Sustainable roads - Is there a future for recycling construction and demolition waste, municipal waste and other waste types in roads?

VIRTUAL INTERNATIONAL WEEK - Sustainability in road and built construction

8th to 12th March 2021

Drs.Ing. Ben Moins
Overview

- Introduction
  - Headlines
  - Sustainability applied to roads
  - Overview of topics to be discussed
- Sustainability of waste products
- References - if you want to find out more
- Q&A
“Australian researchers say used face masks could be recycled to make roads”

“Engineers at RMIT say the road-making material could help tackle the vast amount of waste generated from Covid protective equipment”

The Guardian (03/02/2021)

“A road full of bottlenecks: Dutch cycle path is made of plastic waste”

“Is the road to sustainable asphalt paved with tires?”

“Mixing waste rubber from scrap tires into asphalt binder is one way to make pavement more environmentally friendly”

Chemical & Engineering News (28/02/2021)
“Cigarette butts and roads?”

“Australian researchers have discovered that cigarette butts not only make roads more durable but also mean they generate less heat”

Living Circular (09/02/2021)
Introduction – Sustainability applied to roads

- Which sustainability pillars should be applied to roads?
- Can you give some examples?
Introduction – Sustainability applied to roads

Financial impact
- Transportation costs
- Raw material costs
- Additive costs
- Energy cost
...

Environmental impact
- Transportation distance
- Raw material production
- Energy production
- Production temperature
...

People
- S-LCA

Road users
- WZ delays
- Fuel consumption
- Accidents
- Safety
- Noise
...

Profits
- LCCA

Design
- Monitoring Lab

Sustainable Roads

Durability
- Resistance against rutting
- Resistance against raveling
- Resistance against cracking
- Resistance against fatigue
- Cohesion
...

Planet
- LCA

Sustainable Roads
Introduction – Overview of topics to be discussed

Waste Source | Waste type | Avoided products after recycling
---|---|---
Construction and demolition waste (CDW) | Reclaimed asphalt pavement (RAP) | Filler
Municipal waste (MW) | Recycled concrete aggregate (RCA) | Fine aggregates
Industrial by products | Recycled masonry aggregate (RMA) | Coarse aggregates
End of life vehicles | Glass | Bitumen
 | Plastics | Modifiers
 | Textiles | Fibers
 | Scrap tires | Wood
 | Slags
Question

Which waste type would you focus on and why?

Reclaimed asphalt pavement (RAP)

Source: Asphalt pavements (CDW)

Application in roads: Full structure (Hot vs cold & in place vs in plant)

Avoided products: Filler, sand, coarse aggregate and bitumen

Yearly production in Europe: 88 Mt/y

Recycling potential for roads: 100%

Sustainability (examples):

Performance
- ITS: -56% to no effect
- ITSR: -30%/+3%
- RD: -80%/+55%
- Stiffness: -16%/+99%
- $\varepsilon_6$: -4%/+13%
- SCB (FI): -90%/+18%

Environmental impact
- GWP: -50%/-3%
- EC: -50%/-1%
- Acidification: -22% to -4%
- Eutrophication: -3%/-1%

Economic impact
- Agency cost: -40%/-6%

Social impact
- Skid resistance: -13%/+11%
Recycled concrete aggregate (RCA)

Source: Concrete structures (CDW)

Application in roads: Full structure

Avoided products: Aggregates

Yearly production in Europe: 350 Mt/y

Recycling potential for roads: 13%

Sustainability (examples):

Performance
Compressive strength: -25%  Tensile strength: -10%  Creep: +50%

Environmental impact
GWP: -31%/+3%  EC: -32%/+4%  Acidification: -39%/+3%  Eutrophication: -16%/+3%

Economic impact
Depends on the extra amount of cement that needs to be added

Social impact
Skid resistance: -3%/+11%
Recycled masonry aggregate (RMA)

Source: Masonry structures (CDW)

Application in roads: Unbound layers

Avoided products: Aggregates

Yearly production in Europe: 211 Mt/y

Recycling potential for roads: 19.5%

Sustainability (examples):

Performance
- Compressive strength: +2%/-129%
- Bearing capacity: -69%/-3%
- Deflections: -56%/+63%
- RD: -7%/+7%
- IRI: -46%/-12%

Environmental impact (saving aggregates)
- GWP: -88%/-52%
- Acidification: -96%/-85%
- Eutrophication: -96%/-85%

Economic impact
- Lower IRI => lower RUC

Social impact
- Lower IRI => lower RUC
Glass

**Source:** Windows + panels (CDW), glass recycling (MW) & vehicle windows (ELVs)

**Application in roads:** Full structure and road markings

**Avoided products:** Fine aggregates

**Yearly production in Europe:** 20,2 Mt/y

**Recycling potential for roads:** 43%

**Sustainability (examples):**

<table>
<thead>
<tr>
<th>Performance</th>
<th>Environmental impact</th>
<th>Economic impact</th>
<th>Social impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>ITS: -12%+/15%</td>
<td>GWP: -9%+/3%</td>
<td>Reflective properties: +141% to +178%</td>
<td>Reflective properties: +141% to +178%</td>
</tr>
<tr>
<td>Stiffness: -16%+/9%</td>
<td>EC: +2%</td>
<td>Permeability: +101% to +357%</td>
<td>Permeability: +101% to +357%</td>
</tr>
<tr>
<td>Permanent deformation (MSCR): -31%/-25%</td>
<td>Acidification: +37%</td>
<td>Skid resistance: -4% to +28%</td>
<td>Skid resistance: -4% to +28%</td>
</tr>
<tr>
<td>Resilient modulus: +7%</td>
<td>Eutrophication: +120%</td>
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</tr>
</tbody>
</table>
Plastics

Source: Plastic recycling (MW)

Application in roads: Bitumen-bound layers (wet or dry process)

Avoided products: Modifiers & fine aggregates

Yearly production in Europe: 17.2 Mt/year

Recycling potential for roads: 9%

Sustainability (examples):

- **Performance**
  - ITS: -30%/+17%
  - ITSR: -9%/+32%
  - RD: -60%/+5%
  - Fatigue life: +5%/+40%

- **Environmental impact**
  - GWP: -17%/-3%
  - Acidification: -10%/-2%
  - Eutrophication: -11%/-1%

- **Economic impact**
  - Agency cost: -11%/-5%

- **Social impact**
  - Skid resistance: -3%/+17%

Image source: AXION - https://axiongroup.co.uk/products/recycled-plastics/
Textiles

Source: Textile recycling (MW), old furniture (CDW) & old vehicle seating (ELVs)

Application in roads: Geotextiles & fiber reinforced layers

Avoided products: (Synthetic) Fibers

Yearly production in Europe: 5.1 Mt/y

Recycling potential for roads: 8%

Sustainability (examples):

<table>
<thead>
<tr>
<th>Performance</th>
<th>SCB: no effect</th>
<th>ITS: +12%</th>
<th>ITF: +250% to +450%</th>
<th>Shear stiffness: -60% to +40%</th>
<th>Puncture resistance: -23%/+125%</th>
</tr>
</thead>
<tbody>
<tr>
<td>3PB: no effect</td>
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</table>

? Environmental impact

? Economic impact

? Social impact
Scrap tires

Source: old tires (ELVs)

Application in roads: Bitumen-bound layers (wet or dry process)

Avoided products: Modifiers & fine aggregates

Yearly production in Europe: 3.4 Mt/y

Recycling potential for roads: 17%

Sustainability (examples):

- **Performance**
  - ITS: -14%/+16%
  - ITSR: no effect to +12%
  - RD: -75%/-10%

- **Environmental impact**
  - GWP: -41%/+11%
  - EC: -45%/+14%

- **Economic impact**
  - Agency cost: -47% to +51%

- **Social impact**
  - Road user cost: -8% to no effect
  - Skid resistance: -31%/+52%
Slags

Source: Industrial by-products (industrial by-products)

Application in roads: Full structure

Avoided products: Aggregates

Yearly production in Europe: 21,8 Mt/y

Recycling potential for roads: 100%

Sustainability (examples):

Performance
- ITS: +20%/+30%
- ITSR: +5%/+6%
- Compressive strength: -53% to +10%
- Stiffness modulus: +45%

Environmental impact
- GWP: -26%/+2%
- EC: -9%/-2%
- Acidification: -25% to no effect
- Eutrophication: -17% to no effect

Economic impact
- Agency cost: -25%

Social impact
- Skid resistance: +10%/+67%
- Permeability: -31%/-3%
Wood

Source: Old timber structures (CDW), paper recycling (MW)

Application in roads: Bio-binders and recycling agents (bitumen-bound layers)

Avoided products: Virgin binder and modifiers (recycling agents)

Yearly production in Europe: 32,3 Mt/y

Recycling potential for roads: 3%

Sustainability (examples):

Performance

Fatigue life (LAS): -39%/+1056%  Permanent deformation (MSCR): -49%/+579%  Superpave rutting resistance: +4%/+77%

Environmental impact

Economic impact

Social impact
Question

Would you still focus on the same waste type?

Other examples of used waste types

▪ Reclaimed asphalt shingles (RAS)

▪ Fly ashes

▪ Municipal solid waste incineration (MSWI) bottom ashes

▪ Foundry sand

▪ Recycled steel fibers

▪ Waste cooking and engine oils
Take home messages

- Think about downcycling vs recycling vs upcycling (high quality vs low quality recycling)
- Always consider 4 sustainability pillars for construction materials: economic, environmental, social and durability
- When adding waste materials, adjust your mixture design!
- Asphalt is not trashphalt
  - Roads should not become the new landfilling sites of the 21st century!
  - Always aim for high quality recycling!
References - if you want to find out more


- Lizárraga JM, Ramírez A, Díaz P, Marcobal JR, Gallego J. Short-term performance appraisal of half-warm mix asphalt mixtures containing high (70%) and total RAP contents (100%): From laboratory mix design to its full-scale implementation. Constr Build Mater 2018;170:433–45. https://doi.org/10.1016/j.conbuildmat.2018.03.051.


References - if you want to find out more


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Thank you for your attention

Are there questions?

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