City without Sand

A material conscious approach for the urban construction

metabolism of sand and gravel in the Rijnmond-Drechtseden region

P5 Presentation
Wouter ter Heijden
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MSc Urbanism
Urban Metabolism

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part of the ‘Designing with Sediment Lab’,
(participant of the IABR 2018-20 Delta Atelier),
with input from Deltares
The World is Running Out of Sand
The little-known exploitation of this seemingly infinite resource could wreak political and environmental havoc.

Increasing sand extraction, trade, and consumption pose global sustainability challenges.

Is the world running out of sand? The truth behind stolen beaches and dredged islands

Global building boom has drained sand. Gangs now stealing sand to sell for fashion and development industry.

Even desert city Dubai imports its sand. This is why
Dutch extraction and consumption

Extraction (74.6 million tonnes)
- Fill sand (37.1 million)
- North Sea coastal defence (15.3 million)
- Concrete & mortar sand (11.3 million)
- Gravel (4.6 million)

Import (17.7 million tonnes)
- Concrete & mortar sand
- Gravel (5.4 million)
- Crushed stone (6.9 million)
- Silver sand (0.8 million)
- Clay (0.8 million)

Export (7.3 million tonnes)
- Clay (2.3 million)
- Sand lime (1.9 million)
- Marl (1.4 million)

Consumption (85.0 million tonnes)
- Fill sand (32.1 million)
- North Sea coastal defence (15.3 million)
- Concrete & mortar sand (13.7 million)
- Gravel (10.0 million)
- Crushed stone (7.0 million)

adapted from: H2H advies (2018). Rapportage Monitoring bouwgrondstoffen
One million new houses in the Netherlands before 2040

70% growth in 20% of NL
25% growth in 50% of NL

Rijnmond-Drechtsteden
Urbanised Delta regions: Rijnmond-Drechtsteden
Almost 100,000 dwellings

total: 88,300

prognose x1000 woningen
Towards a circular Dutch economy in 2050

Linear economy

Circular economy
Problem statement

- Primary sand & gravel
- Urbanisation & construction
- Demolition
- Maintenance
- C&D waste

Rijnmond-Drechsteden

Circular ambition for 2050
‘How can urban design reduce the consumption of primary construction sand and gravel in the construction ecosystem in the Rijnmond-Drechtsteden region?’
1) What is the construction sand & gravel metabolism of RMDS region until 2040?

2) What is the impact of the construction sand & gravel metabolism of RMDS region until 2040?

3) How can urban design reduce the material consumption and impact of construction sand & gravel?

4) How can the construction sand & gravel metabolism of RMDS region be improved?
1) What is the construction sand & gravel metabolism of RMDS region until 2040? → Analysis of the current system

2) What is the impact of the construction sand & gravel metabolism of RMDS region until 2040? → LCA evaluation

3) How can urban design reduce the material consumption and impact of construction sand & gravel? → Catalogue of solutions

4) How can the construction sand & gravel metabolism of RMDS region be improved? → Research by design
Theory Urban Metabolism

Urban Metabolism model by Dirk Sijmons and Jurra Raith.
Source: Brugmans et al. 2014.
Theory Sand and gravel metabolism

A) River catchment
B) North Sea

1) Concrete in buildings
2) Asphalt in infrastructure
3) Surface raising
4) Coastal protection
Theory Construction Metabolism

Adapted from Zhang et al. 2018
Theory Metabolic framework
Theory Sand and gravel metabolism (in the Dutch context)
‘Durability is the capability of a building or its part to perform its required function over a specified period of time under the influence of the agents anticipated in service’ (ISO, 2011).
Theory Durability

Adapted from Brand, 1994

- Stuff: 0-3 y
- Space plan: 3-30 y
- Service: 7-15 y
- Skin: 20-50 y
- Structure: 30-300 y
- Site (urban plan): ~
User of a building

Function of a building

Building

Design of public space

Structure of public space

Rhythm of a city
Analysis Metabolic system until 2040
Analysis: Conditions of urban development
Analysis

Conditions of maintenance

- Subsidence
- Sea level rise
- Sediment
- Infrastructure
Analysis Building stock

- Foundation material
  - Recycled as aggregate
  - Entirely reused
  - Recycled in new asphalt

- Urban ecosystem
  - Policy plans
  - Service life
- Concrete sand & gravel
- Road construction (asphalt)
- Surface raising (building sites & civil engineering)
- Land reclamation
- Coastal protection
- C&D waste

- River catchment
- Fill sand
- Sediment
- North Sea
  - River & sediment deposit
  - Sediment dredging
  - Sediment transport

Internal factor
External factor
Building Capacity for urbanisation within the BE

- Densification
- Greenfield development
- Retrofitting
- Transformation of non-residential areas

capacity of 118,567 dwellings (126%)
+/- 11,7 mln tonnes concrete

Source: Vereniging Deltametropool & College van Rijksbouwmeesters, 2014
- 105,433 dwellings
  +/- 22 mln tonnes concrete
+ 105,433 dwellings
  +/- 14 mln tonnes concrete

<table>
<thead>
<tr>
<th>EOL residential stock</th>
<th>in 2020</th>
<th>in 2030</th>
<th>in 2040</th>
<th>in 2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>amount</td>
<td>13.494</td>
<td>14.912</td>
<td>36.472</td>
<td>46.020</td>
</tr>
<tr>
<td>cumulative</td>
<td>13.494</td>
<td>28.406</td>
<td>64.878</td>
<td>110.898</td>
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</tbody>
</table>

= total demolished
Analysis Site preparation

- foundation material
  - recycled as aggregate
  - entirely recycled
  - recycled in new product

- urban ecosystem
- construction ecosystem
- new constructions
- soil conditions
- land reclamation
- coastal protection

- building & infrastructure construction
- C&D waste
- road construction

- concrete sand & gravel
- sand & gravel from river
- fill sand
- sediment

- river catchment
- North Sea
- river & sediment deposit
- sediment dredging
- sediment transport

- internal factor
- external factor
Site preparation: New construction and C&D return flux

- + 188,433 dwellings
- +/- 7,5 mln tonnes fill sand
- +/- 4.666 ha site raising
- +/- 67,6 mln tonnes fill sand
- +/- 22 mln tonnes C&D waste
Site preparation Soil condition
Amount of fill sand =

\[\text{(Area neighbourhood} \times \text{percentage paved area) - built area}) \times \text{subsidence pace}\]

\[\pm 20 \text{ mln tonnes fill sand}\]
Analysis Metabolic model result

Construction sand and gravel metabolism 2018-2040

Rijnmond-Drechsteden

River sediment 21.69 mln tonnes
Fill sand 55.16 mln tonnes
Asphalt 6.2 mln tonnes
North Sea influx: 37.400 mln tonnes
Dredged sand 261.8 mln tonnes
Dike maintenance: 28 mln tonnes
Site preparation 0.23 mln tonnes
Subsidence maintenance: 19.48 mln tonnes
Beach nourishment: 169.68 mln tonnes
Blending: 26.1 mln tonnes
Concrete waste 22.16 mln tonnes
Concrete 25.74 mln tonnes
Voorne: 22.56 mln tonnes
New dwellings 11.7 mln tonnes
Replacement EOL 10.83 mln tonnes
# LCA Building Life Cycle Information

<table>
<thead>
<tr>
<th>PRODUCT stage</th>
<th>CONSTRUCTION PROCESS stage</th>
<th>USE stage</th>
<th>END OF LIFE stage</th>
<th>Benefits and loads</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>A2</td>
<td>A3</td>
<td>A4</td>
<td>A5</td>
</tr>
<tr>
<td>Raw material supply</td>
<td>Transport</td>
<td>Manufacturing</td>
<td>Transport</td>
<td>Construction / installation process</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>B6</th>
<th>B7</th>
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</thead>
<tbody>
<tr>
<td>operational energy use</td>
<td>operational water use</td>
</tr>
</tbody>
</table>
Waste and material efficiency hierarchies

(Cordella et al., 2019)
Bijhouwer's situation consciousness

Fig. 662 Bijhouwer, soil map of Kethel and surroundings

Fig. 663 Bijhouwer, development plan of Kethel and surroundings
Material conscious approach

- **urban ecosystem**
- focus
- construction life-cycle
- metabolism

Design of urban environment

- **strategies**
  - Prevention
  - Reuse
  - Recycling

material life-cycle and supply chain
Tools for a material conscious approach
Tools for a material conscious approach
Reduce Building on water

A) PRODUCT stage  A) CONSTRUCTION stage  B) USE stage  C) EoL stage

Steigereiland, Amsterdam
Reuse Building transformation

A) PRODUCT stage

A) CONSTRUCTION stage

B) USE stage

C) EoL stage

Former Philips Factory Gerard, Eindhoven
Recycling Secondary sources and facility

A) PRODUCT stage
B) USE stage
C) EoL stage
D) recycling potentials

14.2 kg/m²
16.7 kg/dwelling
1 m² = 1.176 dwelling

1 m² = 1.176 dwelling
Spatial intervention of solutions
Focus locations

- Vliesland
- Spijkenisse
- Ommoord
- Rotterdam
- Stationsgebied
- Dordrecht
Focus locations

Ommoord - Vlambloem

Ommoord - Roosbuurt

Spijkenisse - Vliesland

Dordrecht - Spoorzone
Design method

Spatial scenario

Metabolic scenario

Catalogue of Solutions

RMDS in 2050

Design detail

Material sensitive urban design

Pilot project for RMDS region

RMDS

detail

solutions applied on resulting in

a reduced consumption of primary construction sand and gravel through urban design
Regional sand metabolism

vision for circular sand metabolism

- renovate
- repurpose
- retrofit

extend lifespan

Demolition and renovation

on-site

material

New construction

biobased

bio-based alternatives

local storage and treatment

regional storage and treatment

bio-based

bio-based

material

prevent in design

planning → market

www

surface (buildings and roads)

subsurface (soil)

circular alternatives (EPS)

storage and treatment

on-site

treated

sediment

tidal parks and landfarming

www

market

planning

www

planning

www

vision for circular sand metabolism

Regional sand metabolism

SAND
Focus location Spijkenisse - Vliesland

- No artificial sand stock
- Surrounded neighbourhoods
- Concrete (building) 641.790 tonnes
Design options Spijkenisse - Vliesland

Business as usual  CwS01  CwS02  CwS03
Spijkenisse - Vliesland  Business as usual
Spijkenisse - Vliesland CwS02
Impact on region Concrete
Impact on region EPS

Demolition

0.105 mln <1%

13.86 mln
Regional productive scape: Soild treatment

2.268.8 ha
32% (43,606,336 tonnes sand)
Regional productive scape: Tidal park

30,262,989 m$^3$
(58,163,122 tonnes sediment)

≈ 22%
Regional productive scape: *Landfarming*

1.525 ha

30% (79 mln tonnes sediment)
‘How can urban design reduce the consumption of primary construction sand and gravel in the construction ecosystem in the Rijnmond-Drechtsteden region?’

• Applyng the material consciousness approach (in the life-cycle perspective and with material efficiency strategies) in the field of urban design

• Consumption can significantly be reduced through urban design in (inter-) relation to systematic metabolic changes and interventions on regional level

• This results in a multi-scalar approach between technical/local and planning/regional decisions

• In order to practically reduce the consumption and develop a circular construction, a more interdisciplinary process is needed between civil engineering and urbanism where environmental impact, technical feasibility and spatial quality are studied within the material consciousness approach
Rijnmond-Drechtsteden: a sand-balanced region
APPENDIX
Rotterdam - Ommoord  Business as usual
Rotterdam - Ommoord CwS02
Rotterdam - Ommoord overview

Ommoord - Roosbuurt
Design: business as usual

Ommoord - Roosbuurt
CwS01: EPS

Ommoord - Roosbuurt
CwS02: EPS

Business as usual

CwS01

CwS02
Ommoord - Vlambloem
Ommoord - Vlambloem

CwSd-01
Ommoord - Vlambloem

CwSd-02: EPS + Modular
Ommoord - Vlambloem

Ommoord - Vlambloem
CwSd-03
Dordrecht - Spoorzone

Design: business as usual
Dordrecht - Spoorzone

Dordrecht - Spoorzone

CwS01
Dordrecht - Spoorzone

CwS02
Dordrecht - Spoorzone

Dordrecht - Spoorzone
CwS03
**Example**

**Building A**

- Function: residential (RB)
- Year: 1960
- Height: 9m
- Footprint: 90m²

**Database validation**

RB < 12 so Single-Family

Year = 1960

so MI\text{concrete} \ (material intensity) = 0,85 \ metric \ tonnes /m²

**Calculation**

Total floorspace (GFA) is needed

GFA = (9/3)×90 = 270 m²

Total material intensity of concrete:

GFA×MI = 270×0,85 = 229,5 \ metric \ tonnes.
LCA Systematic and spatial

Buildings

Site raising

Dikes

Beach nourishment

Dredging
Mapping the current sand stock
based on Stephen & Athanassiadis 2017, AMS-PUMA 2017
Annually, we extract enough sand from the earth to cover the entire Netherlands with a layer of 60cm of sand.

“Sand is, after water, the most used raw material on earth [...] and greatly exceeds their natural renewal rates”

*average of +/- 40 billion (40,000,000,000) tonnes
(March). Sand, Rarer Than One Thinks.