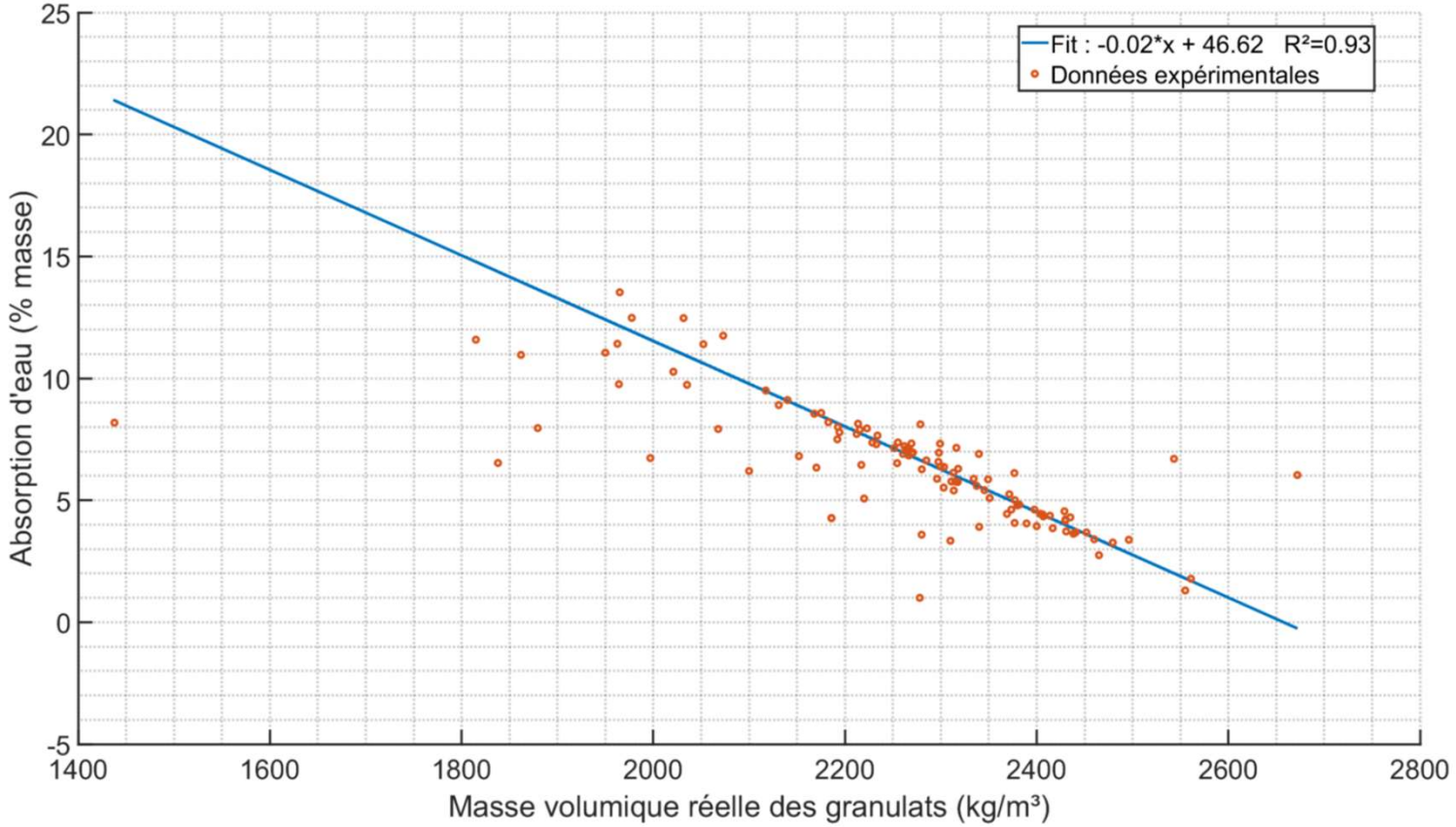
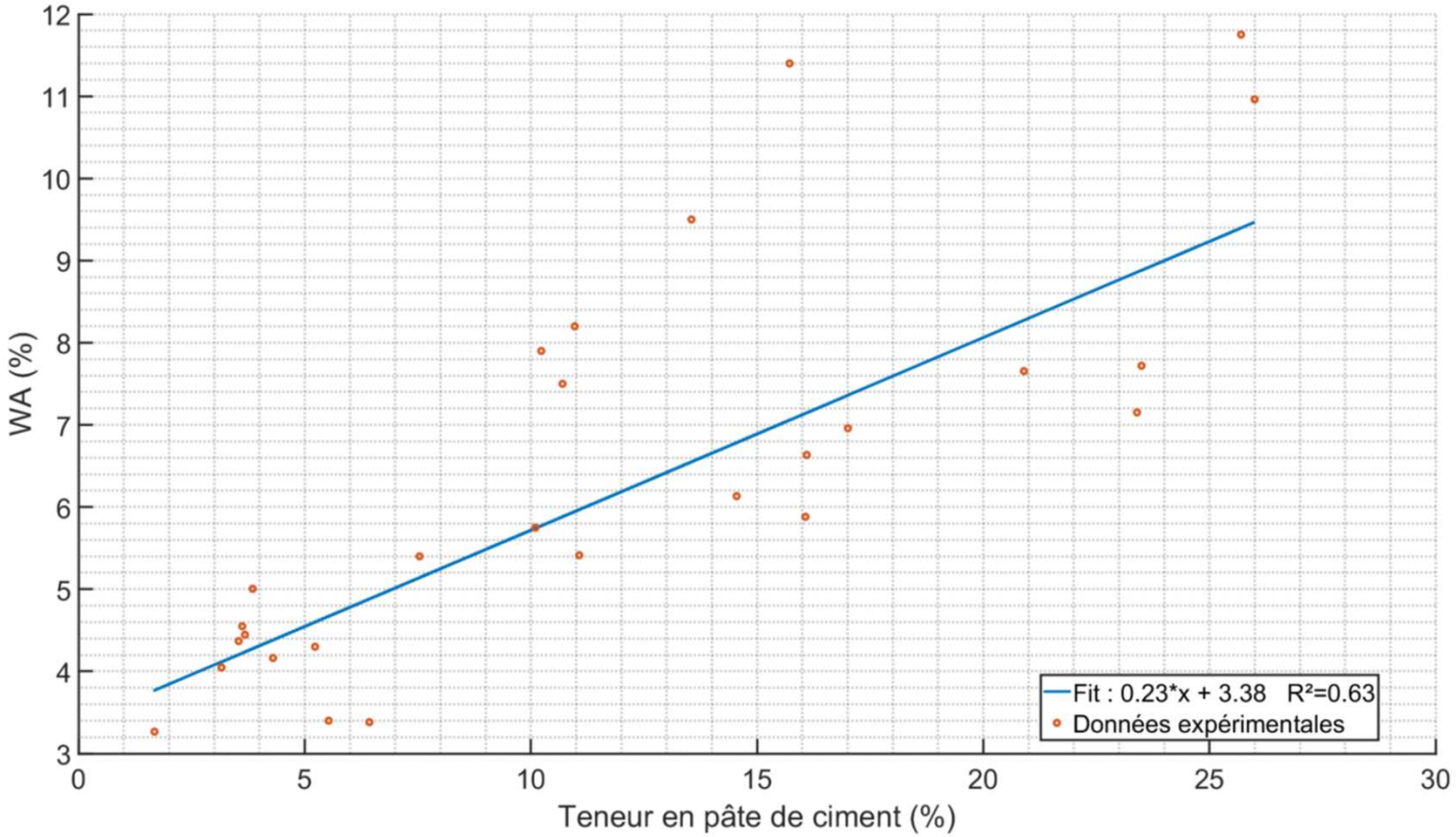
Learning

- Water absorption vs density



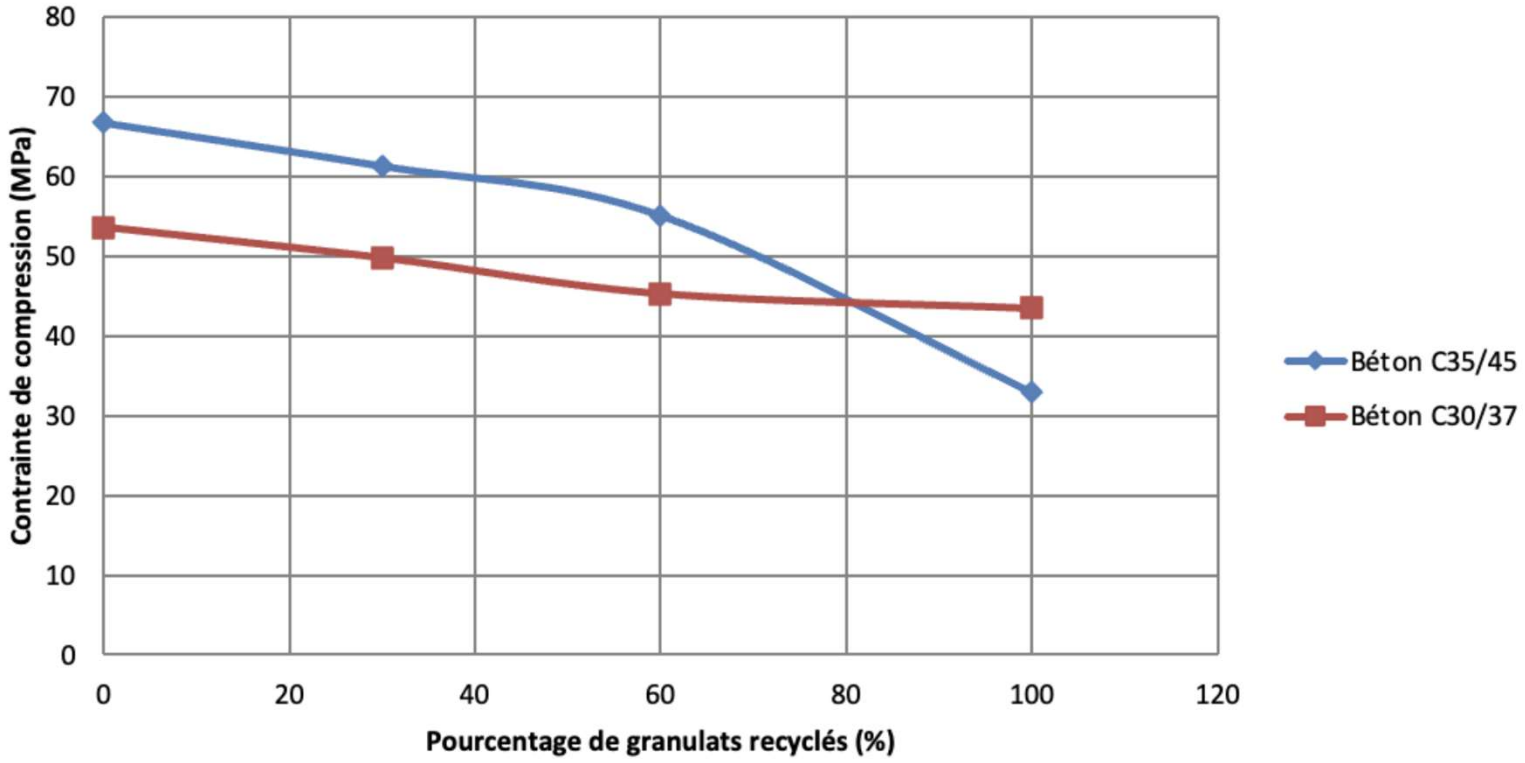
Learning

- Water absorption vs cement paste content



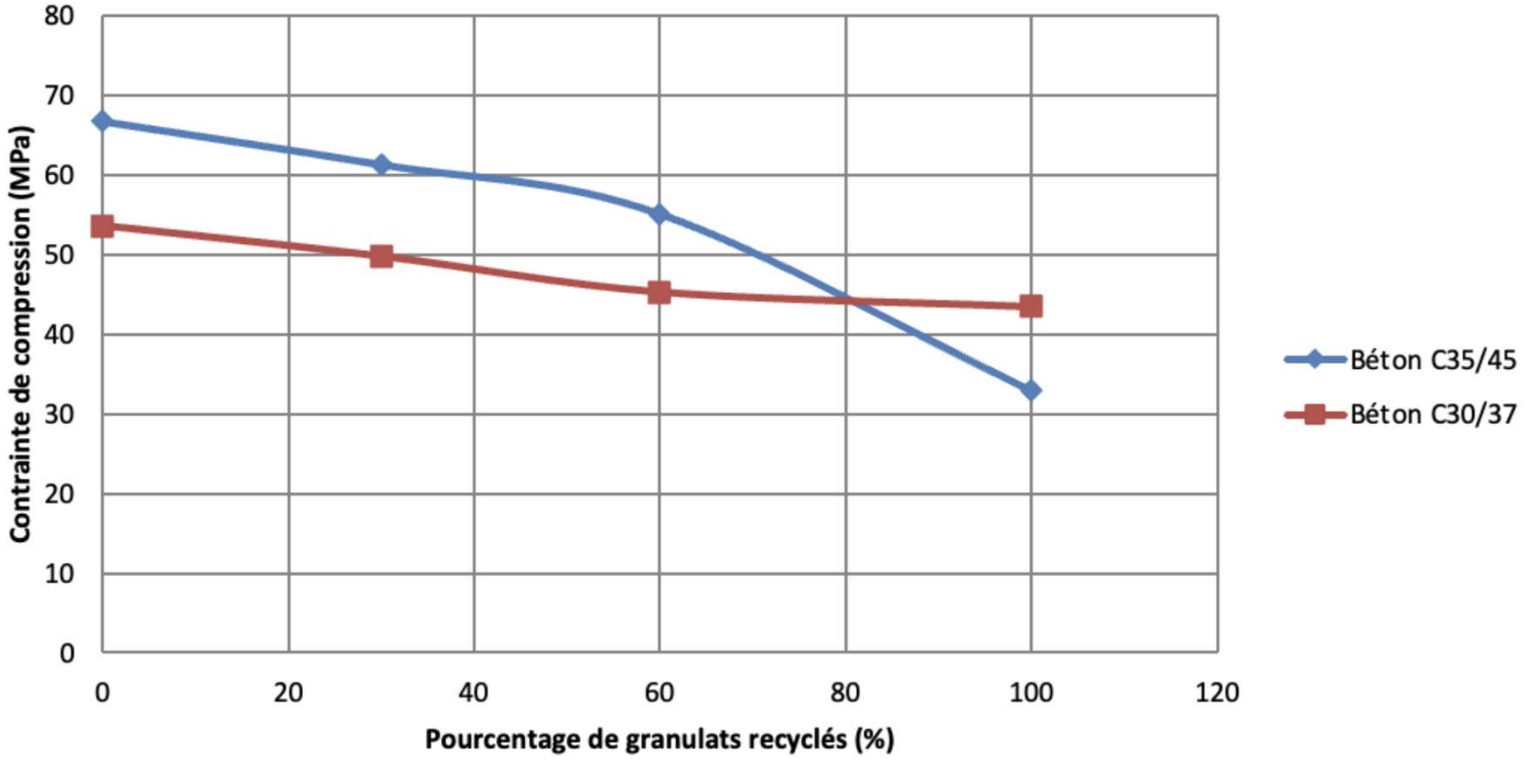
Learning

- Mechanical strength



Learning

- Density



Conclusions

- Recycled aggregates and sands form C&DW

Good opportunities (quantities)

Preparation is important

Grading and washing

Specific treatment (fineness, shape, grading)

AGGREGATES/SAND FROM RECYCLING

are suitable for several applications

Acknowledgment

- Wallonia Brussels International
  - WalDeCoViet II
    High-quality recycled materials : setting up a construction and demolition waste recovery system in Vietnam

Wallonie - Bruxelles International.be
Délégation Viet Nam