LIÈGE université
Sciences Appliquées

Reducing Environmental Impacts of Construction Waste through Concrete Recycling Technologies

L. Courard, University of Liege
Building Materials – Urban and Environmental Engineering
Luc.Courard@uliege.be

15th Scientific Day, Institut de Technologie du Cambodge, Phnom Penh
June 4th, 2026

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Global context

- 4 main impacts for construction industry

energy consumption (40%)

primary resources consumption (40-50%)

gas emission (around 40% of CO_2)

waste production (50%)

Global context

- 3R: Reduce, Reuse and Recycle

3R Symbol, Reduce Reuse Recycle Illustration Vector 34989145 Vector Art at Vecteezy

Global context

- 3R: Reduce, Reuse and Recycle

3R Symbol, Reduce Reuse Recycle Illustration Vector 34989145 Vector Art at Vecteezy

Global context

- 6R: Refuse, Reduce, Repair, Reuse, Recycle and Rot

The 6 R`s of Sustainability, Illustrated in 6 Mugs with Relevant Contents. Refuse, Reduce, Recycle, Repair, Reuse, Rot Stock Photo - Image of carbon, biodegradable: 185591672

Refuse: stop consumption

- We refuse means that we should avoid purchasing or even getting for free something that is not essential
  - Low tech
  - Frugality
  - Sustainability
  - Local loop products

Refuse: stop consumption

- We consume natural resources (per year)
  - Aggregates: 4.7 billions tons

  (670 pyramids of Cheops)
  - Sand: 2.2 billions tons

  (22 millions wagons = train 264000 km long)
  - Cement: 1.3 billions tons

  (17000 ocean liner type Norway = 2.34 billions tons of limestone and clay)
  - Water: 800 billions litres

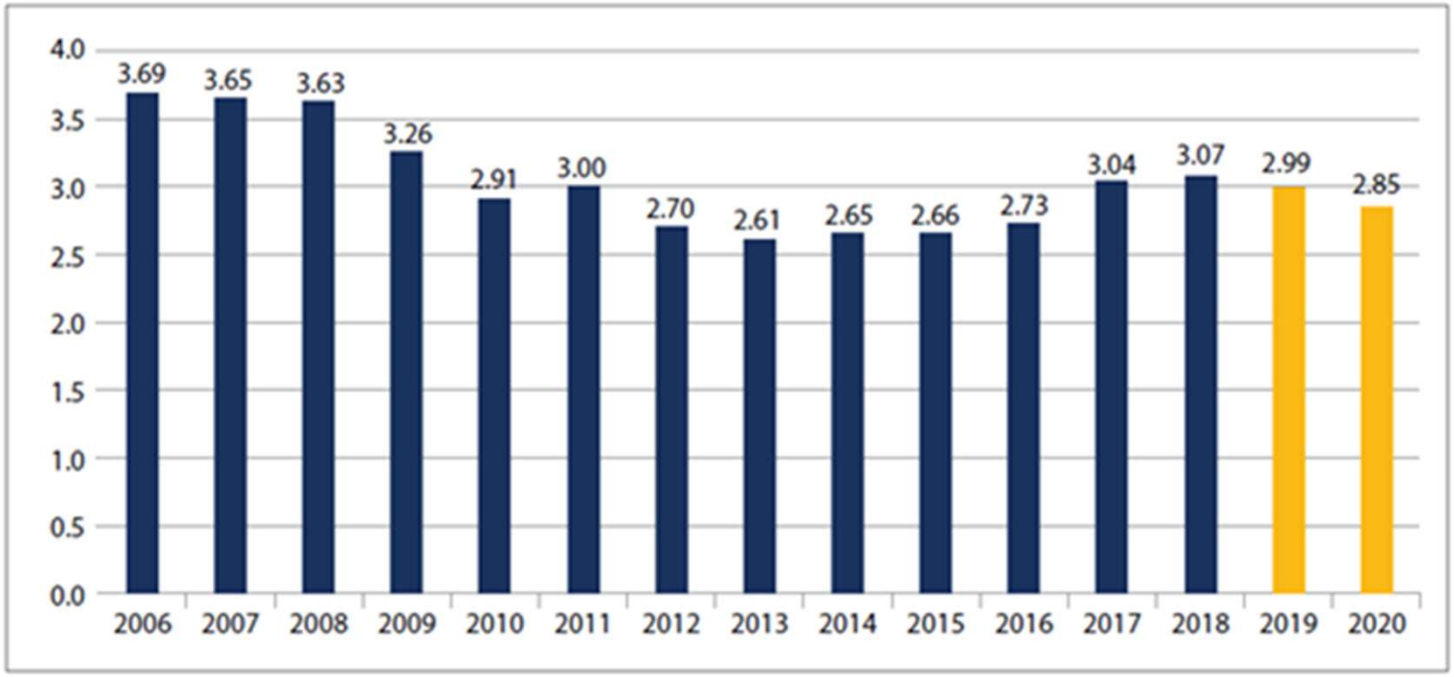
  (23 times the dayly flow of river Seine, Paris)

  - Concrete: 9 billions tons

  (30000 archs of Defense, Paris)

Refuse: stop consumption

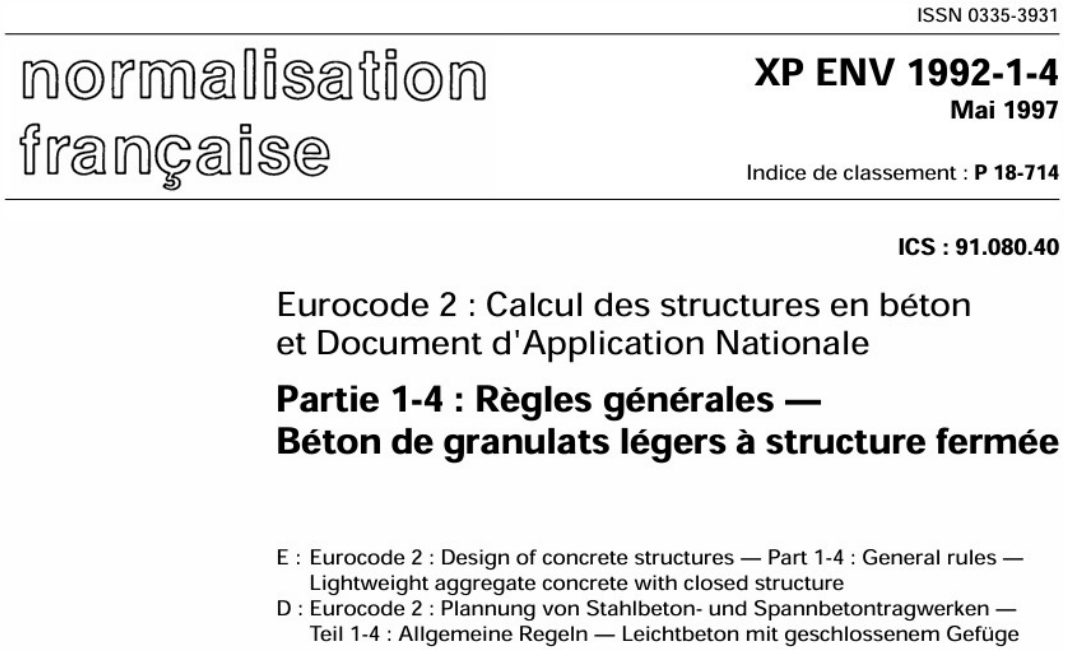
- We consume natural resources (per year)
  - Trend in total EU27 + UK + EFTA Tonnages (in billions of tonnes) for the production of aggregates (UEPG 2021) - 26,000 quarries and pits, operated by 15,000 companies



UEPG, 2021

Reduce: optimization in construction

- Design for disassembly
- Optimization of calculation codes
- Adaptation of safety coefficient



ISSN 0335-3931

normalisation française

XP ENV 1992-1-4
Mai 1997

Indice de classement : **P 18-714**

ICS : 91.080.40

Eurocode 2 : Calcul des structures en béton et Document d'Application Nationale

Partie 1-4 : Règles générales — Béton de granulats légers à structure fermée

E : Eurocode 2 : Design of concrete structures — Part 1-4 : General rules — Lightweight aggregate concrete with closed structure
D : Eurocode 2 : Plannung von Stahlbeton- und Spannbetontragwerken — Teil 1-4 : Allgemeine Regeln — Leichtbeton mit geschlossenem Gefüge

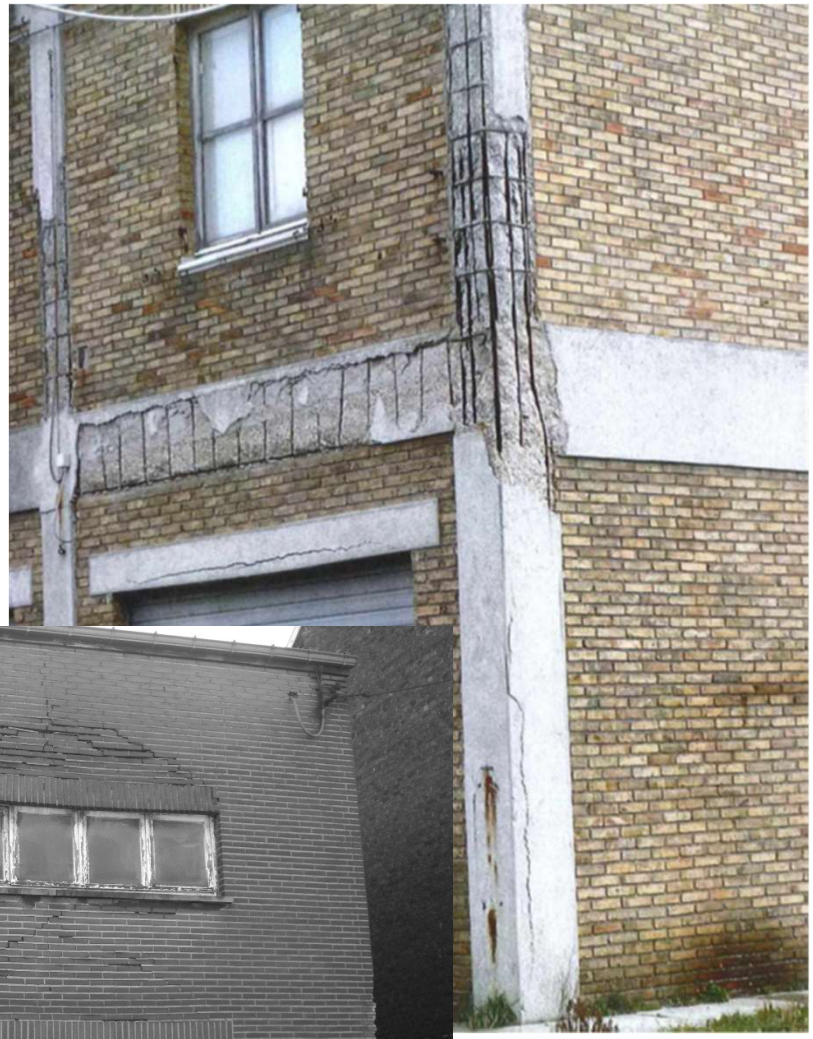
Reduce: optimization in construction

- Decreasing grey energy
  - The concept of “grey energy” - that is, the energy, measured in kWh/m^3 or T, associated with a material - takes the following factors into account:
    - extraction machinery,
    - fuel for transportation,
    - electricity consumption for processing, and
    - oil used in production

Material	Grey energy (kWh/m³)
Fired brick	700
Silica brick	350
Synthetic plaster	3300
Cement plaster	1100
Steel profile	57000
Wood beam	180
Prefabricated wood panel (with syntetic resin)	2000
Wood fiber pannel	1400
EPS (insulating)	450
Cellulosic panel (wood fibers)	50

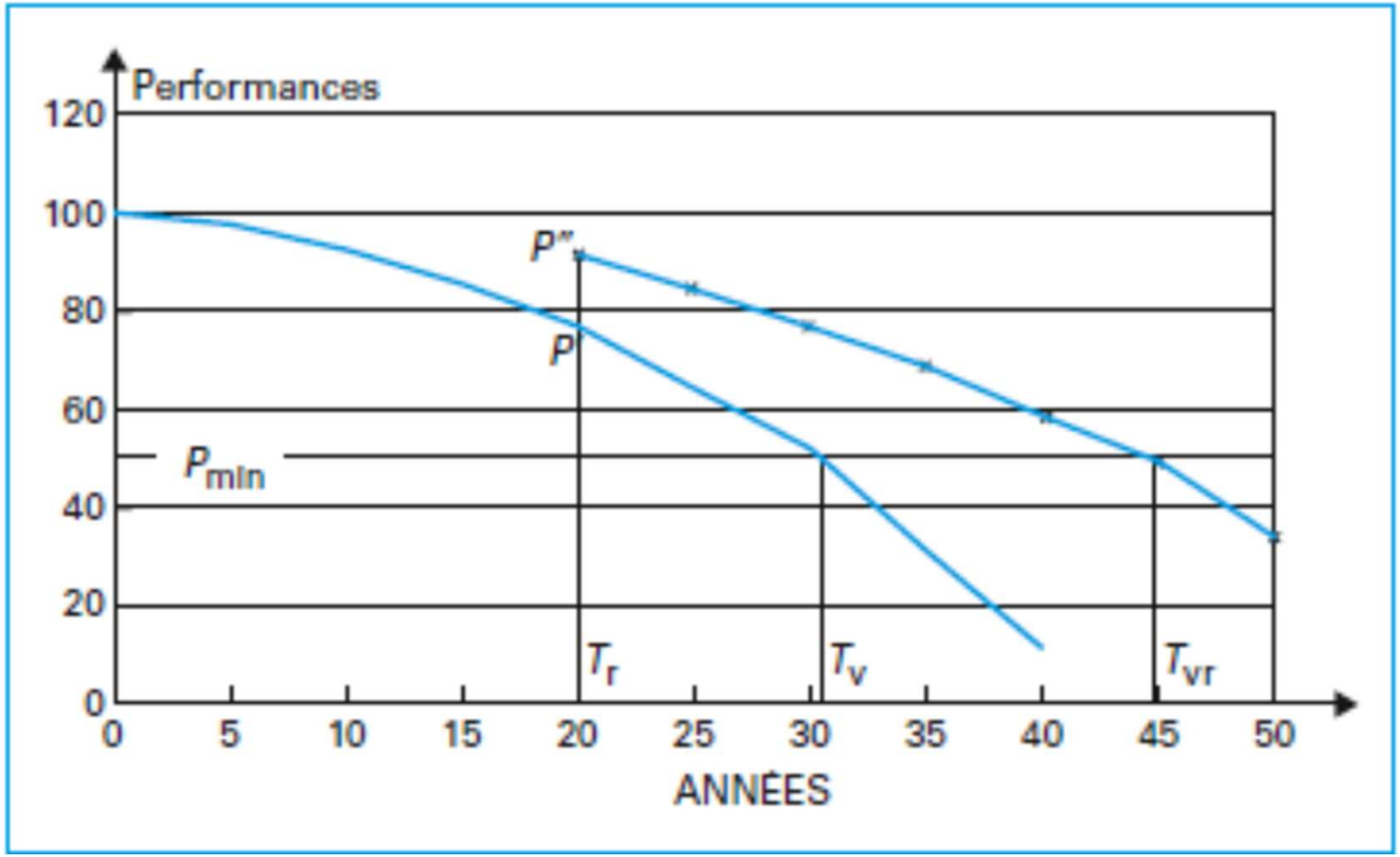
Repair: restore, reinforce

- Pathologies of materials and structures



Repair: restore, reinforce

- Postponing end of life



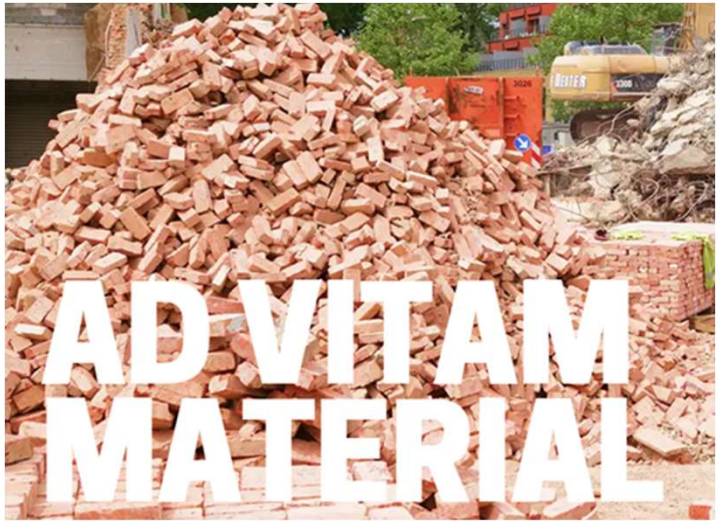
Repair: restore, reinforce

- Techniques and materials

Reuse: dismantling in construction

- Reuse of non structural elements

Rotor Deconstruction – Reuse of building materials made easy



AD VITAM MATERIAL - Réseau du réemploi dans la construction en Belgique

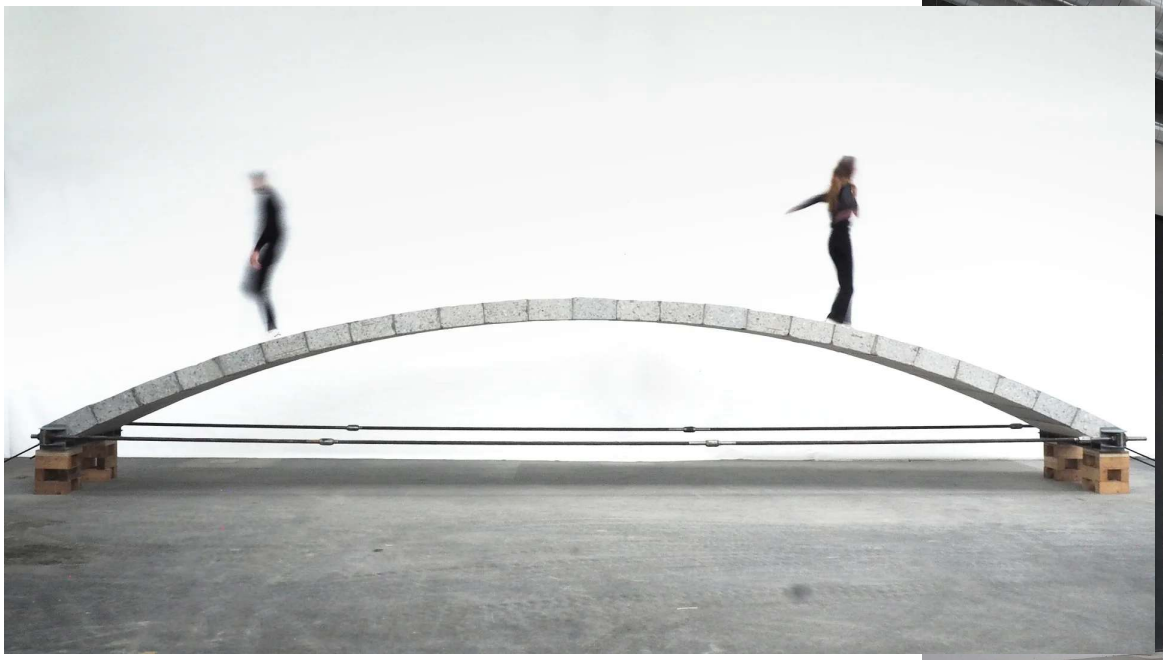
Reuse: dismantling in construction

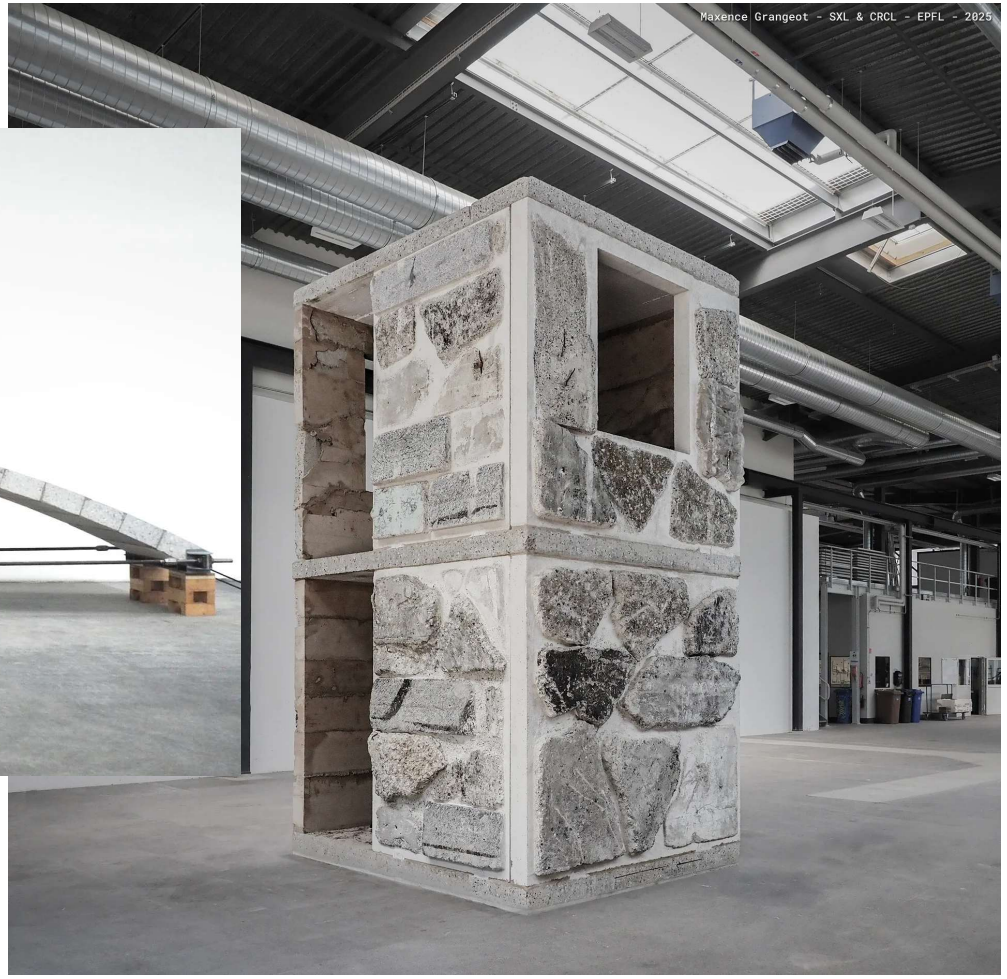
- Reuse of structural elements

NEST project, Dübendorf (Suisse)

Reuse: dismantling in construction

- Reuse of structural elements



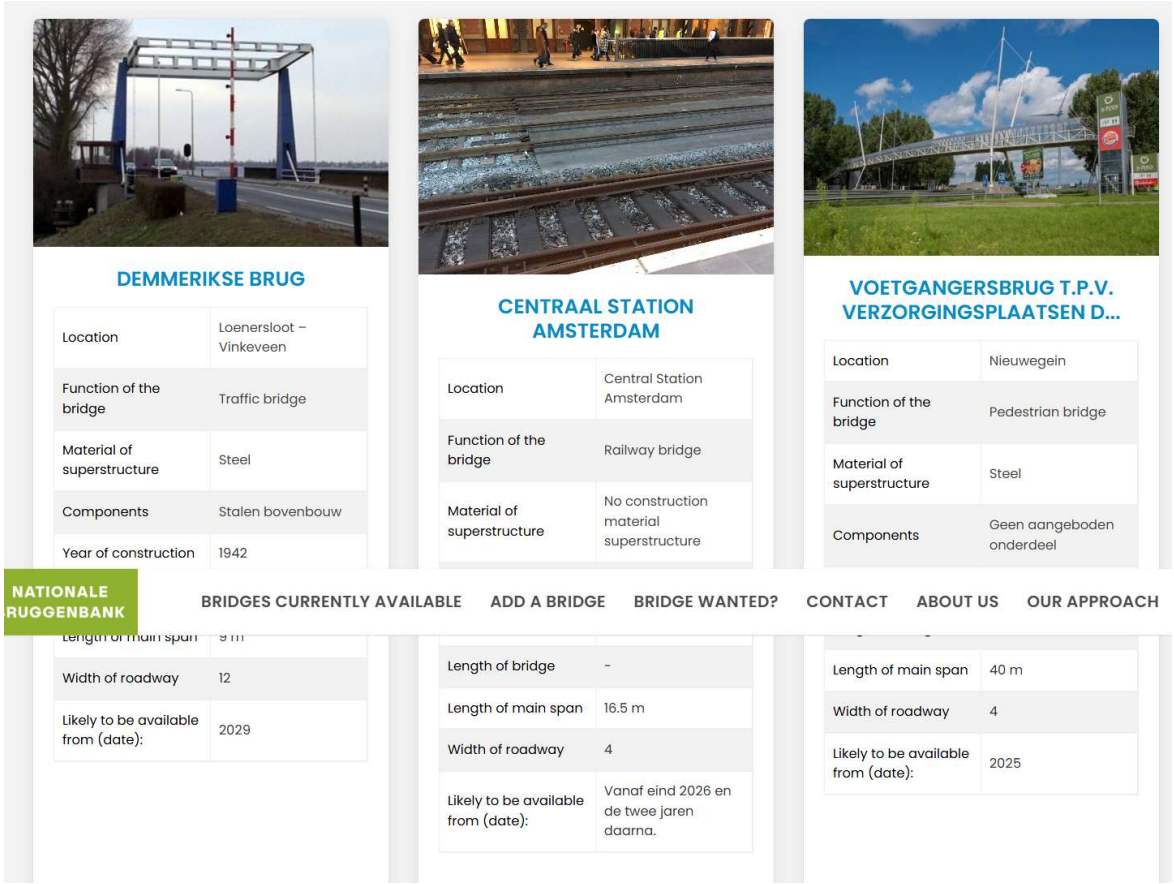


Re:Crete footbridge

Re:bble tower (credits: ©Maxence Grangeot / SXL EPFL)

Reuse: dismantling in construction

- How to buy a bridge?



NATIONALE RUGGENBANK

BRIDGES CURRENTLY AVAILABLE | ADD A BRIDGE | BRIDGE WANTED? | CONTACT | ABOUT US | OUR APPROACH

DEMMERIKSE BRUG

Location	Loenersloot – Vinkeveen
Function of the bridge	Traffic bridge
Material of superstructure	Steel
Components	Stalen bovenbouw
Year of construction	1942
Length of main span	9 m
Width of roadway	12
Likely to be available from (date):	2029

CENTRAAL STATION AMSTERDAM

Location	Central Station Amsterdam
Function of the bridge	Railway bridge
Material of superstructure	No construction material superstructure
Length of bridge	-
Length of main span	16.5 m
Width of roadway	4
Likely to be available from (date):	Vanaf eind 2026 en de twee jaren daarna.

VOETGANGERSBRUG T.P.V. VERZORGINGSPLAATSEN D...

Location	Nieuwegein
Function of the bridge	Pedestrian bridge
Material of superstructure	Steel
Components	Geen aangeboden onderdeel
Length of main span	40 m
Width of roadway	4
Likely to be available from (date):	2025

Home - Nationalebruggenbank

Reuse: dismantling in construction

- Reuse of materials

NEST project, Dübendorf (Suisse)

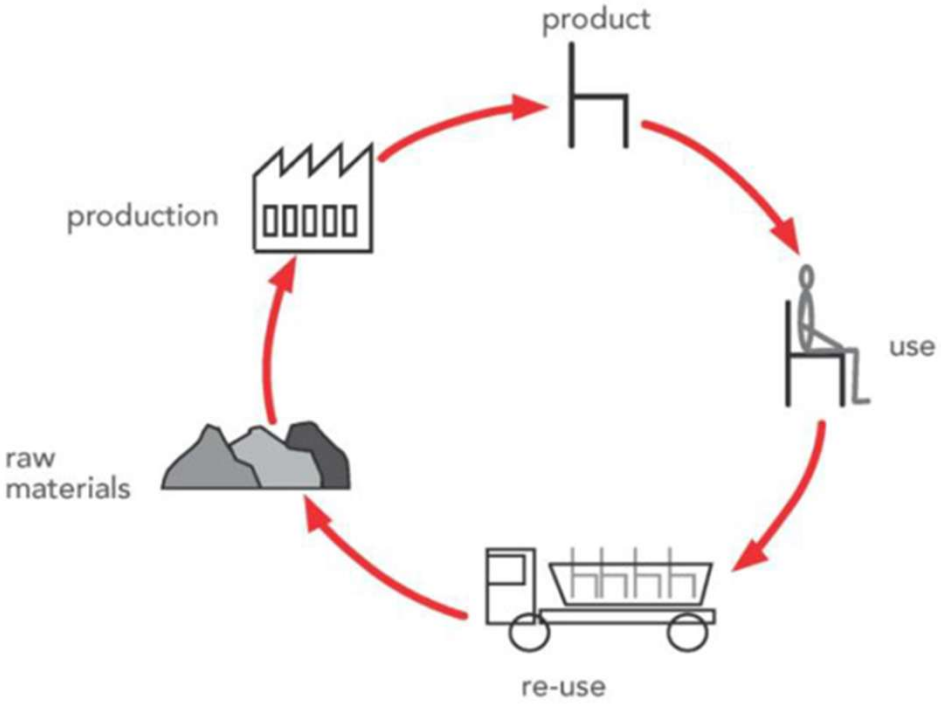
Reuse: dismantling in construction

- Reuse of buildings

Wiels centre d'art contemporain

Boekhandel Dominicanen (Maastricht)

Recycling: new life cycle



C2C - TECHNICAL NUTRIENT CYCLE

S. BECKERS (from M. Braungart – EPEA, Cradle to Cradle)

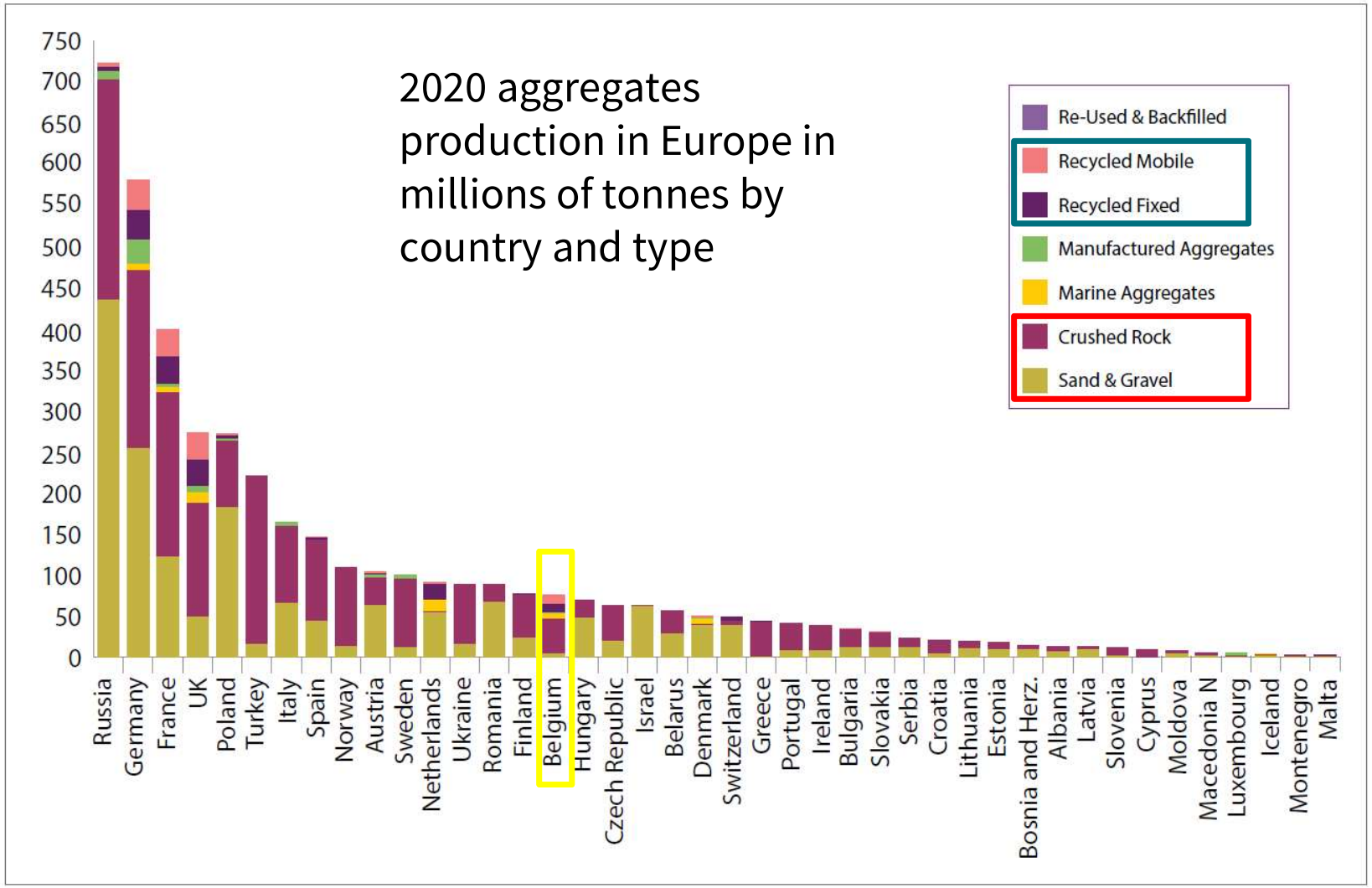
Recycling: new life cycle

- Transforming wastes …

Recycling: new life cycle

- … into secondary ressources

Recycling: next life cycle



UEPG, 2021. European Aggregates Association – Annual Review 2020-2021, Brussels, 30 p.

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Recycling: next life cycle

- 3 billion tons produced in EU27+UK+EFTA in 2022 (UEPG 2023)

Virgin Aggregates

46.9% crushed rock

39.7% sand & gravel

Recycled Aggregates

Construction & demolition wastes (CDW)

9.3% recycled (278 million tonnes)

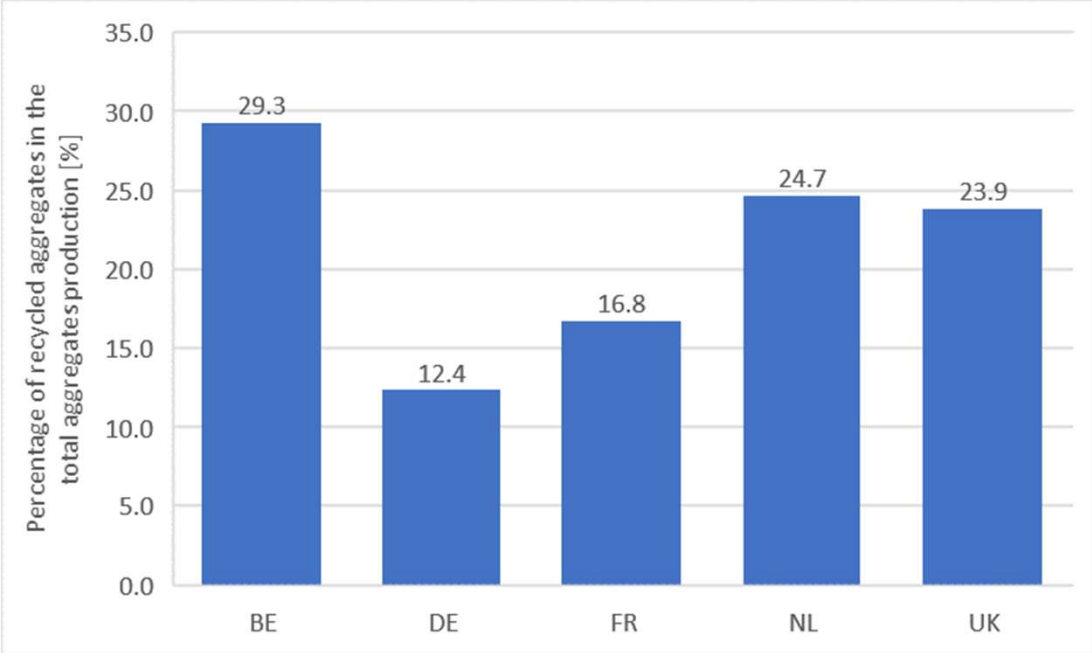
Concrete

Mixed

Recycling: next life cycle

- NWE countries (BE, DE, FR, NL, UK) are responsible for:
  - 47% of the virgin aggregates production (1417 Mtons)
  - 89% of the recycled aggregates production (248.4 Mtons)

Recycled aggregates/natural aggregates



Recycling: new life cycle

- **Recycled Fine Aggregates**
  - low maintenance, low-tech construction process and are economical to build

Recycling: new life cycle

- 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)

Recycling: new life cycle

Prefab products:*Parkour Park (Seraing)*

Cement produced with recycled fines

Recycled concrete aggregates

Natural sand

Rc : 50-55 MPa
W/C <= 0.45
Ciment >= 340 kg/m³
Absorption d'eau <= 6.5%

Recycling: new life cycle

3D printing

Interreg
North-West Europe
EUROPEAN UNION

CIRMAP

European Regional Development Fund

THEMATIC PRIORITY:

RESOURCE AND MATERIALS EFFICIENCY

PROJECT AREA

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

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

IMT Lille Douai
ARMINES
UNIVERSITE D'ORLEANS

www.nweurope.eu

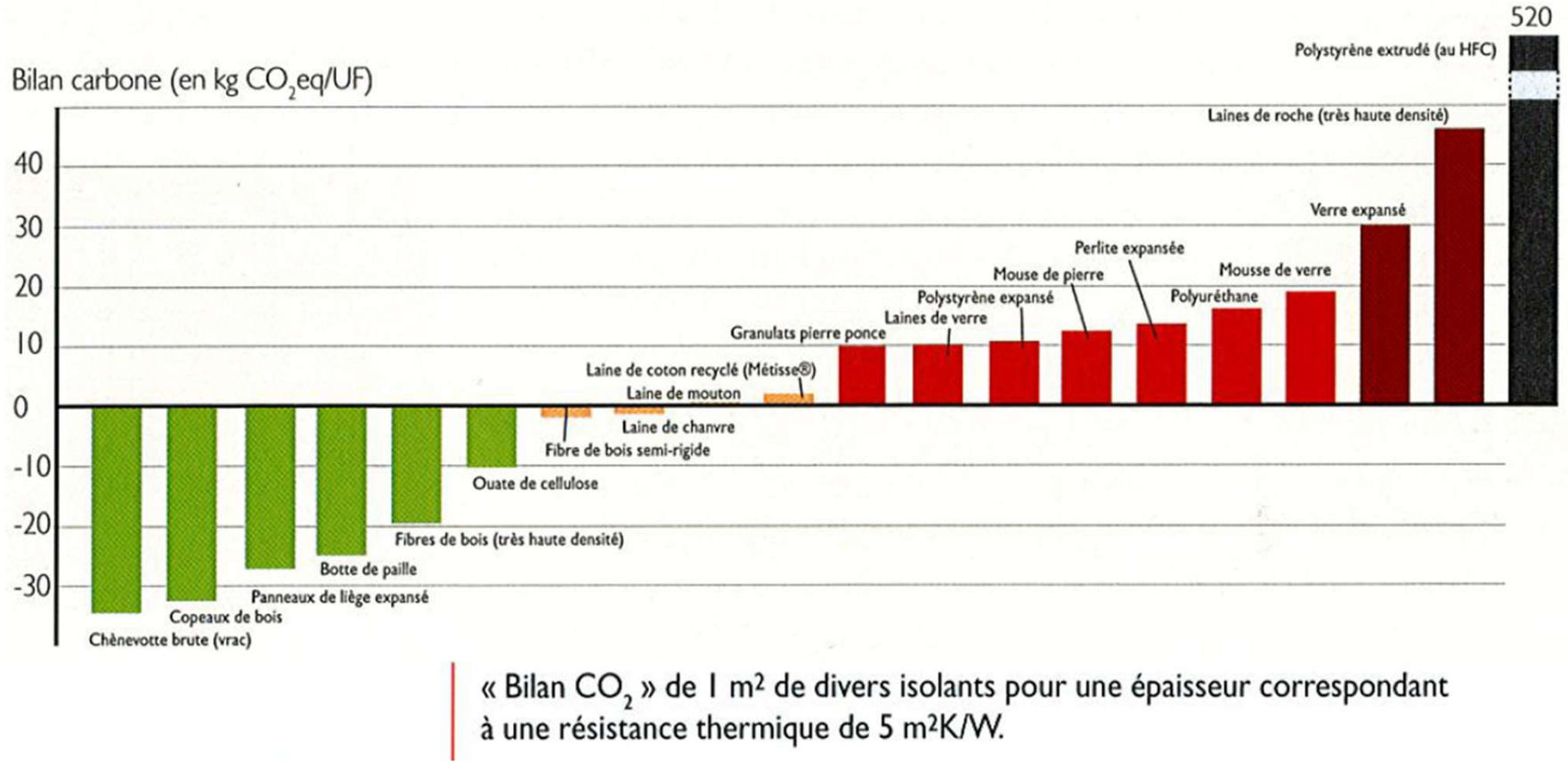
Rot: use of renewable and bio-sourced materials

Rot: use of renewable and bio-sourced materials

Green: minimally processed or high-density "carbon sink" insulation

Yellow: carbon-neutral insulation: plant-based fibers

Red: insulation with a very poor carbon footprint: mineral and synthetic materials



« Bilan CO_2 » de 1 m² de divers isolants pour une épaisseur correspondant à une résistance thermique de 5 m²K/W.

Isolation thermique et écologique J.P. Oliva et S. Courgey (d'après G. Escadeillas, Métamorphoses, Liège, 2011)

Rot: use of renewable and bio-sourced materials

- Approximate value of energy consumed for each phase

M. F. Ashby Materials selection in mechanical design (4th edition ,Elsevier Ltd), 2011

Conclusions: functional economy

- The functional economy is an economic model focused on services and usage rather than the sale of physical goods. The fundamental principle is that **the seller retains ownership of the good** throughout its life cycle, while **the customer pays for the use or performance** of that good. This model is based on three key principles:
  - *Material frugality and sustainability*: reducing resource consumption, extending the lifespan of goods, and promoting reuse and refurbishment.
  - *Creation of intangible value*: developing skills, health, knowledge, and the quality of relationships.
  - *Regional cooperation*: encouraging collaboration among citizens, businesses, and local governments to foster a positive impact on organization and sustainable development

https://economie.fgov.be/fr/publications/vers-une-belgique-pionniere-de-l'économie-circulaire (2014

Conclusions: functional economy

- A lever for ecological transition: moderation
  - Moderation in use
  - Moderation in real estate
- A lever for ecological transition: efficiency
  - Energy-efficient renovation – residential
  - Energy-efficient renovation – commercial
  - High-performance new construction
- Lever for an ecological transition: decarbonization and circularity
  - **More environmentally efficient materials**
  - **Circularity of products and materials**
  - Decarbonization of energy

Conclusions

Science is essential but not enough

Rachel Hurley, NIVA

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Merci pour votre attention
Thank you for your attention

3CFoLEx (CirCularité des matériaux de Construction : mise en place d'une Formation spécifique et d'un Laboratoire Expérimental)

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