



Recycled sands: problem or solution?

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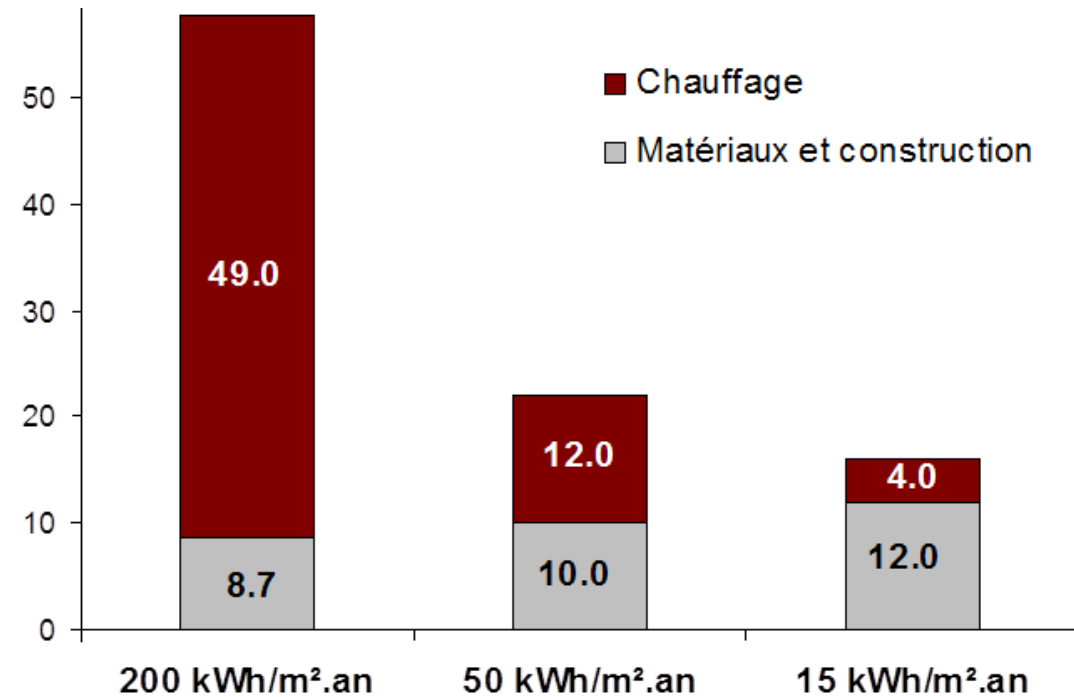
Global context

Development of materials and alternative techniques for buildings

Increasing insulation (energy) performances of housing

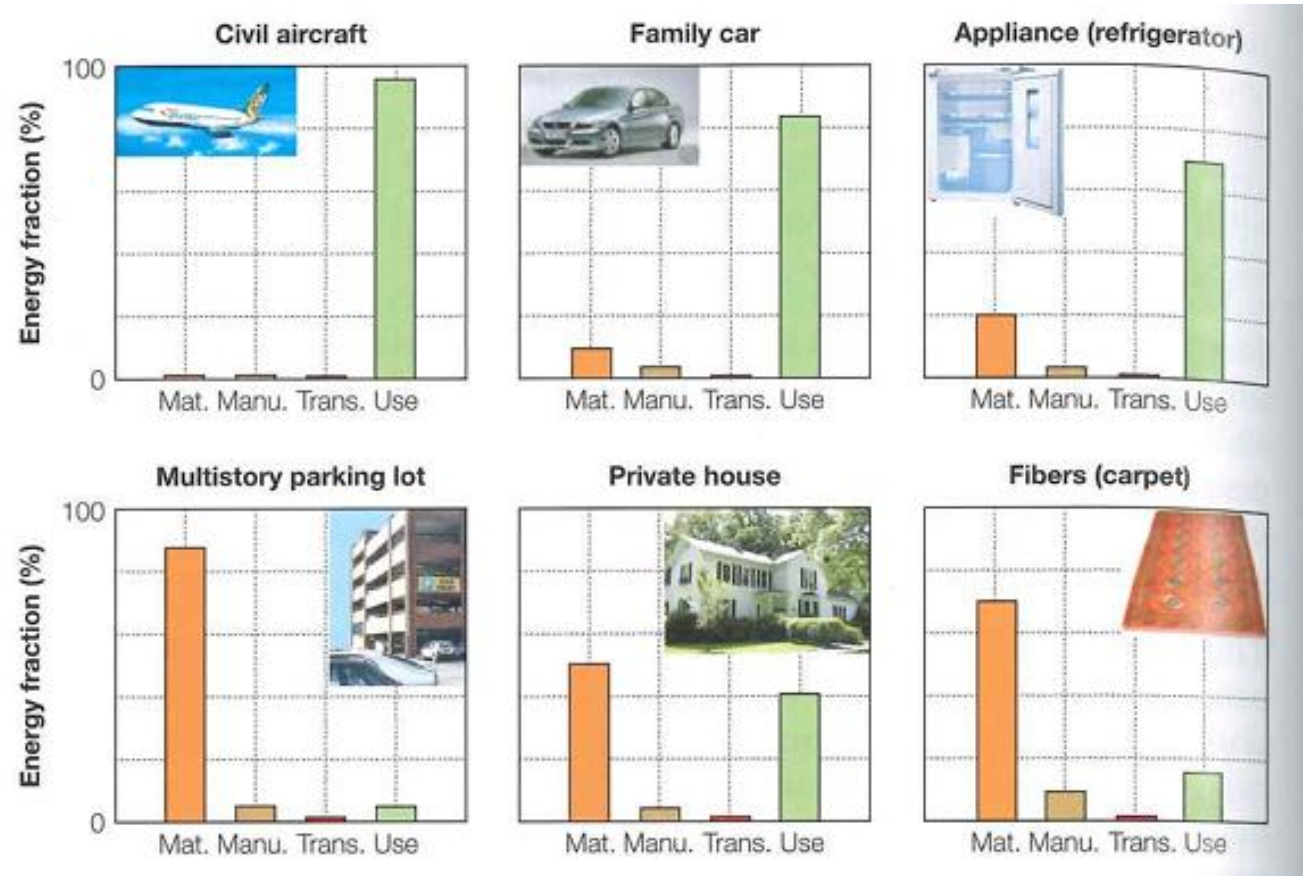
Increase of relative weight of building materials vs environmental impact

Needs for developing new materials



Global context

Approximate value of energy consumed at each phase

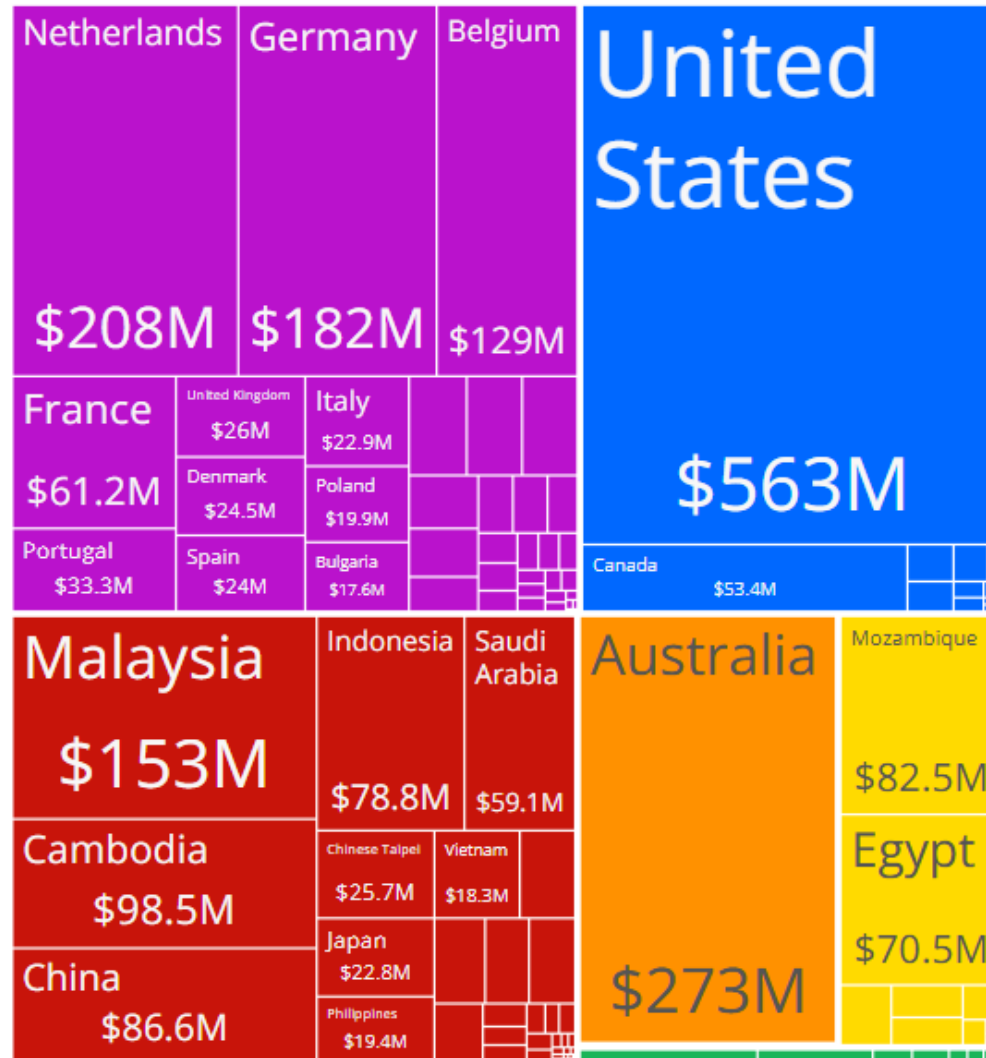


Global context

Sand exporting countries over the world in 2023 (total \$2.57B)

In 2023, the leading exporters of sand were United States (\$563M), Australia (\$273M) and Netherlands (\$208M)

<https://oec.world/en/profile/hs/sand>



Natural resources



Extraction of sand (BGS, 2023)



(Nedeljkovic et al., 2021)

Erosion (rivers,
coasts, ...)



Natural Sand vs Recycled Sand

Recycled aggregates : production



Réception of C&DW



First crushing



Magnetic separator



Second crushing



Recycled aggregates sorted by granulometry



Sieving



Washing + air separation



Manual separation

Recycled aggregates : production

Construction and Demolition Waste



FRCA (d < 4 mm)



CRCA (d > 4 mm)



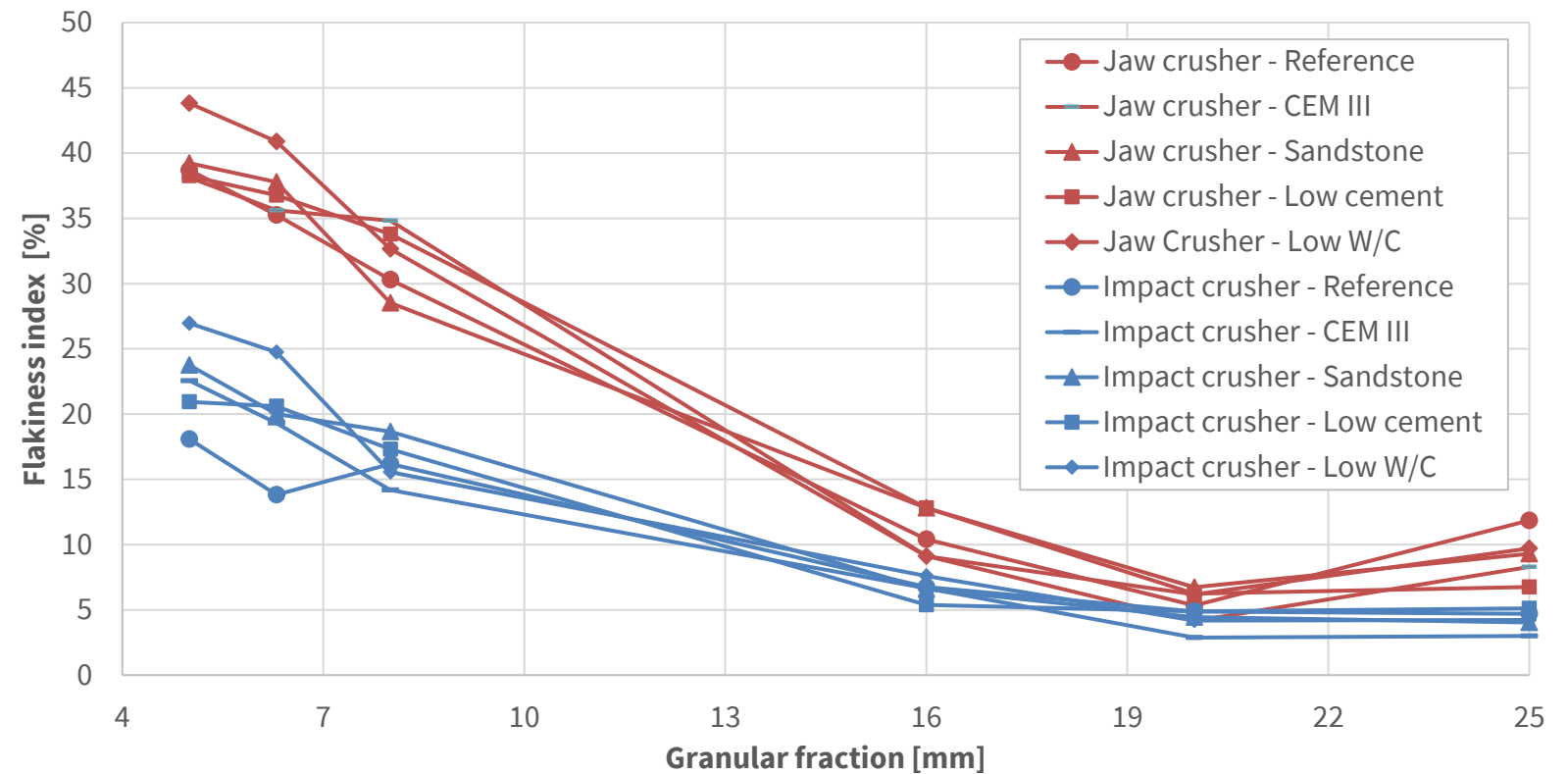
Sands
(0.125 mm < d < 4 mm)



Fines
(0 mm < d < 0.125 mm)

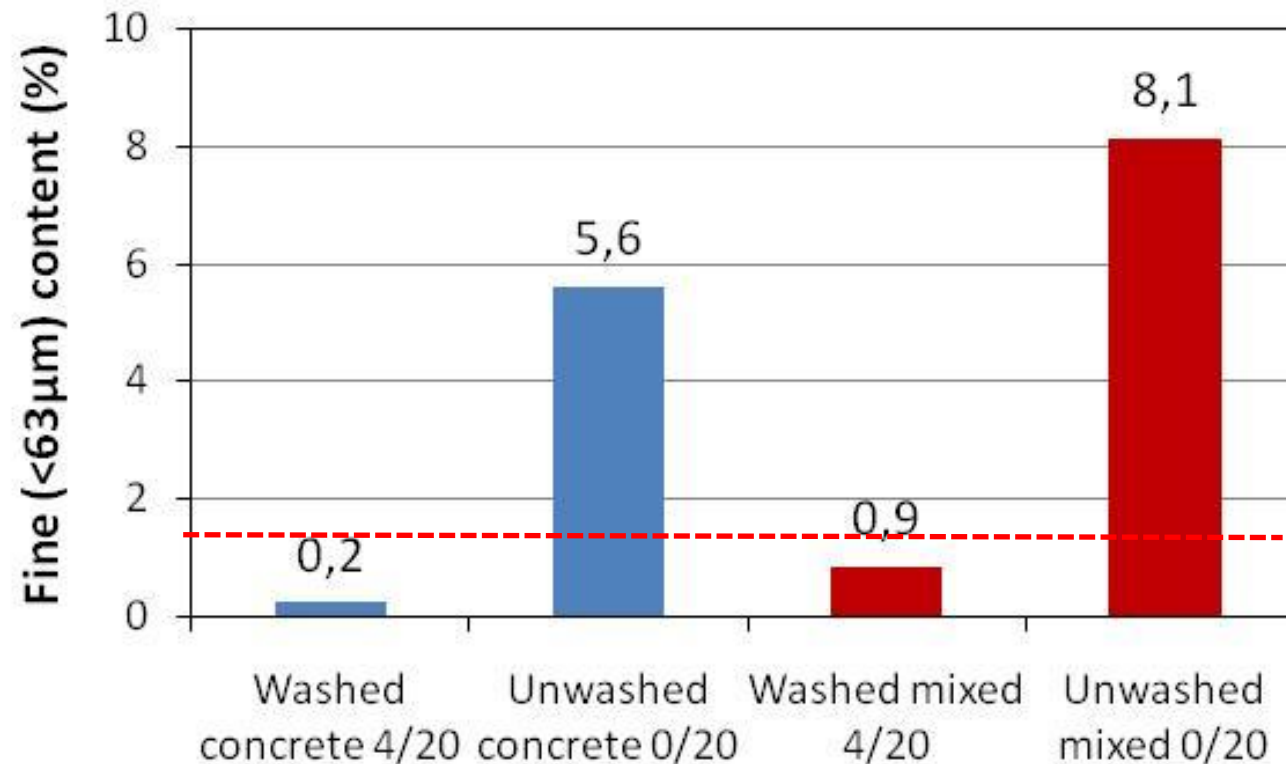
Materials processing : washing

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



Materials processing : crushing

- Fine content ($< 63\mu\text{m}$) higher in mixed aggregates and significantly reduced by washing
- Fine fraction higher in mixed aggregates
- Washed aggregates respect regulations in all considered countries



Max. allowed

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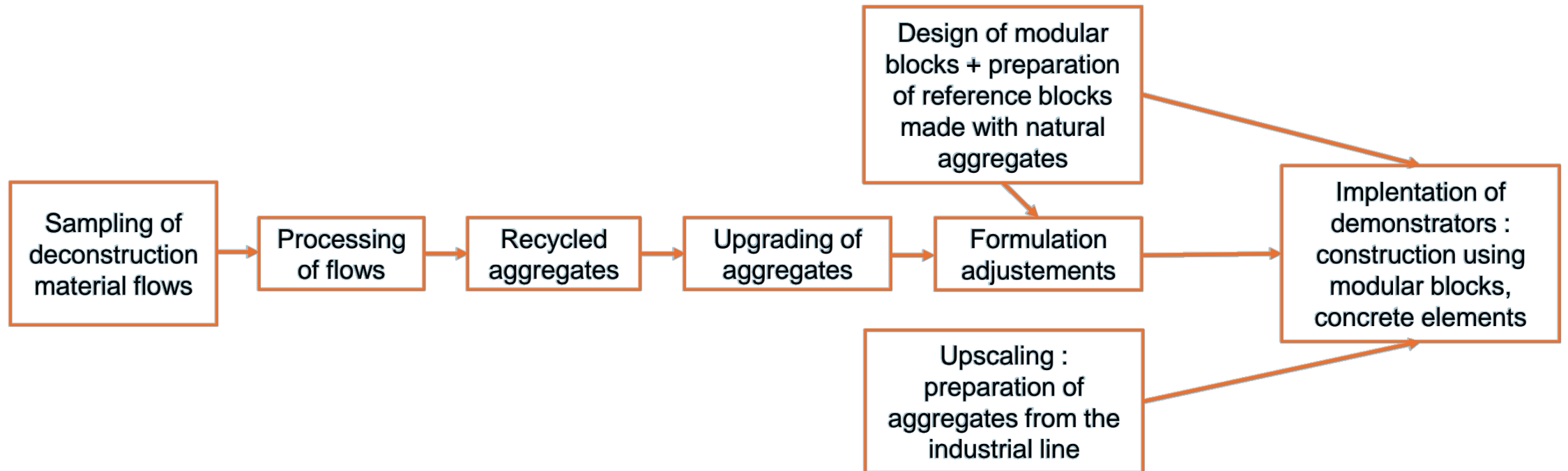
CIBER



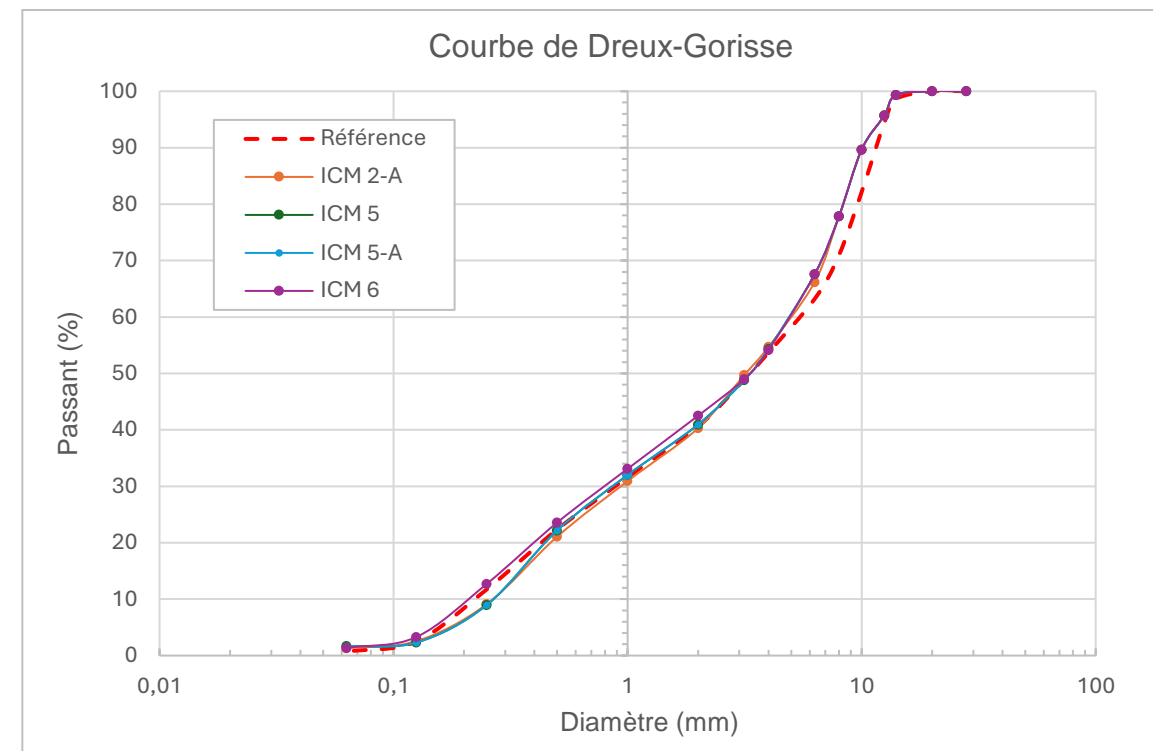
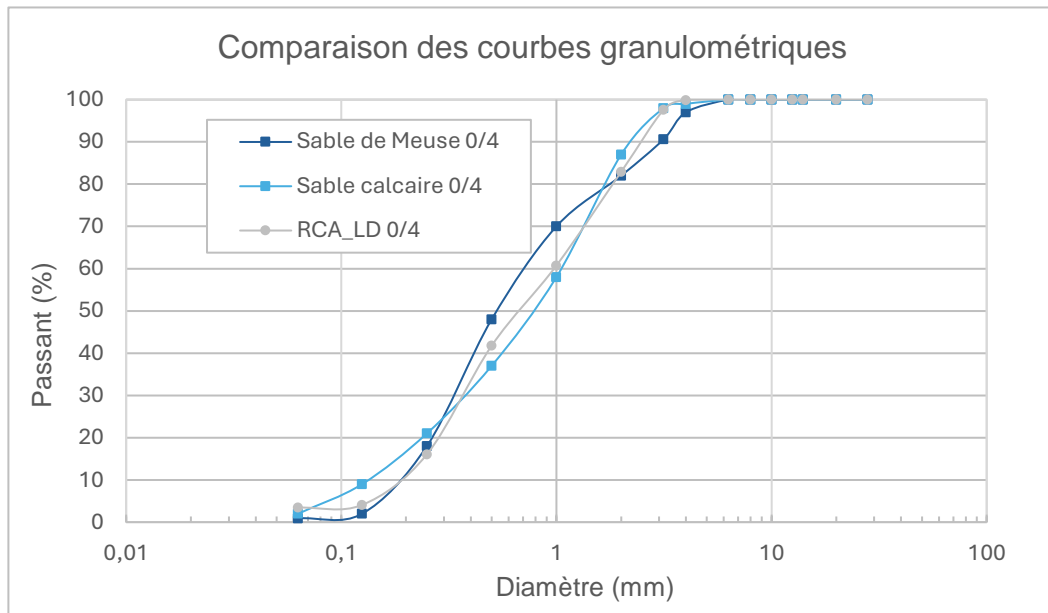
Circularité des BEtons pRéfabriqués



CIBER project : PREFAB concrete elements



Comparison between natural and recycled sands

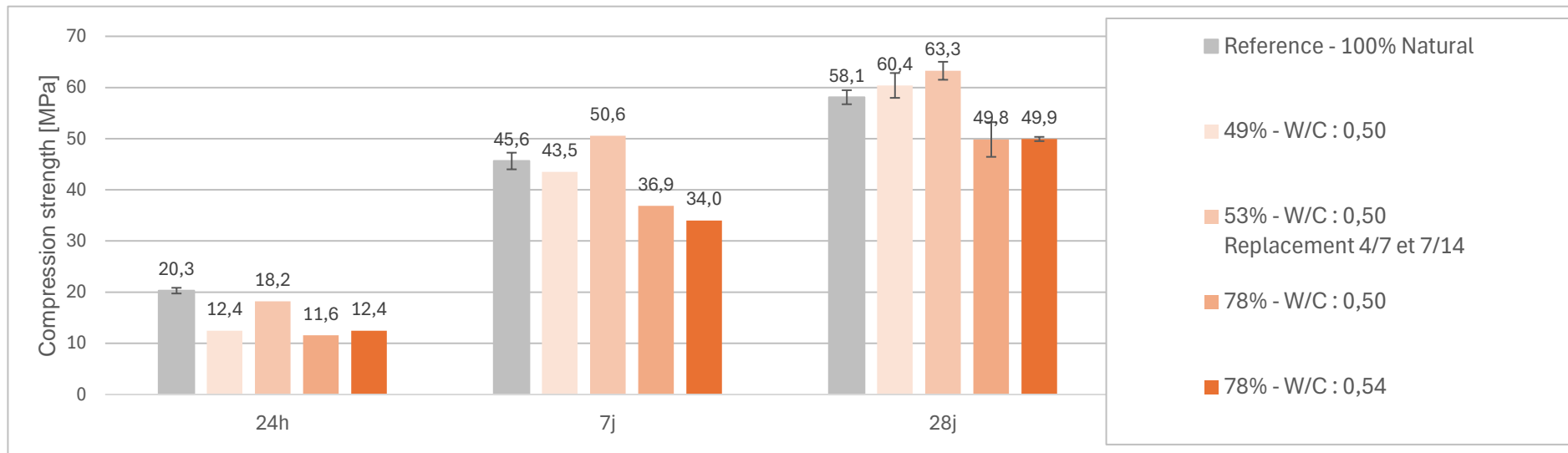


Aggregates	Fine content (%)	Water absorption (%)	Density (kg/m ³)
Meuse sand 0/4	0.9	0.5	2750
Limestone sand 0/4	2	0.75	2700
RCA_LD 0/4	3.44	5.88	2296

Results for fresh and hardened concrete

Resistance : C30/37
Environment : EE3

Results			
Composition	Density (kg/m ³)	Slump (mm)	Air content (%)
Reference	2361	230	2,2
ICM 2-A	2266	245	2,8
ICM 5	2190	220	3,6
ICM 5-A	2204	210	3,1
ICM 6	2313	230	1,6



3D printing with Recycled Sand

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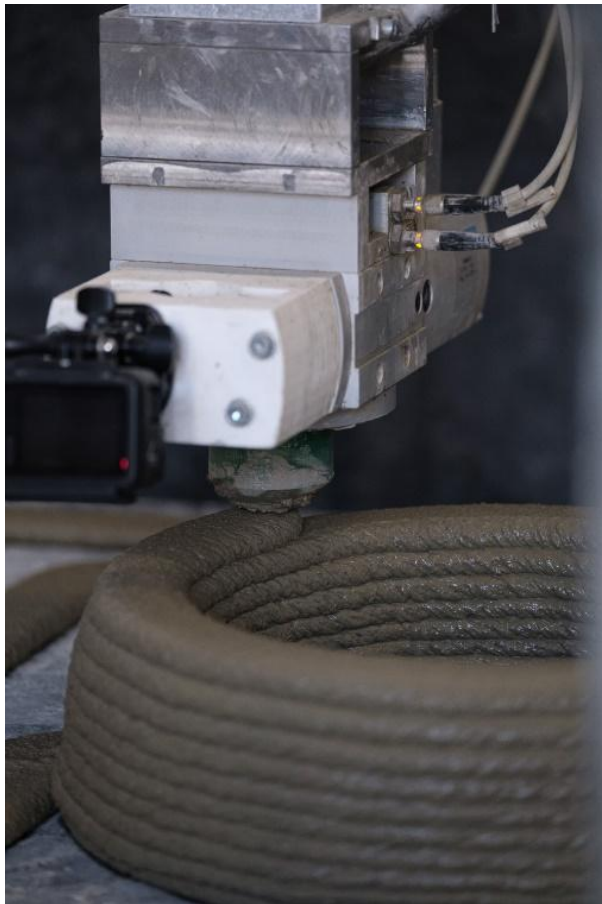
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3D printing

- + design opportunities
- environmental impact



alternative binder
100% recycled sand





EUROPEAN UNION

Interreg

North-West Europe

CIRMAP

European Regional Development Fund

THEMATIC PRIORITY:
 RESOURCE AND MATERIALS EFFICIENCY



Project objectives:
 CIRMAP aims at finding new opportunities for the valorisation of Recycled Concrete Fine Aggregate through 3D printing of customized shapes.



PROJECT AREA

Total budget : € 6.98 Million
 EU funding : € 4.19 Million
 Duration : 36 months (April 2020 - March 2023)





www.nweurope.eu







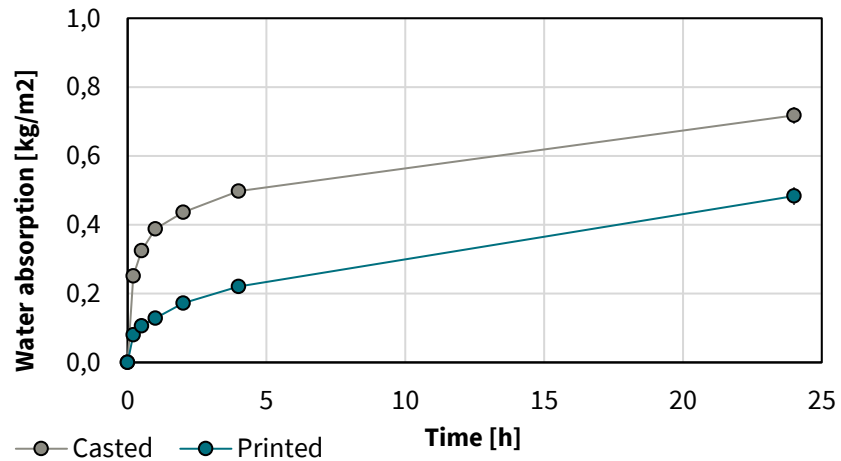


3D printing



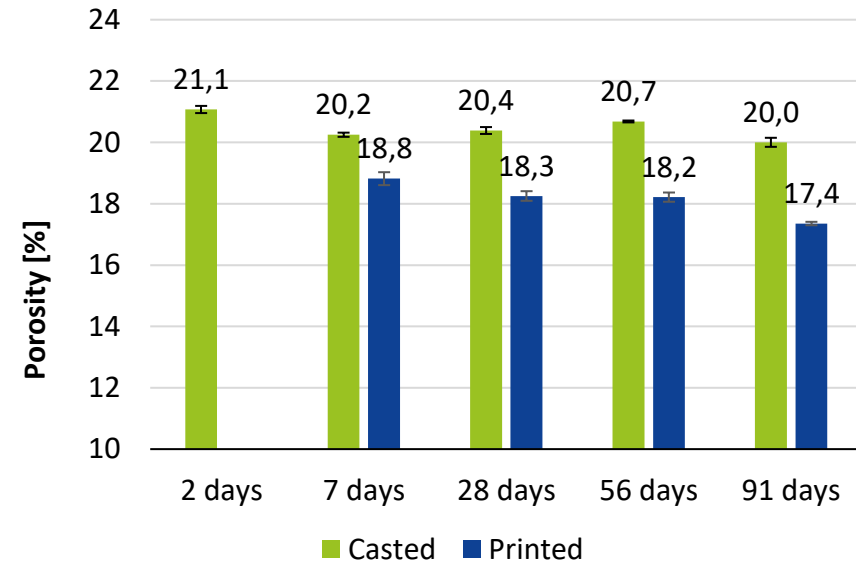
Capillary absorption tests NBN EN13057

- Influence of the **printing process** (casted samples vs printed samples)
- Water absorption [kg/m²] and absorption coefficient [mm/h^{0,5}]



Porosity

- Influence of the **printing process** (casted samples vs printed samples)



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3D printing

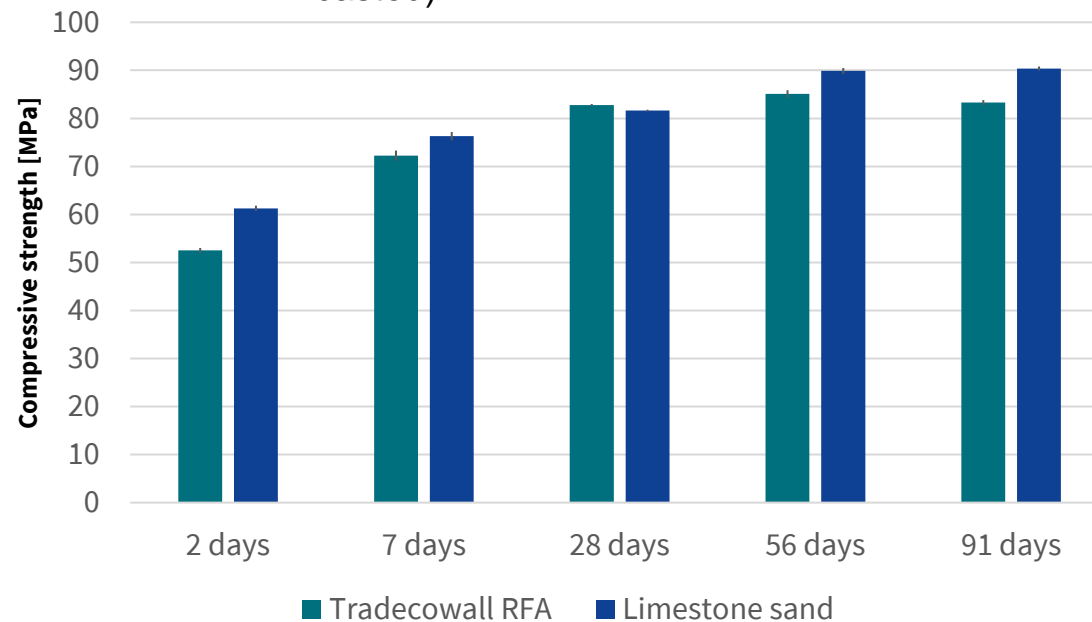
Three points bending and compressive strength :

- Influence of the **type of sand** (natural crushed limestone sand vs concrete RFA)
- Compressive strength
- Water curing (20°C and 95±5% relative humidity)



Casted samples (4x4x16 cm prismatic samples are casted)

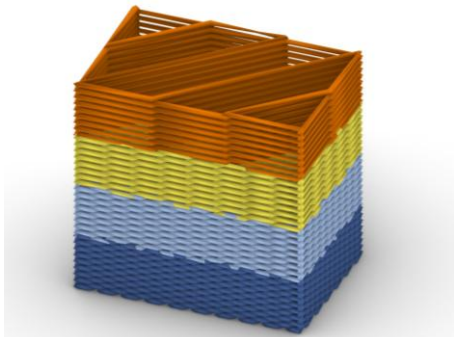
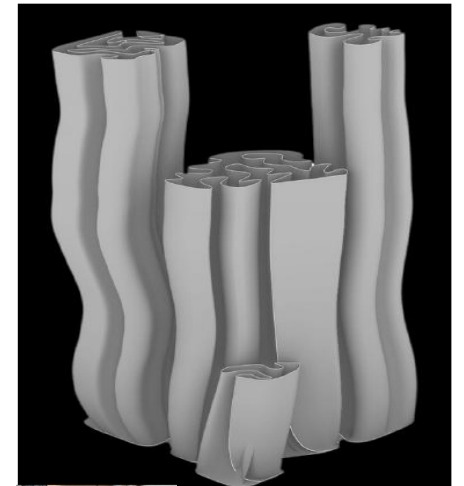
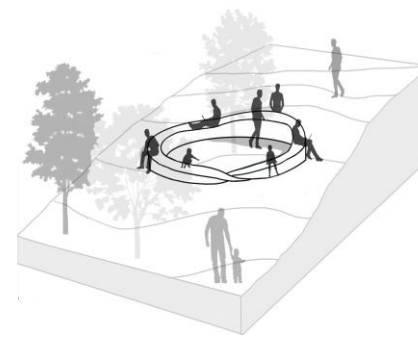
Printed samples (4x4x16 cm prismatic samples are extracted from S shaped printed éléments)



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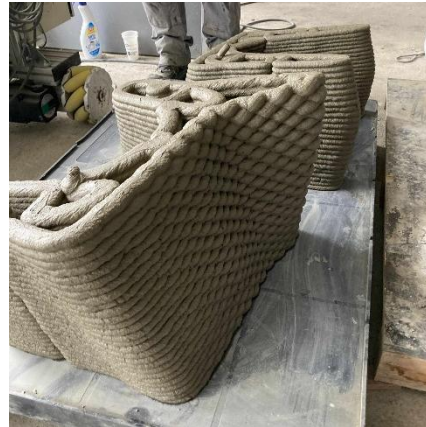
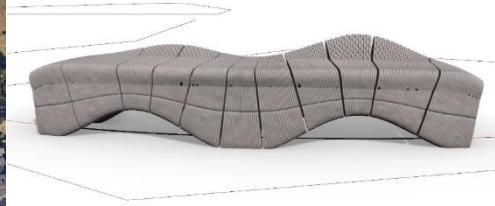
3D printing : student contest



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3D printing



Rammed Concrete with Recycled Fine Aggregates

Pisé with Recycled Fine Aggregates



Peter Zumthor's Secular Retreat (Walsh, 2018)



Rammed concrete for one-storey private house (Astbury, 2019)



The chapel, by Thomas von Arx

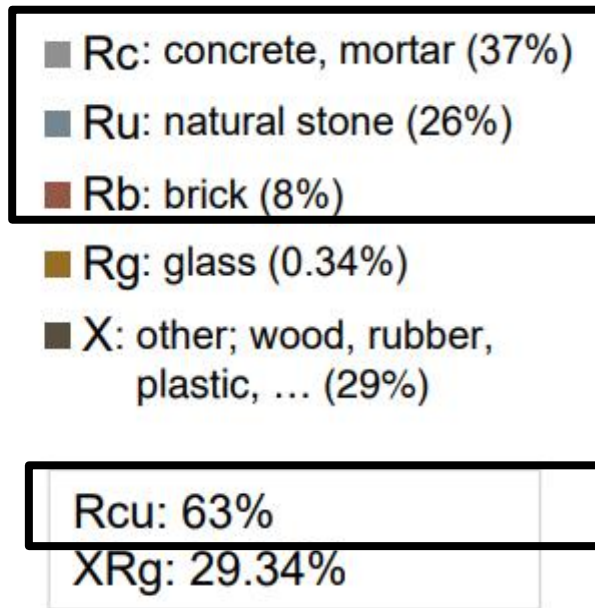
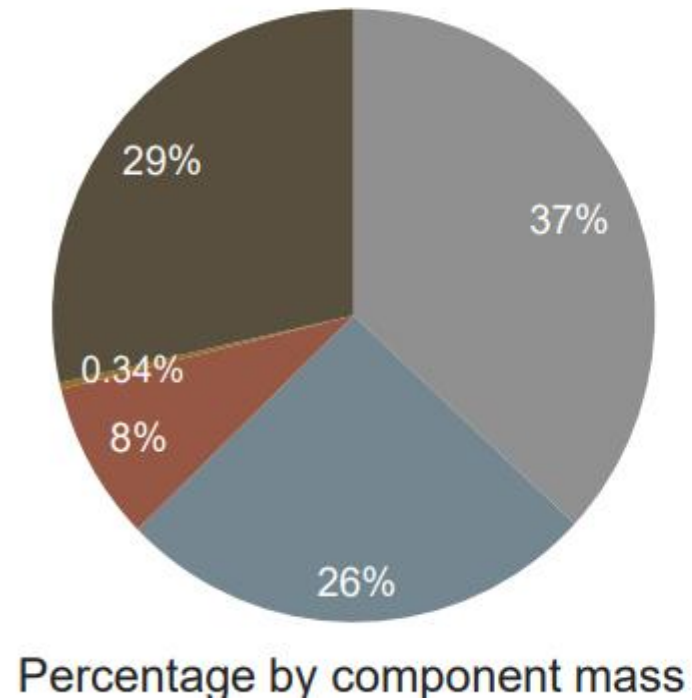
Pisé with Recycled Fine Aggregates

- low maintenance, low-tech construction process and economical to build



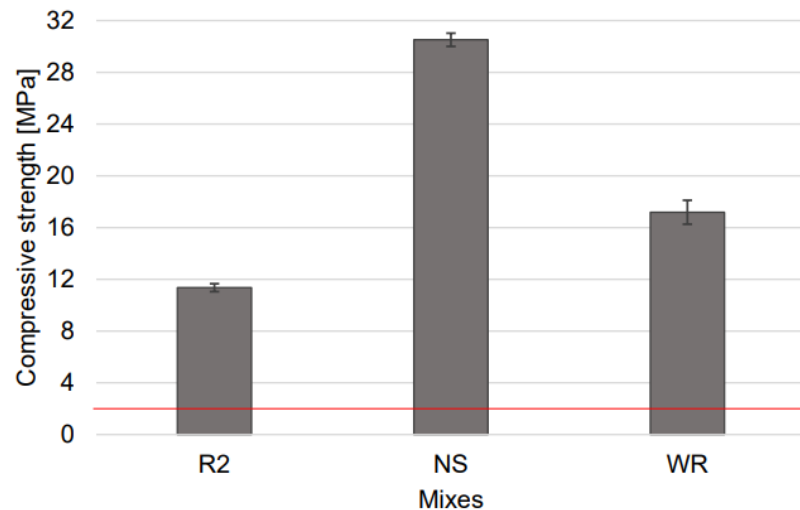
Recycled Fine Aggregates (Makara, 2023)

- Composition
- Granulometry 0/4

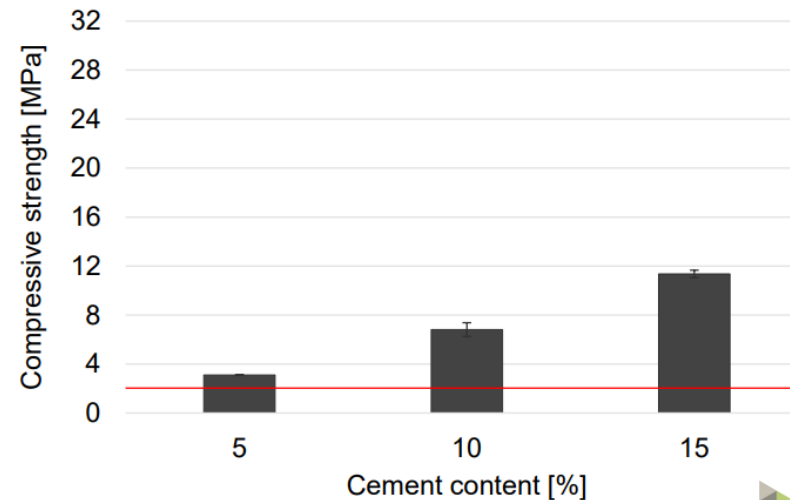


Recycled Fine Aggregates (Makara, 2023)

- Compressive strength vs mixes (15% cement + 10% water + 75% RFA 0/4) with different aggregates (NS = natural sand – R2 = Original RFAs – WR = Washed RFAs)



Influence of cement content



DUN³ES FTJ project : composition and design



Fines



Sand



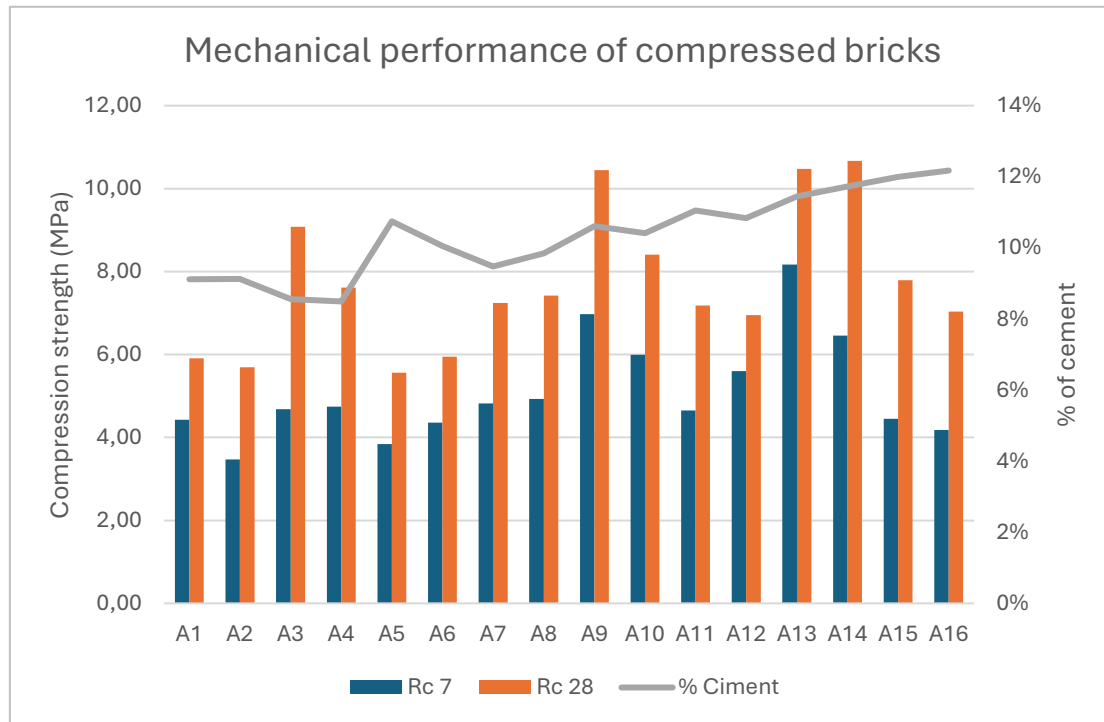
Cement



Water



DUN³ES FTJ project : mechanical performances



Cement : CEM III/B 32.5 N

Concrete block : 15 MPa

Fire bricks : 10 MPa

Gypsum : 5-6 MPa

Compressed earth brick : 4 MPa

Stabilised Compressed Earth Brick : 6 MPa



Carbonated Municipal Solid Waste Incinerated Sand

Carbonated MSWI

Grey colour material (200kg/ton)

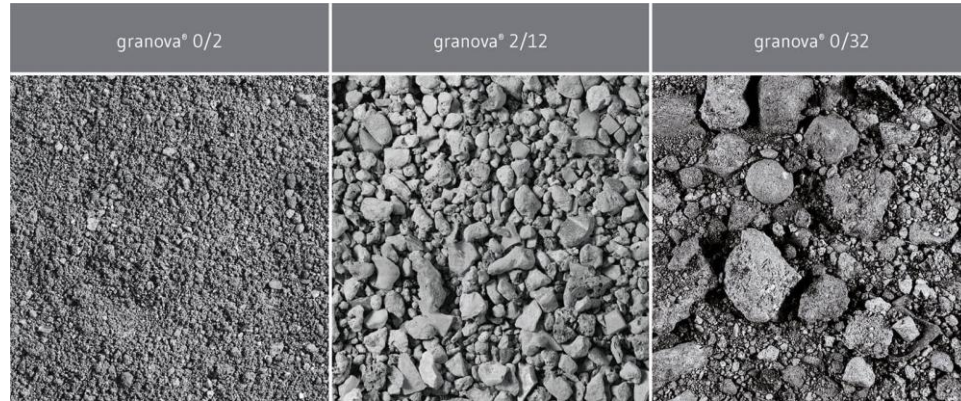
Variable granulometry

Humidity content

- up to 20% by weight after extinction
- 10% by weight after draining

Density

- 1000 kg/m³ when extracted
- 1100 to 1200 kg/m³ after treatment



ReMEX GmBh



CARBOC

Carbonated MSWI

Parameters:

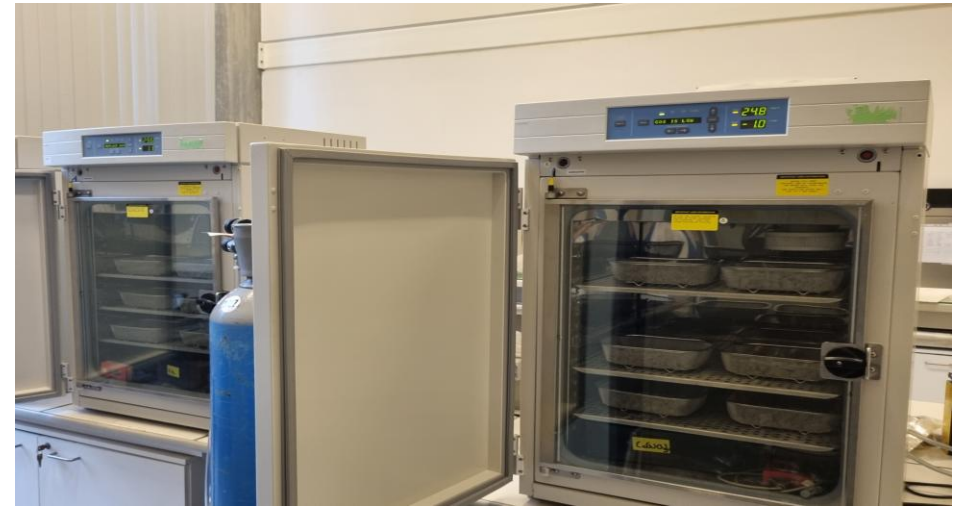
- Particle size: 0/2 & 0/20 mm
- Exposure period: 1, 2, 4, 8, 24, 48 & 168 h
- Moisture content (WC): 2, 20 & 45%

Carbonation conditions:

- Temperature: 30 ± 1 °C
- Relative humidity: 60 ± 3 %
- CO₂ concentration: 12 %vol

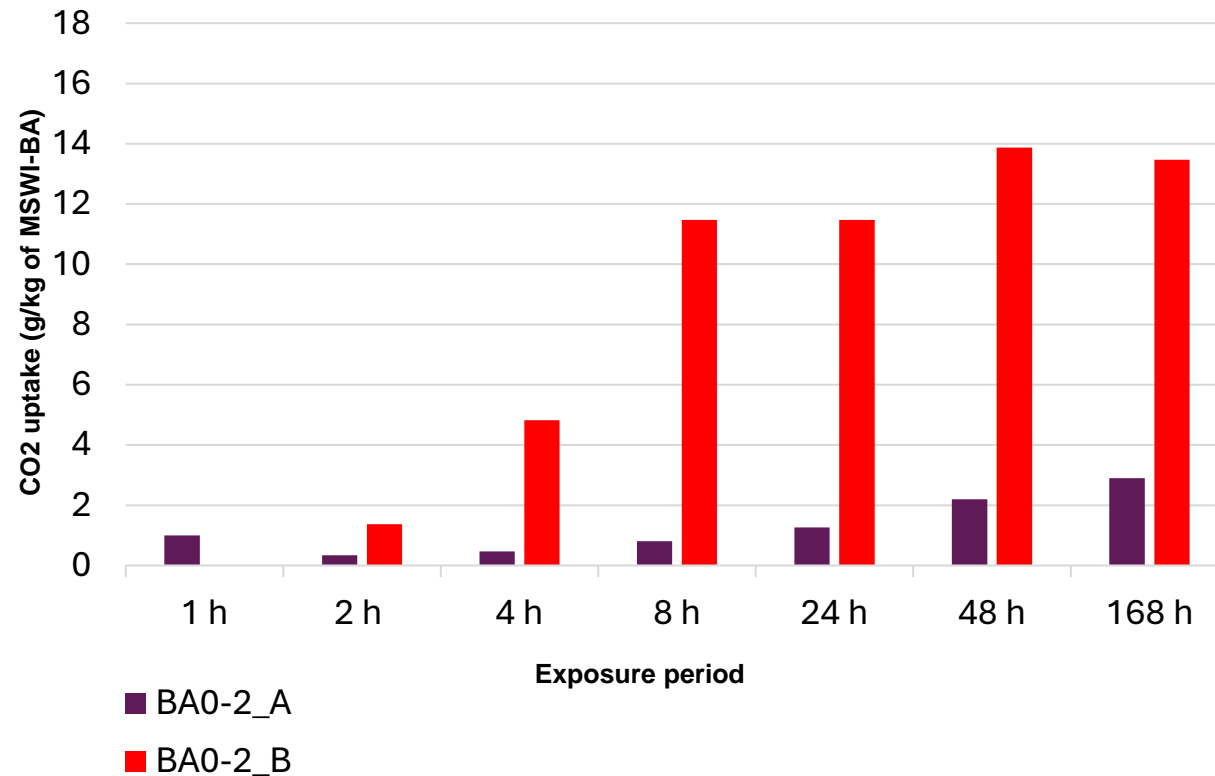


CARBOC



Carbonated MSWI

- CO2 uptake - 0/2 particle size



CARBOC

CarboNEX

- Experimental room for accelerated carbonation (temperature, humidity and CO2 concentration)



Brick Fine Aggregates

Bricks Fines

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



Bricks Fines

■ Mineralogy

Oxides (%)	CaO	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	K ₂ O	Na ₂ O	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

■ 3 types of granulometry

- B1 : $d_{50} = 3.3 \mu\text{m}$ (with supplementary cyclogrinding)
- B2 : $d_{50} = 20 \mu\text{m}$
- B3 : $d_{50} = 190 \mu\text{m}$

Bricks Fines : Alkali Activated Materials

Brick fine particles
B2

GGBFS

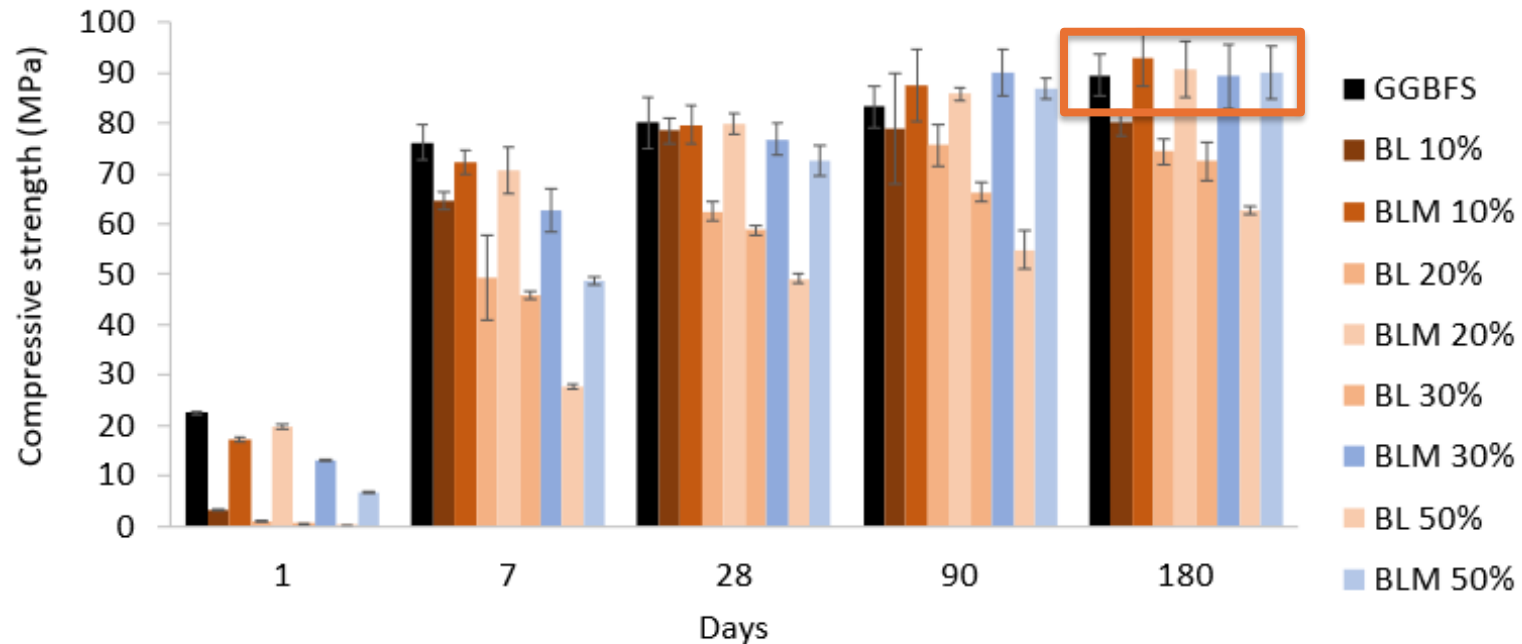
Alcali-Activating Solution

Soda (NaOH)
Sodium Silicates (Na_2SiO_3)
($\text{SiO}_2/\text{Na}_2\text{O}$: 1.45)

Substitution
10, 20, 30 and 50 %

Characterization at
7 and 90 days

Bricks Fines : mechanical strength



- BL: slower kinetics – $R_c \downarrow$ when [brick fines] \uparrow
- BLM: quicker kinetics - $R_c \geq$ GGBFS from 90 days
- Brick fines can act as a precursor

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Conclusions

Natural resources vs recycled resources for sand

Good opportunities (quantities)

Preparation is important

Grading and washing

Specific treatment (fineness, shape, granulometry)

