Downcycling vs Recycling for construction materials: the case of concrete aggregates

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Construction & Demolition Waste (CDW)

Construction sector (globally)

- 40% of raw materials
- 35% of waste
- CDW main fractions: concrete, bricks, wood

Directive 2008/98/EC (waste directive)

By 2020, the preparing for re-use, recycling and other material recovery (...) of non-hazardous construction and demolition waste (...) shall be increased to a minimum of 70% by weight.

Belgium has already reached the percentage required by the WFD

Most of the recycled aggregates are used in low grade applications (road construction, embankments, fundations)

- open loop recycling/downcycling

The market for concrete aggregates is getting more and more saturated
Downcycling of Recycled Concrete Aggregates

Technical issues in recycling
Impurities (wood, mortar and cement paste, organics, gypsum)
- Lowering the properties (density, strength, water adsorption) of concrete

Solutions:
1. Advance cleaning after crushing
2. Advance sorting during demolition
Downcycling of Concrete Recycled Aggregates

Closing the loop in concrete life cycle

The potential of waste concrete to close the material cycle for concrete can be fully exploited only if waste concrete substitutes natural aggregates in concrete production (Recycling).

Technological & economic barriers to recycling

• Raw materials are cheap compared to labour, energy and technologies required for high quality recycled concrete aggregates
• General lack of an efficient quality-control system

Goal of this study...

• To analyse the possible environmental effects in switching from a downcycling to an recycling scheme for concrete recycled aggregates
Downcycling of concrete aggregates: LCA
Downcycling of recycled concrete aggregates: LCA

System
Multifunction system with 2 lines:

→ Recycled aggregates for road construction
→ Recycled aggregates for construction material

Functional unit
“Processing of 1 Kg of recycled concrete aggregates that has been pre-sorted through a selective demolition, with a **sufficient level of purity** to be used to make new concrete”

Transports
Transports depends on availability of quarries and recycling plants

- Natural aggregates from mines: 50 Km
- Recycled concrete: 20 Km
Downcycling of recycled concrete aggregates: LCA

System Analysis: Downcycling & Recycling scenarios

Recycling Rate (RR):
RR=0 → complete downcycling
RR=1 → complete Recycling

- Input
- Final output
- Process
- Intermediate product
- Avoided impact

Sorting plant (Crushing, Sieving, Water washing)

1 kg Recycled aggregates

(1 RR) Kg Concrete aggregates

Towards downcycling

Towards recycling

1 kg Aggregates road construction

1 kg Aggregates for new concrete

Natural aggregates (mining process)

(RR) Kg Natural aggregates

(Crushing & refining)

(RR) Kg Natural crushed aggregates

(Natural aggregates for new concrete)

(1 RR) Kg Natural aggregates

(Natural aggregates for road construction)

1 Kg concrete aggregates

(1- RR) Kg Natural aggregates

(Natural aggregates for new concrete)

(1- RR) Kg Natural aggregates
Downcycling of recycled concrete aggregates: LCA

System Analysis: Downcycling & Recycling scenarios

Recycling Rate (RR):
RR=0 → complete downcycling
RR=1 → complete Recycling

- **Input**
- **Final output**
- **Process**
- **Intermediate product**
- **Avoided impact**

1 Kg concrete aggregates

Sorting plant (Crushing, Sieving, Water washing)

1 kg Recycled aggregates

Towards recycling

1 kg Recycled aggregates

Towards downcycling

(1-RR) Kg Concrete aggregates

(1-RR) kg Natural aggregates

1 kg Aggregates road construction

1 kg Aggregates for new concrete

Natural aggregates (mining process)

(RR) Kg Natural aggregates

(1- RR) Kg Natural aggregates

Natural crushed aggregates

Crushing & refining

1 kg Aggregates for new concrete

(RR) kg Natural crushed aggregates
Downcycling of recycled concrete aggregates: LCA

System Analysis: Landfill scenario

System Boundaries

1 Kg Concrete Aggregates

Natural aggregates (mining process)

Crushing

Landfilling

1 kg Aggregates Road Construction

1 kg Aggregates for new concrete
Downcycling of recycled concrete aggregates: LCA Results

Higher recycling rate reduces the environmental impacts
Landfilling is the worst scenario due to the use of natural aggregates (transports)
Downcycling of concrete aggregates: Conclusions

- **Reduction of landfilling is the best way to follow**
The avoided impacts of using natural resources are higher than the impacts caused by the recycling system.

- **Recycling of concrete aggregates appears to be beneficial compared with downcycling**

- **Benefits are valid only if selective demolition or advanced sorting of CDW is applied**
Downcycling of concrete aggregates: Work in Progress

- Insert scenarios with advanced sorting
- Economic analysis
Thank you for your attention!

Questions?

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Downcycling of recycled concrete aggregates: The role of impurities

- The possibility of recycling concrete aggregates depends on their level of purity!
- Impurities in recycled concrete aggregates lower the properties of the concrete.
- In order to keep the properties of concrete made from unclean recycled concrete aggregates, the quantity of cement must be increased.
- Taking into account results from various authors, an increase of 5% of cement is required when substituting 25% of natural aggregates with low quality recycled concrete aggregates.

![Diagram showing the process of downcycling recycled concrete aggregates](image)
Downcycling of recycled concrete aggregates: The role of impurities

LCIA for the production of 1kg concrete with 100% substitution of natural aggregates by recycled concrete aggregates with different level of impurity

- Impurity 0%: + 4.5%
- Impurity 25%: + 9.5%
- Impurity 50%: + 15%
- Impurity 100%
Downcycling of concrete aggregates: LCIA

**Calculation methodology**

**ReCiPe**

### Substances
- Raw Materials
- Land use
- CO₂
- VOC
- P
- SO₂
- NOₓ
- CFC
- PAH
- DDT

### Midpoints
- Ozone depletion
- Human toxicity
  - Radiation
- Ozone formation
- Particules form.
  - Climate change
- Terr. ecotox
- Terr. acidif.
- Agr. land occ.
- Urban. land occ.
- Nat. land transf.
- Marine ecotox.
- Marine eutr.
- Freshwater eutr.
- Freshw. Ecotox.
- Fossil fuel cons
- Mineral cons.
- Water cons.

### Endpoints
- **Damage**
  - Human Health (Daly)
  - Ecosystems (Species yr.)
  - Resources (Cost)

### Uncertainty

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