Reuse of marine sediments in Belgium

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Ir. Johan Van Dessel

WTCB-CSTC-BBRI
Reuse of marine sediments in Belgium

Content of the presentation

- Challenges and opportunities
- Current practice
- Legal framework
- Technical possibilities
- Social, economic, environmental and spatial issues
- CEAMaS website
- Conclusions
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Challenges

- 4 major Belgian seaports (Antwerpen, Zeebrugge, Oostende, Gent) + some smaller coastal ports (Blankenberge, Nieuwpoort)
- dredging is necessary to guarantee access to the Belgian ports
- maintenance dredging and capital dredging
- about 20-30 Mm³ of marine sediments are dredged each year
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**Challenges**

- **dredging**
  - large costs
  - large amounts
  - more or less polluted sediments

- **problems**
  - legislation
  - technology
  - solutions are too expensive
  - social acceptability (NIMBY)
  - lack of / differences in knowledge
  - dependent on local context

long-term solution has to be found
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Opportunities

– large dredging companies with a lot of experience on reference and innovative dredging technologies

– positive attention of the government regarding economic and environmentally friendly reuse solutions for dredged sediments

  • sediments as a secondary resource
    – reuse as soil
    – reuse in or as construction product
    – reuse as artificial sealing for disposal sites

– Flanders is a pioneer in the treatment of sediments with the AMORAS installation in the Port of Antwerp

– circular economy and opportunities for the construction sector: sediments are a new business and a new source of resources for construction products and civil engineering applications
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Current practice

different options for dredged marine sediments

- dumping
  - at sea
  - in river and on riverbanks
  - in harbour

- treatment on land and landfill
  - AMORAS
  - other treatment

<table>
<thead>
<tr>
<th>Treatment option</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dumping</strong></td>
<td></td>
</tr>
<tr>
<td>- at sea</td>
<td>11.5 Mtds/y</td>
</tr>
<tr>
<td>- in river and on riverbanks</td>
<td>5 Mm³/y</td>
</tr>
<tr>
<td>- in harbour</td>
<td>14.000 tds/y</td>
</tr>
<tr>
<td><strong>Treatment</strong> on land and landfill</td>
<td>25.000 m³/y</td>
</tr>
<tr>
<td><strong>Treatment</strong> in AMORAS</td>
<td>600.000 tds/y</td>
</tr>
</tbody>
</table>
Reuse of marine sediments in Belgium

Current practice

- dumping at North Sea
  - at five dumping sites
  - according to specific permits

<table>
<thead>
<tr>
<th>Treatment option</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dumping</td>
<td>11.5 Mtds/y</td>
</tr>
</tbody>
</table>

Dredging & dumping sites:
- dredging location
- dredged material dumping site
- former ammunition dumping site
- former industrial waste dump site
- former dredging spoil dumping site
- alternative disposal site for dredged material
Reuse of marine sediments in Belgium

Current practice

- dumping in river and on riverbanks (Schelde)
  - ‘building with nature’

<table>
<thead>
<tr>
<th>Treatment option</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dumping</td>
<td>5 Mm$^3$/y</td>
</tr>
<tr>
<td>in river and on riverbanks</td>
<td></td>
</tr>
</tbody>
</table>
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Current practice

- treatment on land and landfill
  - AMORAS installation in Port of Antwerp

<table>
<thead>
<tr>
<th>Treatment option</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment in AMORAS</td>
<td>600,000 tds/y</td>
</tr>
</tbody>
</table>

- Rotating sieves – removal of coarse elements (> 8 mm)
- Hydrocyclones – separation of sand (grain size > 63 μm)
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# Reuse of marine sediments in Belgium

## Legal framework

### Legislation

<table>
<thead>
<tr>
<th>International</th>
<th>Regional (Flemish)</th>
<th>European</th>
<th>Other documents</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Convention of London</td>
<td>- Materials decree + VLAREMA</td>
<td>- Habitat directive</td>
<td>- Code of good practice</td>
</tr>
<tr>
<td>- OSPAR convention</td>
<td>- Soil decree + VLAREBO</td>
<td>- Water directive</td>
<td>- Compendium for sampling and analysis</td>
</tr>
<tr>
<td></td>
<td>- Decree on environmental permits + VLAREM I-II</td>
<td>- Marine strategy directive</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Birds directive</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### National

- Federal law and Royal resolution on the protection of the marine environment
- Royal and Ministerial resolutions on disposal of dredged sediments in the North Sea
- Cooperation agreement between the federal and Flemish government
Reuse of marine sediments in Belgium

Legal framework

- Flemish legislation
  - reuse of sediments as a secondary resource

<table>
<thead>
<tr>
<th>Reuse option</th>
<th>Legislation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reuse in or as a construction product (shaped and non-shaped)</td>
<td>VLAREMA</td>
</tr>
<tr>
<td>Reuse in or as landfill cover</td>
<td>VLAREMA</td>
</tr>
<tr>
<td>Reuse as soil</td>
<td>VLAREMA + VLAREBO</td>
</tr>
<tr>
<td>Storage</td>
<td>VLAREM I + VLAREM II</td>
</tr>
<tr>
<td>Treatment</td>
<td>VLAREM I + VLAREM II</td>
</tr>
<tr>
<td>Landfill (final disposal)</td>
<td>VLAREM I + VLAREM II</td>
</tr>
<tr>
<td>Filling of quarries, pits, ponds and lakes</td>
<td>VLAREBO + VLAREM I + VLAREM II</td>
</tr>
<tr>
<td>Dumping at specific locations within the North Sea</td>
<td>Federal law + specific permissions</td>
</tr>
</tbody>
</table>

Bijlage 2.3.2. Voorwaarden inzake samenstelling voor gebruik als bouwstof

<table>
<thead>
<tr>
<th>METALEN (1)</th>
<th>TOTAALCONCENTRATIE in mg/kg droge stof (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenen (As)</td>
<td>250</td>
</tr>
<tr>
<td>Cadmium (Cd)</td>
<td>10</td>
</tr>
<tr>
<td>Chroom (Cr)</td>
<td>1250</td>
</tr>
<tr>
<td>Koper (Cu)</td>
<td>375</td>
</tr>
<tr>
<td>Kwik (Hg)</td>
<td>5</td>
</tr>
<tr>
<td>Lood (Pb)</td>
<td>1250</td>
</tr>
<tr>
<td>Nikkel (Ni)</td>
<td>250</td>
</tr>
<tr>
<td>Zink (Zn)</td>
<td>1250</td>
</tr>
</tbody>
</table>

Bijlage 2.3.2.a Voorwaarden voor gebruik als bouwstof

<table>
<thead>
<tr>
<th>MONOCYLISCH DE KOWWATERSTOFFEN</th>
<th>TOTAALCONCENTRATIE in mg/kg droge stof (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benzeen</td>
<td>0,5</td>
</tr>
<tr>
<td>Ethylbenzeen</td>
<td>5</td>
</tr>
<tr>
<td>Styreene</td>
<td>1,5</td>
</tr>
<tr>
<td>Tolueen</td>
<td>15</td>
</tr>
<tr>
<td>Xyleen</td>
<td>15</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>POLYCYCLISCH DE AROMATISCHE KOWWATERSTOFFEN</th>
<th>TOTAALCONCENTRATIE in mg/kg droge stof (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benzo(a)antraeenc</td>
<td>35</td>
</tr>
<tr>
<td>Benzo(a)pyreene</td>
<td>8,5</td>
</tr>
<tr>
<td>Benzo(ghi)perylen</td>
<td>35</td>
</tr>
<tr>
<td>Benzo(b)fluoranteen</td>
<td>55</td>
</tr>
<tr>
<td>Benzo(k)fluoranteen</td>
<td>55</td>
</tr>
<tr>
<td>Chrysean</td>
<td>400</td>
</tr>
<tr>
<td>Fenantrien</td>
<td>30</td>
</tr>
<tr>
<td>Fluoranteen</td>
<td>40</td>
</tr>
<tr>
<td>Indeno(1,2,3cd)pyreene</td>
<td>35</td>
</tr>
</tbody>
</table>
### Reuse of marine sediments in Belgium

#### Legal framework

- Flemish legislation versus legislation in neighbouring countries
  - large differences between countries

<table>
<thead>
<tr>
<th>Antimony</th>
<th>Arsenic</th>
<th>Barium</th>
<th>Cadmium</th>
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<th>Cobalt</th>
<th>Copper</th>
<th>Lead</th>
<th>Molybdenum</th>
<th>Nickel</th>
<th>Selenium</th>
<th>Tin</th>
<th>Zinc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low IRL</td>
<td>Low BE</td>
<td>Low FR</td>
<td>Low NL</td>
<td>Low IRL</td>
<td>Low BE</td>
<td>Low FR</td>
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- French Level 1 (N1)
- French Level 2 (N2)
- Dutch (*) Bul, living; Dutch (*) sou, industry; Dutch (** ZBB)

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Reuse of marine sediments in Belgium

Technical possibilities

- Flowchart
  - different ways of treatment and reuse are possible, depending on the sediment characteristics
Reuse of marine sediments in Belgium

Technical possibilities

- Possible applications of sediments
  - different options are possible
  - legislation, documents, guidelines, standards, ... with specific requirements for the sediments

<table>
<thead>
<tr>
<th>Road construction</th>
<th>Soils</th>
<th>Building industry</th>
<th>Dikes and safety against flooding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road embankment, tines</td>
<td>Soil elevation (meadow deposit lift up of lowlands)</td>
<td>Brick production</td>
<td>Trench shoring</td>
</tr>
<tr>
<td>Road embankment, sand</td>
<td>Wet storage (deposit)</td>
<td>Artificial gravel production</td>
<td>River Embankment</td>
</tr>
<tr>
<td>Road embankment, self-clear</td>
<td>Filter cake press</td>
<td>Artificial basalt</td>
<td>Dike, river site scouring protection</td>
</tr>
<tr>
<td>Road sub base</td>
<td></td>
<td></td>
<td>Dike, land site terrace</td>
</tr>
<tr>
<td>Parking lot road surface</td>
<td></td>
<td></td>
<td>Lake, erosion protection</td>
</tr>
</tbody>
</table>

- Technical possibilities:
  - Reuse of marine sediments in Belgium

- Soils:
  - Soil development, on land/nature development, wetland/sand separation
  - Hydrocyclone for sand separation
  - Natural ripening

- Soils enhanced ripening with geopolam land farming

- Energy crops
- Sound walls
- Capping of deposits

- Building industry
  - Cement granulate, production/stabilization/solidification

- Relocation within river
- Land reclamation / lowland uplift

- Dumping at river banks
  - Building with nature (salt marshes and mud flats)

- Dumping at sea
  - Filling of pits and quarries

- Disposal at land (after dewatering)
  - Dams and dikes construction

- Storage and treatment at land
  - Sand extraction

- Storage within underwater cells
  - Reuse as soil

- Beach nourishment
  - Reuse as construction material (bricks, granulates, concrete filler, roads foundation)

- Coastal protection
  - Landfill cover

- Dewatering with filter press or geotubes or lagooning
## Technical possibilities

- Technical feasibility of possible applications
  - SWOT analysis

<table>
<thead>
<tr>
<th>Civil Engineering Family</th>
<th>Application type</th>
<th>DM Quality</th>
<th>Volume</th>
<th>BE guide</th>
<th>Strength</th>
<th>Weakness</th>
<th>Opportunity</th>
<th>Threat</th>
</tr>
</thead>
</table>
| Geotechnical             | Road embankments | below VLAREMA limits for reuse as non-designed construction products. Full time requirements of 38250 | ?       | VLAREMA 38250 (standard specifications for reuse in Flanders) | reuse of large quantities of sediments is possible. | no restrictions according to 38250. Wide range of alternatives available. Technical quality could be enhanced by technical improvements. | uptake within 38250. Only if specific knowledge on availability and technical quality is available. | Resource certificate mandatory. Not the case for primary resources.
|                          |                  |            |        |          |          |          |             |        |
|                          | Noise barriers   | below VLAREMA limits for reuse as non-designed construction products. Full time requirements of 38250 | ?       | VLAREMA 38250 (standard specifications for reuse in Flanders) | reuse of large quantities of sediments is possible. | no restrictions according to 38250. Wide range of alternatives available. Technical quality could be enhanced by technical improvements. | uptake within 38250. Only if specific knowledge on availability and technical quality is available. | Resource certificate mandatory. Not the case for primary resources.
|                          |                  |            |        |          |          |          |             |        |
|                          | Gravel/stone sand separation | below VLAREMA limits for reuse as non-designed construction products. Full time requirements of 38250 for application in roads | Part of Annex 100,000 tons | VLAREMA 38250 (standard specifications for reuse in Flanders) | relatively simple and easy to apply without further restrictions (sands and gravel fractions). | not always good with respect to technical properties and is more expensive than primary sand. Wide range of alternatives available. Technical quality could be enhanced by technical improvements. | separate from non-designed materials with high technical properties. Not distinguishable from primary sand and should be able to reach the market. | Resource certificate mandatory. Not the case for primary resources. |
|                          |                  |            |        |          |          |          |             |        |
|                          | Land Reclamation - no additional effort measured | below limits within VLAREMA for reuse as soil and below limits within VLAREMA | Parts of Ostend and Zeeland | VLAREMA - reuse as soil | reuse of large quantities of sediments is possible. | Chilean contaminated sediments. Relatively strict limits for reuse. Large range of alternatives available (reused soils). | Objection by environment protection groups, neighbors and farmers. Closed soil balance for specific location. | Objection by environment protection groups, neighbors and farmers. Closed soil balance for specific location. |
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Technical possibilities

- Innovative reuse solutions
  - reuse of sediments in geotechnical applications
    - literature study
  - reuse of sediments in concrete and mortar
    - literature study
    - laboratory study
  - other Belgian projects
    - VAMORAS
    - PRISMA
Reuse of marine sediments in Belgium

Technical possibilities

• Innovative reuse solutions
  – reuse of sediments in geotechnical applications
    • literature study
  – reuse of sediments in concrete and mortar
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    • laboratory study
  – other Belgian projects
    • VAMORAS
    • PRISMA
Reuse of marine sediments in Belgium

Technical possibilities

• Innovative reuse solutions
  – reuse of sediments in geotechnical applications
    • literature study
      – reinforced fills with dredged material used as fill material
      – road sub-bases
      – use of geotextile tubes
        » dewatering of the dredged sludges
        » geotechnical structures made of geotextile tubes (dikes, embankments, breakwaters, etc.) filled with dredged material
  – stabilisation/solidification of (potentially contaminated) dredged materials (possibly for land reclamation)
Reuse of marine sediments in Belgium

Technical possibilities

• Innovative reuse solutions
  – reuse of sediments in geotechnical applications
  • literature study
    – reinforced fills with dredged material used as the fill material

• execution standard - EN 14475 (2006)

Table A.1 — Typical combinations of fills, reinforcements and facings

<table>
<thead>
<tr>
<th>FILL TYPE</th>
<th>Type 1</th>
<th>Type 2</th>
<th>Type 3</th>
<th>Type 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Draining</td>
<td>&lt;5%</td>
<td>&lt;12%</td>
<td>12 to 35%</td>
<td>&gt;35%</td>
</tr>
<tr>
<td>Granular</td>
<td>n.a.</td>
<td>&lt;10%</td>
<td>&gt;10%</td>
<td>&lt;40%</td>
</tr>
<tr>
<td>Intermediate</td>
<td>12 to 35%</td>
<td>n.a.</td>
<td>n.a.</td>
<td>&lt;25</td>
</tr>
<tr>
<td>Fine</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td>&lt;25</td>
</tr>
</tbody>
</table>

APPLICATION

- Parts of structure exposed to flooding and/or rapid water draw-down
- Structure supporting bridge abutments, railways, buildings
- High reinforced fill walls
- High reinforced fill slopes
- Common walls and slopes

• various standards in European countries for the control of the mechanical characteristics of the fill material for the design of such geotechnical structures
Reuse of marine sediments in Belgium

Technical possibilities

- Innovative reuse solutions
  - reuse of sediments in geotechnical applications
    - literature study
      - road sub-bases

- different certification documents (labelling, etc.)
  → NBN EN 13242 (2013)
  → requirements in terms of the characteristics of the aggregates

- geotechnical requirements for the design (bearing capacity, permeability of the road sub-bases)

- requirements of various job specifications in function of the Belgian Regions (SB 250 etc.)

- stabilisation with cement or lime: BRRC Requirements R81/10

Road and railway sub-bases
Reuse of marine sediments in Belgium

Technical possibilities

• Innovative reuse solutions
  – reuse of sediments in geotechnical applications
    • literature study
      – use of geotextile tubes
        » dewatering of the dredged sludges
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Technical possibilities

• Innovative reuse solutions
  – reuse of sediments in geotechnical applications
• literature study
  – use of geotextile tubes
    » geotechnical structures made of geotextile tubes (dikes, embankments, breakwaters, etc.) filled with dredged material

CUR-publication 222 (2009)

→ design aspects
1. volumetric mass of the sediments (ρ)
2. grain-size distribution: average grain diameter \( d_{mf} \)

\[
d_{mf} = \frac{d_{10} + d_{20} + d_{30} + d_{40} + d_{50} + d_{60} + d_{70} + d_{80} + d_{90}}{9}
\]
Technical possibilities

• Innovative reuse solutions
  – reuse of sediments in geotechnical applications
    • literature study
      – stabilisation/solidification of (potentially contaminated) dredged materials (possibly for land reclamation)

1. chemical stabilisation/solidification of the contaminants
2. increase of the hydro-mechanical properties of the dredged material

As underlined in Topolnicki (2004): “shallow dry-method offers a cost-effective solution for ground improvement works or site remediation when dealing with substantial volumes of very weak or contaminated superficial soils with high water content, such as deposits of dredged sediments, wet organic soils or waste sludges”
Technical possibilities

- Innovative reuse solutions
  - reuse of sediments in geotechnical applications
  - literature study
    - stabilisation/solidification of (potentially contaminated) dredged materials (possibly for land reclamation)

Design criteria of (permanent) use of this treated dredged material could be based on execution monitoring (mixing energy, depth, etc.) and performance tests including unconfined compression strength tests, tests for the determination of the modulus of elasticity, freeze-thaw and wet-dry durability, leachability, porosity and permeability tests performed on the material after its in-situ hardening (by coring samples).

Permanent in-situ monitoring (observational method)
Technical possibilities

- Innovative reuse solutions
  - reuse of sediments in **concrete and mortar**
    - literature study
      - overview of relevant standards and their requirements for aggregates and fillers
    - laboratory study
      - orientating mortar tests in which a reference filler is replaced by CEAMaS sediment

Reuse of marine sediments in Belgium
Re-use of marine sediments in Belgium

Technical possibilities

- Innovative re-use solutions
  - re-use of sediments in concrete and mortar
  - literature study
    - overview of relevant standards and their requirements for aggregates and fillers
## Reuse of marine sediments in Belgium

### Technical possibilities

Characterisation of aggregates and fillers for concrete according to the different standards

<table>
<thead>
<tr>
<th>Properties</th>
<th>Sand and filler fraction</th>
<th>Sand fraction</th>
<th>Aggregate fraction</th>
<th>Recycled aggregates</th>
<th>Filler fraction</th>
<th>Rockdust</th>
<th>Flyash</th>
<th>Ground granulated slag</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Physical</strong></td>
<td></td>
<td></td>
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<tr>
<td>Moisture content</td>
<td>NBN EN 933-1 of 933-10</td>
<td>NBN EN 12620 of NBN EN 13242</td>
<td>NBN EN 933-1</td>
<td>NBN EN 933-1</td>
<td>NBN EN 933-1</td>
<td>NBN EN 933-1</td>
<td>NEN EN 1097-6</td>
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<tr>
<td>Particle size distribution</td>
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<td>NBN EN 933-1</td>
<td>NBN EN 933-1</td>
<td>NBN EN 933-1</td>
<td>NBN EN 933-1</td>
<td>NF ISO 2591-1, X-11-640, NBN EN 196-6</td>
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<tr>
<td>Percentage of fines (&lt;63 µm)</td>
<td>NBN EN 933-1</td>
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<td>NBN EN 933-1</td>
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<tr>
<td>Fineness Modulus</td>
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<td></td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>Blaine</td>
<td>NBN EN 933-9</td>
<td>NBN EN 933-9</td>
<td>NBN EN 933-9</td>
<td>NBN EN 933-9</td>
<td>P 18-592</td>
<td>NBN EN 933-9</td>
<td>NBN EN 96-6</td>
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<td>Methylen blue adsorption</td>
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<td>NBN EN 933-9</td>
<td>P 18-592</td>
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<td>Density</td>
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<td>NBN EN 1097-6</td>
<td>NBN EN 1097-6</td>
<td>NBN EN 1097-6</td>
<td>NBN EN 1097-6</td>
<td>NBN EN 1097-6</td>
<td>NBN EN 196-6</td>
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<tr>
<td>Waterabsorption (1 and 24h)</td>
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<td>NBN EN 1097-6</td>
<td>NBN EN 1097-6</td>
<td>NBN EN 1097-6</td>
<td>NBN EN 1097-6</td>
<td>NBN EN 1097-6</td>
<td>NBN EN 196-6</td>
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<tr>
<td>Resistance to wear (micro Deval)</td>
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<td>NBN EN 1097-1</td>
<td>NBN EN 1097-1</td>
<td>NBN EN 1097-1</td>
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<td>NBN EN 1097-1</td>
<td>NBN EN 196-6</td>
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<td>Flakiness index</td>
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<td>NBN EN 933-3</td>
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<td>Shell content</td>
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<td>NBN EN 589-209</td>
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<tr>
<td><strong>Chemical</strong></td>
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<td>LOI</td>
<td>NBN EN 1097-6</td>
<td>NBN EN 1097-6</td>
<td>NBN EN 1097-6</td>
<td>NBN EN 1097-6</td>
<td>NBN EN 1097-6</td>
<td>NBN EN 1097-6</td>
<td>NBN EN 196-6</td>
<td></td>
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<td>TOC</td>
<td>NBN EN 1744-1</td>
<td>NBN EN 1744-1</td>
<td>PTV 406/ NBN EN 1744-1</td>
<td>NBN EN 1744-1</td>
<td>NBN EN 1744-1</td>
<td>NBN EN 1744-1</td>
<td>Zement-kalk-Gips 43 nr 8/1990</td>
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<td>Chloride content</td>
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<td>NBN EN 1744-1</td>
<td>PTV 406/ NBN EN 1744-1</td>
<td>NBN EN 1744-1</td>
<td>NBN EN 1744-1</td>
<td>NBN EN 1744-1</td>
<td>NBN EN 196-2</td>
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<tr>
<td>Total sulfur (S)</td>
<td>NBN EN 1744-1</td>
<td>NBN EN 1744-1</td>
<td>NBN EN 1744-1</td>
<td>NBN EN 1744-1</td>
<td>NBN EN 1744-1</td>
<td>NBN EN 1744-1</td>
<td>NBN EN 196-2</td>
<td></td>
</tr>
<tr>
<td>Magnesium oxide (MgO)</td>
<td>NBN EN 196-21</td>
<td>NBN EN 196-21</td>
<td>NBN EN 196-21</td>
<td>NBN EN 196-21</td>
<td>NBN EN 196-2</td>
<td>NBN EN 196-2</td>
<td>NBN EN 196-2</td>
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<tr>
<td><strong>Influence on concrete/mortar</strong></td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Delay setting time</td>
<td>NBN EN 1744-1</td>
<td>NBN EN 1744-1</td>
<td>NBN EN 1744-1</td>
<td>NBN EN 1744-1</td>
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<td>NBN EN 196-2</td>
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<tr>
<td>Decrease compressive strength</td>
<td>NBN EN 1744-1</td>
<td>NBN EN 1744-1</td>
<td>NBN EN 1744-1</td>
<td>NBN EN 1744-1</td>
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<td>NBN EN 1744-1</td>
<td>NBN EN 196-2</td>
<td></td>
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</table>
# Reuse of marine sediments in Belgium

## Technical possibilities

Requirements of aggregates and fillers for concrete according to the different standards

<table>
<thead>
<tr>
<th>Aggregates</th>
<th>Aggregates</th>
<th>Recycled high quality concrete aggregate</th>
<th>Recycled aggregates</th>
<th>Fillers</th>
<th>Rockdust</th>
<th>Flyash</th>
<th>Ground granulated slag</th>
</tr>
</thead>
<tbody>
<tr>
<td>sand and filler fraction</td>
<td>sand fraction</td>
<td>aggregate fraction</td>
<td>sand fraction</td>
<td>filler fraction</td>
<td>filler fraction</td>
<td>filler fraction</td>
<td>filler fraction</td>
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### Physical

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>moisture content</td>
<td>≤1% m/m</td>
</tr>
<tr>
<td>Particle size distribution</td>
<td></td>
</tr>
<tr>
<td>Percentage of fines</td>
<td>lowest class ≤22%</td>
</tr>
<tr>
<td>Finess Modulus</td>
<td>lowest class 0.6-2.1</td>
</tr>
<tr>
<td>Blaine</td>
<td>lowest class &gt;600 m2/kg</td>
</tr>
<tr>
<td>Methylene blue adsorption</td>
<td>lowest class ≤3</td>
</tr>
<tr>
<td>Density</td>
<td>&gt; 2000 kg/m3 or &gt;1500 kg/m3 if recycled</td>
</tr>
<tr>
<td>Waterabsorption (1 and 24h)</td>
<td></td>
</tr>
<tr>
<td>Resistance to fragmentation (LA coefficient)</td>
<td>lowest class ≤60</td>
</tr>
<tr>
<td>Resistance to wear (micro Deval)</td>
<td>lowest class ≤50</td>
</tr>
<tr>
<td>Flakiness index</td>
<td>lowest class ≤50</td>
</tr>
<tr>
<td>Shell content</td>
<td>lowest class ≤50</td>
</tr>
<tr>
<td>Density</td>
<td>≤1.2%</td>
</tr>
</tbody>
</table>

### Chemical

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOI</td>
<td>lowest class 4-9% ≤3,0%</td>
</tr>
<tr>
<td>TOC</td>
<td>≤0.2 % m/m ≤0.5 % m/m</td>
</tr>
<tr>
<td>Chloride content</td>
<td>lowest class ≤0.10% ≤0.10% ≤0.10% ≤0.10%</td>
</tr>
<tr>
<td>Total sulfur (S)</td>
<td>lowest class ≤1 ≤0.3% m/m</td>
</tr>
<tr>
<td>Water soluble sulfur</td>
<td>lowest class ≤1.3</td>
</tr>
<tr>
<td>Sulfite content (SO3)</td>
<td>≤1.0% ≤0.5% m/m ≤3,0% ≤2,5%</td>
</tr>
<tr>
<td>Total alkali content</td>
<td>≤5,0 % ≤5.0 % m/m ≤4,0% ≤18,0%</td>
</tr>
<tr>
<td>Magnesium oxide (MgO)</td>
<td></td>
</tr>
</tbody>
</table>

### Influence on concrete/mortar

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delay setting time</td>
<td>max. twice as long (for 25% cement replacement)</td>
</tr>
<tr>
<td>Decrease compressive strength</td>
<td>max. twice as long (for 50% cement replacement)</td>
</tr>
<tr>
<td>max 20% (28d)</td>
<td></td>
</tr>
</tbody>
</table>
Reuse of marine sediments in Belgium

Technical possibilities

• Innovative reuse solutions
  – reuse of sediments in concrete and mortar
    • laboratory study
      – orientating mortar tests in which a reference filler is replaced by CEAMaS sediment
Reuse of marine sediments in Belgium

Technical possibilities

• Innovative reuse solutions
  – reuse of sediments in concrete and mortar
    • laboratory study
      – orientating mortar tests in which a reference filler is replaced by CEAMaS sediment
        » step 1: preparation of the CEAMaS sediment
          • drying at low temperature (55°C) → moisture content <1%
          • grinding of the dried aggregated chunks (for this the micro-Deval test-setup was used)
Reuse of marine sediments in Belgium

Technical possibilities

• Innovative reuse solutions
  – reuse of sediments in concrete and mortar
    • laboratory study
      – orientating mortar tests in which a reference filler is replaced by CEAMaS sediment
        » step 2: development of a mortar recipe with CEAMaS sediment as a filler
          • small mixtures (1l)
Reuse of marine sediments in Belgium

Technical possibilities

• Innovative reuse solutions
  – reuse of sediments in **concrete and mortar**
    • **laboratory study**
      – orientating mortar tests in which a reference filler is replaced by CEAMaS sediment
        » **step 3: determination of the influence of the sediments on the fresh and hardened properties of the mortar**
          • comparative tests on mortar with CEAMaS filler and with reference filler
          • **fresh mortar**
            • consistency (flow-table) (NBN EN 1015-3)
            • air content and volumic mass (NBN EN 1015-6 and -7)
            • setting time (NBN EN 480-2)
Innovative reuse solutions
- reuse of sediments in concrete and mortar
  - laboratory study
    - orientating mortar tests in which a reference filler is replaced by CEAMaS sediment
      - step 3: determination of the influence of the sediments on the fresh and hardened properties of the mortar
        - comparative tests on mortar with CEAMaS filler and with reference filler
        - hardened mortar
          - volumic mass and the compressive & flexural strength (NBN EN 1015-10 and NBN EN 196-1)
Re-use of marine sediments in Belgium

Technical possibilities

• Innovative re-use solutions
  – re-use of sediments in concrete and mortar
    • laboratory study
      – orientating mortar tests in which a reference filler is replaced by CEAMaS sediment

  » results

• composition of the mortars

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Reference mortar Dosage [gr]</th>
<th>CEAMaS mortar Dosage [gr]</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEN reference sand</td>
<td>1350</td>
<td>1350</td>
</tr>
<tr>
<td>Calcite filler</td>
<td>300</td>
<td></td>
</tr>
<tr>
<td>CEAMaS sediment</td>
<td>300</td>
<td></td>
</tr>
<tr>
<td>Cement CEM I 42,5 R HES</td>
<td>450</td>
<td>450</td>
</tr>
<tr>
<td>Superplast (Glenium Ace)</td>
<td>/</td>
<td>1,35</td>
</tr>
<tr>
<td>Total water</td>
<td>292,5</td>
<td>292,5</td>
</tr>
<tr>
<td>W/C</td>
<td>0,65</td>
<td>0,65</td>
</tr>
<tr>
<td>W/P</td>
<td>0,39</td>
<td>0,39</td>
</tr>
</tbody>
</table>

Table 5: The mortar compositions.
Reuse of marine sediments in Belgium

Technical possibilities

• Innovative reuse solutions
  – reuse of sediments in **concrete and mortar**
    • laboratory study
      – orientating mortar tests in which a reference filler is replaced by CEAMaS sediment
        » results
          • tests on fresh CEAMaS mortar in comparison to reference mortar

<table>
<thead>
<tr>
<th>Mixture</th>
<th>Consistency (mm)</th>
<th>Air content (%)</th>
<th>Fresh bulk density (kg/m³)</th>
<th>Setting time Initial (min)</th>
<th>Setting time Final (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference mortar</td>
<td>225</td>
<td>3,9</td>
<td>2200</td>
<td>225</td>
<td>405</td>
</tr>
<tr>
<td>CEAMaS mortar</td>
<td>175</td>
<td>4,2</td>
<td>2180</td>
<td>405</td>
<td>520</td>
</tr>
</tbody>
</table>

Table 6: Results of the tests on the fresh mortar.

Table 7: Pictures of the consistency test on the reference and on the CEAMaS mortar.
Reuse of marine sediments in Belgium

Technical possibilities

• Innovative reuse solutions
  – reuse of sediments in concrete and mortar
    • laboratory study
      – orientating mortar tests in which a reference filler is replaced by CEAMaS sediment
        » results
          • tests on fresh CEAMaS mortar in comparison to reference mortar
Technical possibilities

- Innovative reuse solutions
  - reuse of sediments in concrete and mortar
    - laboratory study
      - orientating mortar tests in which a reference filler is replaced by CEAMaS sediment

  » results
    - tests on hardened CEAMaS mortar in comparison to reference mortar (after 7 days and after 28 days)

<table>
<thead>
<tr>
<th>Mixture</th>
<th>Dry bulk density (kg/m³)</th>
<th>Flexural strength (N/mm²)</th>
<th>Compressive strength (N/mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>7 days</td>
<td>28 days</td>
</tr>
<tr>
<td>Reference mortar</td>
<td>2220</td>
<td>6.8</td>
<td>7.9</td>
</tr>
<tr>
<td>CEAMaS mortar</td>
<td>2190</td>
<td>6.1</td>
<td>6.3</td>
</tr>
</tbody>
</table>
Technical possibilities

• Innovative reuse solutions
  – reuse of sediments in concrete and mortar
    • laboratory study
      – orientating mortar tests in which a reference filler is replaced by CEAMaS sediment

  » conclusions
    • only small influence on air content and density
    • superplasticizer necessary to enhance consistency
    • initial and final setting times of mortar are delayed
    • smaller compressive strength
    • values are within limits of European standards

=> CEAMaS sediment can be used as alternative for limestone filler in mortar and concrete
Reuse of marine sediments in Belgium

Technical possibilities

• Innovative reuse solutions
  – other Belgian projects
    • VAMORAS
    • PRISMA
Reuse of marine sediments in Belgium

Technical possibilities

- Innovative reuse solutions
  - other Belgian projects

**VAMORAS**
- Use as a resource for light-weight aggregates
- Use as a resource for bricks
- Use as a filler for concrete and mortar
- Bulk use in infrastructure works, road construction
- Use as a binder (through calcination)
- Use as hypercake

**PRISMA**
- Compartment dike
Reuse of marine sediments in Belgium

Content of the presentation

- Challenges and opportunities
- Current practice
- Legal framework
- Technical possibilities
- Social, economic, environmental and spatial issues
- CEAMaS website
- Conclusions
Reuse of marine sediments in Belgium

Social issues

• Social acceptability
  – based on interviews of different groups of stakeholders in five countries (Be, Nl, Fr, UK, Irl)
  – conclusions
    • local context is different everywhere, except in Be and Nl
    • no common vision on sediment management
    • dumping at sea is actually used by all, as well as building with nature
    • knowledge is induced by different practices
    • lack of knowledge for the smallest harbours and knowledge gap between stakeholders
    • waste legislation is a key parameter in decision making in each country
    • sediment treatments are additional cost working against sediment reuse
    • important costs for dredging, transport, treatment
    • need for reliable applications
Economic issues

- Economic analysis of different management scenarios
  - economic model => direct costs, direct, indirect and induced contribution to GDP and job creation
Economic issues

- Economic analysis of different management scenarios
  - Belgium
    - disposal at sea
    - treatment and disposal in facility (AMORAS)
Reuse of marine sediments in Belgium

Economic issues

• Economic analysis of different management scenarios
  – Belgium
    • disposal at sea
Reuse of marine sediments in Belgium

Economic issues

- Economic analysis of different management scenarios
  - Belgium
  - treatment and disposal in facility (AMORAS)

Dredging volume: 100,000 m³
Sailing distance: 6 km
Reuse of marine sediments in Belgium

Economic issues

- Economic analysis of different management scenarios
  - Belgium
    - disposal at sea
    - treatment and disposal in facility (AMORAS)

Dredging volume: 100,000 m³
Sailing distance: 150 km
Reuse of marine sediments in Belgium

Environmental issues

• Environmental analysis (LCA) of different management scenarios
  – Life Cycle Assessment (LCA)

The management of 1 cubic meter (m³) (or dry ton) of dredged sediments in North-West Europe in 2014.
Re-use of marine sediments in Belgium

Environmental issues

- Environmental analysis (LCA) of different management scenarios
  - Belgium
  - treatment and disposal in facility (AMORAS)

<table>
<thead>
<tr>
<th>CEAMaS Partner Countries</th>
<th>Scenarios</th>
<th>Wetland Creation/Building with Nature</th>
<th>Brick Manufacture</th>
<th>Road SubBase Construction</th>
<th>Amoras</th>
<th>Slufter/Disposal on Land</th>
<th>Underwater Cell</th>
<th>Dumping at Sea</th>
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<tbody>
<tr>
<td>Belgium</td>
<td></td>
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</tbody>
</table>
Reuse of marine sediments in Belgium

Environmental issues

- Environmental analysis (LCA) of different management scenarios
  - Belgium
    - treatment and disposal in facility (AMORAS)

functional unit = 1 dry ton of sediments
Reuse of marine sediments in Belgium

Spatial issues

- CEAMaS Web-GIS application
Reuse of marine sediments in Belgium

Content of the presentation

- Challenges and opportunities
- Current practice
- Legal framework
- Technical possibilities
- Social, economic, environmental and spatial issues
- CEAMaS website
- Conclusions
Reuse of marine sediments in Belgium

Welcome on CEAMAS Website

www.ceamas.eu

- background information
- reports
- tools
- online training
- partners
Reuse of marine sediments in Belgium

Content of the presentation

- Challenges and opportunities
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Reuse of marine sediments in Belgium

Conclusions

- dredged marine sediments offer both challenges and opportunities

- legislation provides possibilities for beneficial reuse of sediments as a secondary resource

- many technical solutions with specific requirements for the sediments exist

- current practice: limited beneficial reuse (e.g. building with nature), but research is ongoing (e.g. AMORAS)
Conclusions

- research into new applications of sediments:
  - geotechnical applications
  - concrete and mortar
  - other projects

- economic model shows both assets and costs of beneficial reuse of sediments

- environmental analysis and GIS application allow optimisation of beneficial reuse options

- social acceptability remains an important issue
We would like to thank especially Jürgen Suffis, MOW-aMT
Agnes Heylen, Port of Antwerp
Stefaan Ides, Port of Antwerp
Lieve De Greeff, OVAM

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t.debuigne@cd2e.com

www.ceamas.eu