



**A sustainable material consideration –
bicycle tunnels above groundwater level:
in situ concrete vs galvanized corrugated steel sheets**

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SBE

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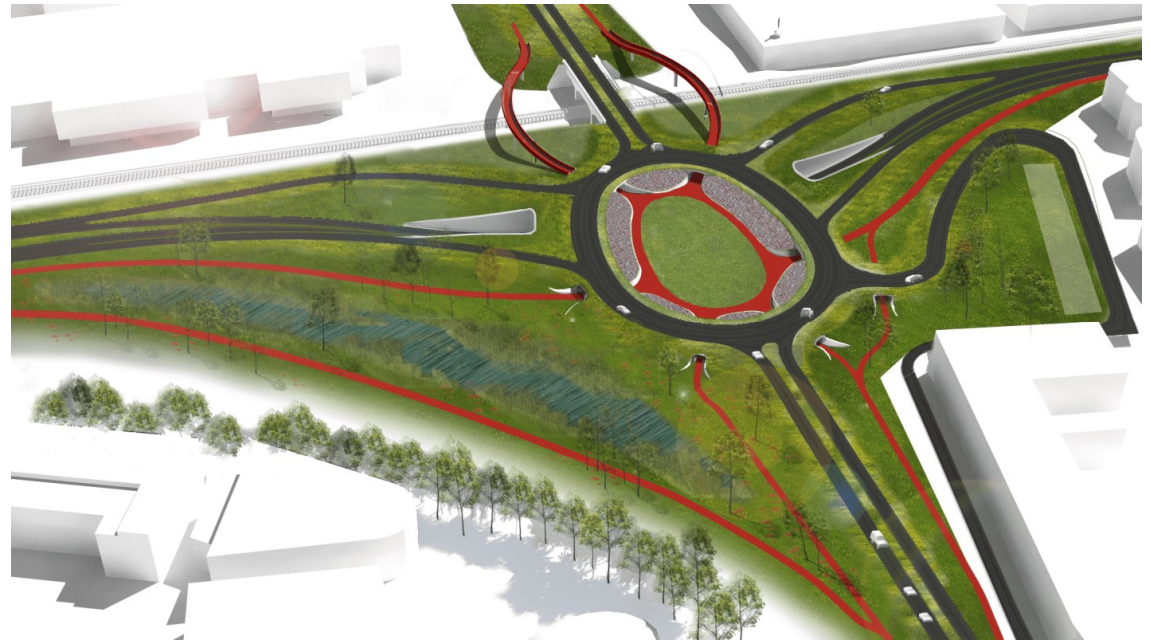
ELECTROMECHANICS



Eastern Tangent Sint-Niklaas – Mercator Junction

7 bicycle tunnels:

- Above groundwater level
- Length 30m (incl. slopes)
- Clearance profile :
3,75m x 2,5m



Trade-off

In situ poured concrete



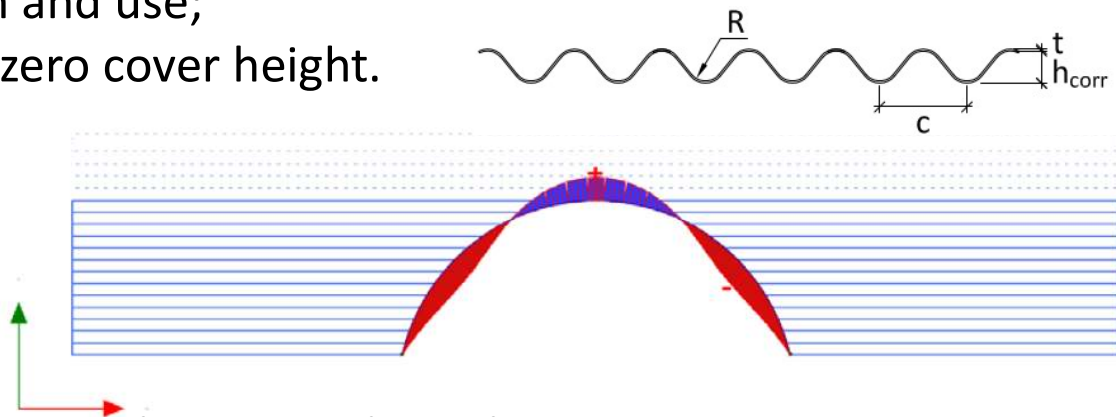
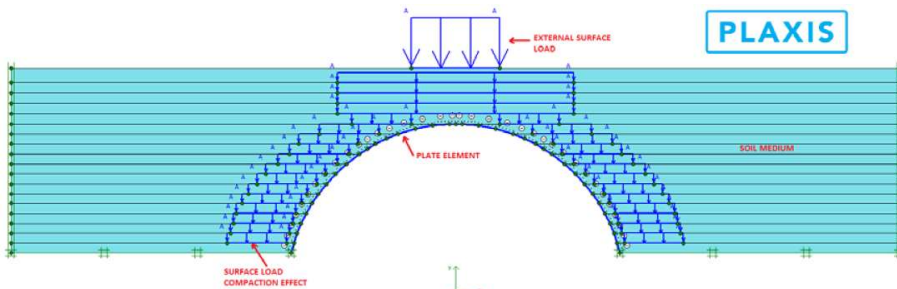
Corrugated steel sheets



About corrugated steel sheets

'Soil Steel Composite Bridges'

- Petterson-Sundquist design method (aka SDM - Swedish Design method)
- FEM-modelling: geotechnical software needed
- Checks:
 - SLS: plastic flow of steel
 - ULS: development of plastic hinge (upper part structure)
 - ULS: capacity lower part
 - ULS: general buckling
 - ULS: capacity bolted joints
 - CON: stiffness during installation and use;
 - CON: control of the structure at zero cover height.



Source: Amer H. H. Wadi - 'Soil Steel Composite Bridges: a comparison between the Petterson-Sundquist design method and the Klöppel & Glock design method including finite element modelling'

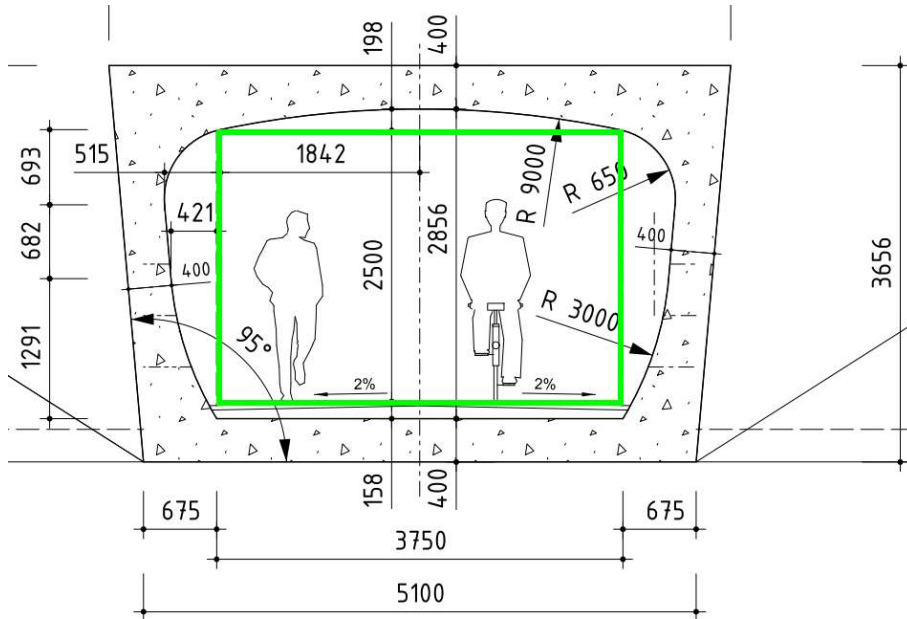
About corrugated steel sheets

'Soil Steel Composite Bridges'

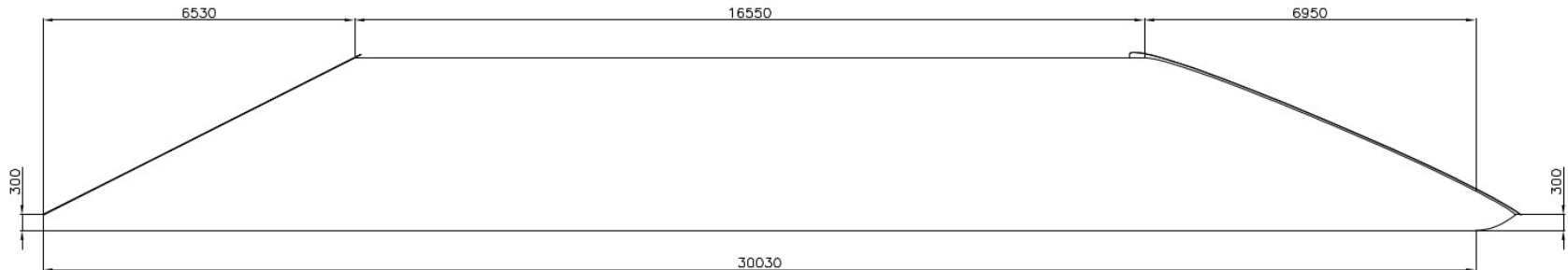
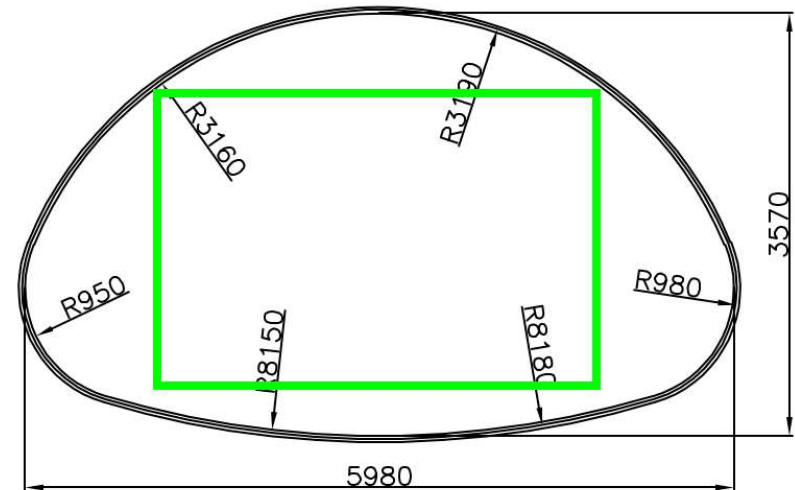
- Advantages:
 - No run-on slab necessary
- Points of attention:
 - Minimal cover required
 - Not watertight



Concrete



Corrugated steel sheets



Trade-off

	Concrete	Corrugated Steel Sheets
Cost	€ 192.840	€ 108.859
Guaranteed lifespan	100 years	100 years
Maintenance	+ In principle, the concrete structure requires no maintenance during its lifetime.	+ The corrugated steel sheet structure is protected by a combination of a zinc layer and coating (duplex system) that would guarantee protection over its lifetime without maintenance. - Given the possible acute failure mechanism, inspection is of higher importance.
Environmental impact	75196 kgCO ₂ eq	42441 kgCO ₂ eq
Benefits beyond life	+ The Concrete structure is demolished and typically reused In an “inferior application” such as roadway substructure.	+ Steel is typically 95% fully recycled.
Adaptability, detachability and reuse potential	- Geotechnical construction: low reuse frequency - Concrete tunnels are not dismountable. - The high weight makes the elements difficult to move and therefore not reusable.	- Geotechnical construction: low reuse frequency + Theoretically, the tunnels can be dismantled and reused in another location + The light weight makes the elements easier to move.
Construction time & complexity	- For a tunnel poured on site, the construction time taking into account the curing of the concrete is estimated to be 3/4 months (excluding soil backfilling and roadway construction).	+ Installation time is typically about 3/4 working days (excluding soil backfilling and roadway construction) + The light weight promotes manoeuvrability and simplifies installation.
Experience with the application	+ Concrete is a well-known material For bicycle tunnels In Belgium. + The national standard specifications can be used.	- Experience with bicycle tunnels made of corrugated sheet steel in Belgium is limited. There is significantly more experience abroad (including the Netherlands).
Failure mechanism	+ Damage to concrete will typically manifest itself in the form of cracking or visible deterioration due to corrosion. Thus, in most cases, failure does not occur acutely.	- If the structure collapses, “acute” failure can occur, resulting in increased risks.
Market availability	+ Number of suppliers is very wide.	- Number of suppliers in Belgium is limited but amounts to at least 2.

Trade-off:

- Financial cost
- Durability & maintenance
- Environmental impact
- Circularity potential
- Construction time
- Experience
- Market availability

Financial cost:

- Concrete:
 - Priced based on MEDIAAN-platform (flemisch government)
 - Run-on slab included (approx. 10% of total price)

- Corrugated steel sheets:
 - Priced based on quotation supplier
 - Conservation included

- Conclusion: Price corrugated steel sheets 40% lower

	Concrete	Corrugated Steel Sheets
Cost	€ 192.840	€ 108.859

Durability:

- Lifespan: 100 years
- Concrete:
 - No conservation necessary (unless anti-graffiti)
- Corrugated steel sheets:
 - Duplex conservation system:
Galvanisation 85 µm (64 year) + epoxy coating 150 µm (14 year)
Duplex factor: $1,3 \times (64+14) = 101$ years
 - Protection against mowing damage
 - No maintenance necessary



	Concrete	Corrugated Steel Sheets
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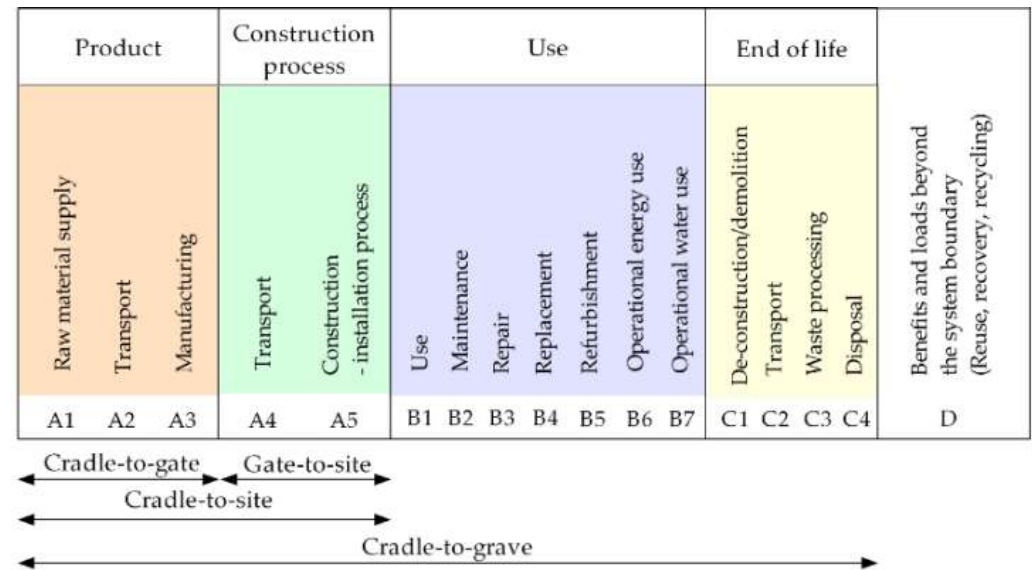
Trade-off

Environmental impact:

- General:
 - Cradle-to-grave (LCA phase A-C)

- Concrete:
 - Cement type: CEM III/A – 40% GGBS
 - Rebars: 97% secondary steel

- Corrugated steel sheets:
 - EPD Supplier
 - 20% secondary steel



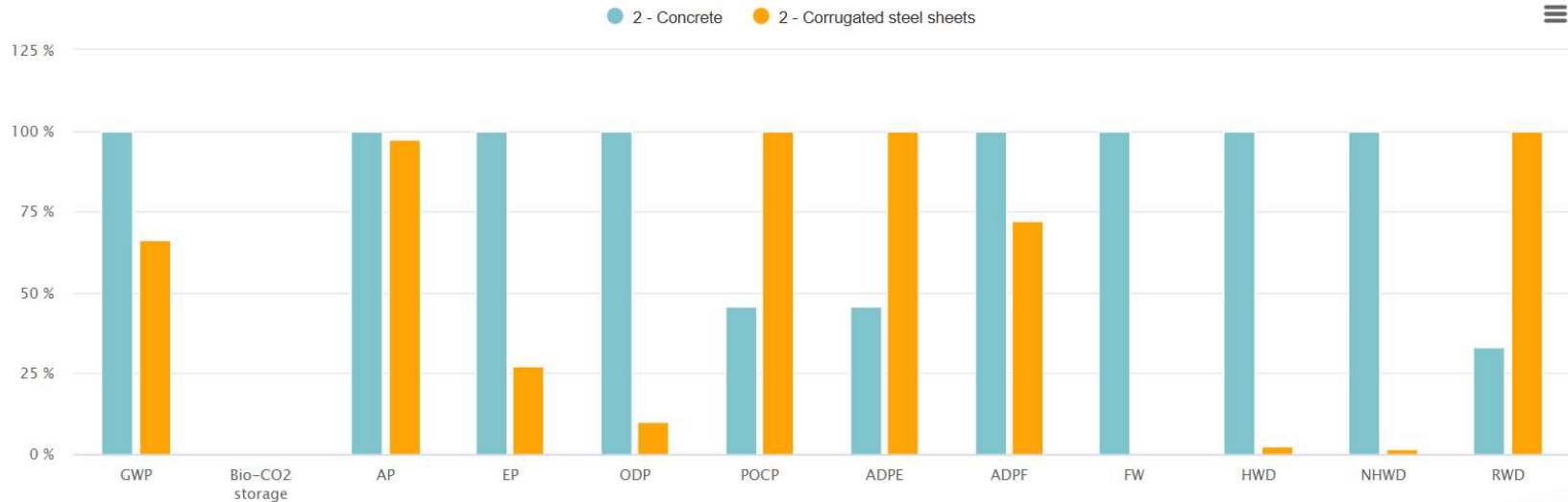
Environmental impact:

- Conclusion:
 - Global Warming potential (GWP) - Corrugated steel sheets 40% lower

	Concrete	Corrugated Steel Sheets
Environmental impact	75196 kgCO2eq	42441 kgCO2eq

- Other impact categories

BREEAM Infrastructure LCA (CEEQUAL) - All impact categories



Benefits beyond life (module D)

	Concrete	Corrugated Steel Sheets
Benefits beyond life	+ The Concrete structure is demolished and typically reused In an “inferior application” such as roadway substructure.	+ Steel is typically 95% fully recycled.

Circularity potential (adaptability, detachability, reuse)

	Concrete	Corrugated Steel Sheets
Adaptability, detachability and reuse potential	<ul style="list-style-type: none"> - Geotechnical construction: low reuse frequency - Concrete tunnels are not dismantable. - The high weight makes the elements difficult to move and therefore not reusable. 	<ul style="list-style-type: none"> - Geotechnical construction: low reuse frequency + Theoretically, the tunnels can be dismantled and reused in another location + The light weight makes the elements easier to move.

Construction time

- Corrugated steel sheets have lower construction time

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Experience

- Concrete:
 - Lot of experience
 - Typical damage:
 - Spalling
 - Reinforcement corrosion
 - Concrete cracks

- Corrugated steel sheets:
 - Limited experience
 - Possibility of corrosion, leading ‘acute’ failure



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Experience with the application	+ Concrete is a well-known material For bicycle tunnels In Belgium. + The national standard specifications can be used.	- Experience with bicycle tunnels made of corrugated sheet steel in Belgium is limited. There is significantly more experience abroad (including the Netherlands).
Failure mechanism	+ Damage to concrete will typically manifest itself in the form of cracking or visible deterioration due to corrosion. Thus, in most cases, failure does not occur acutely.	- If the structure collapses, “acute” failure can occur, resulting in increased risks.

Experience – vision EBS

- Culverts
 - Historical application: ARMCO Culvert in 1960's
 - Some recent problems: soil subsidence but: > predetermined life span?
 - No inspection, no maintenance
 - Sensitivity wind-water line
 - Possibility of 'acute' failure
 - No plans, no calculation notes
 - Conclusion:
 - In general: not desirable for EBS
 - Need for inspection, but inspection often proves to be difficult



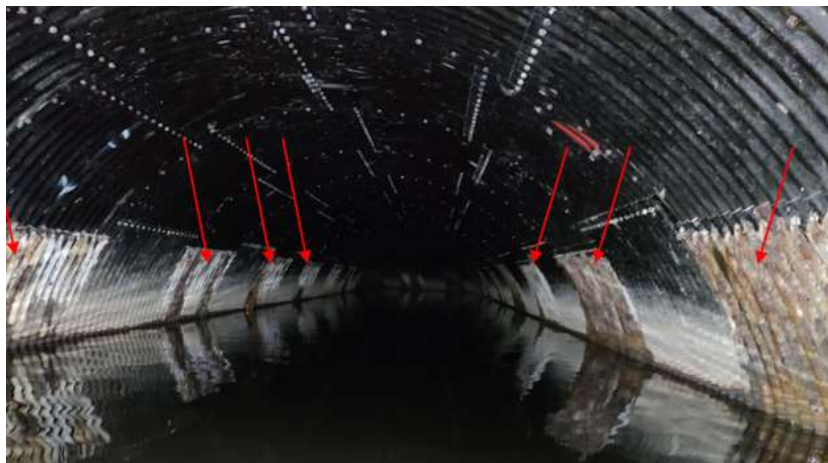
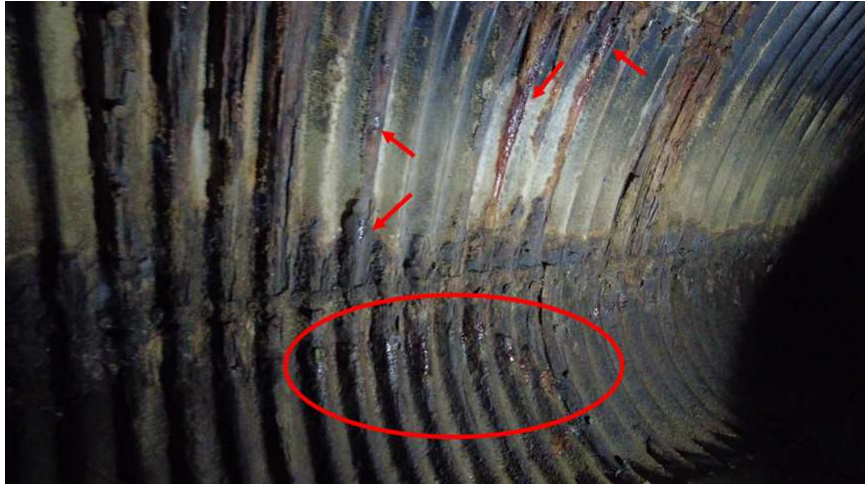
Reaction suppliers

- Good design: stability > lifetime
- Observations would show damage before collapse (redundancy – bolt connections)
- Thickness measurements
- Less risks than concrete variant

Trade-off

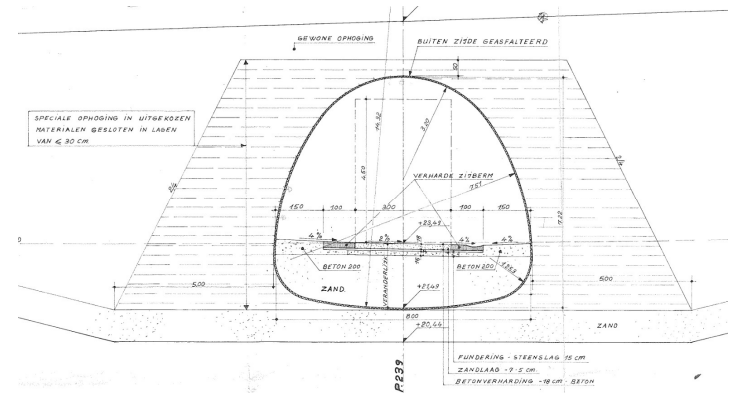
Experience – vision EBS

- Culverts: severe corrosion – scaling – perforation – failure

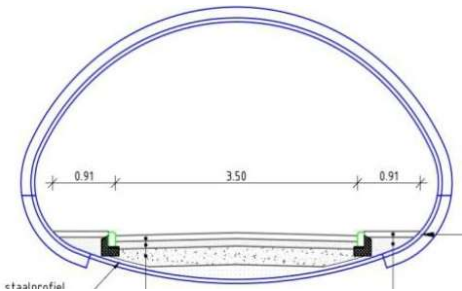


Experience – vision EBS

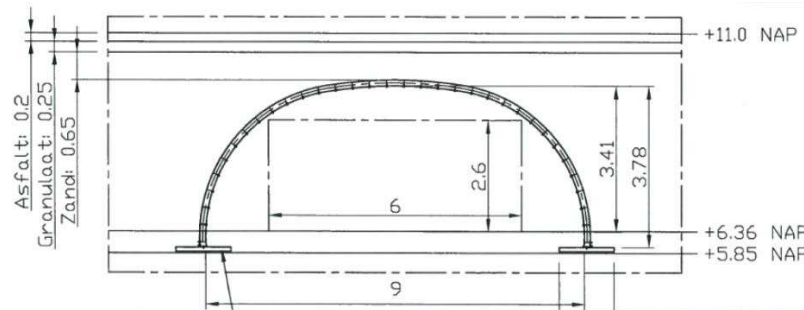
- Bicycle tunnels
 - Number of applications in Belgium is limited
 - Observations are positive
 - Oldest known application BE: 1969 - In good condition
 - Clear preference for ‘closed section’
 - Points of attention: transition zone



Closed variant



Open variant



Trade-off

Experience – vision EBS

- Bicycle tunnels: no (severe) problems



Trade-off

Market availability

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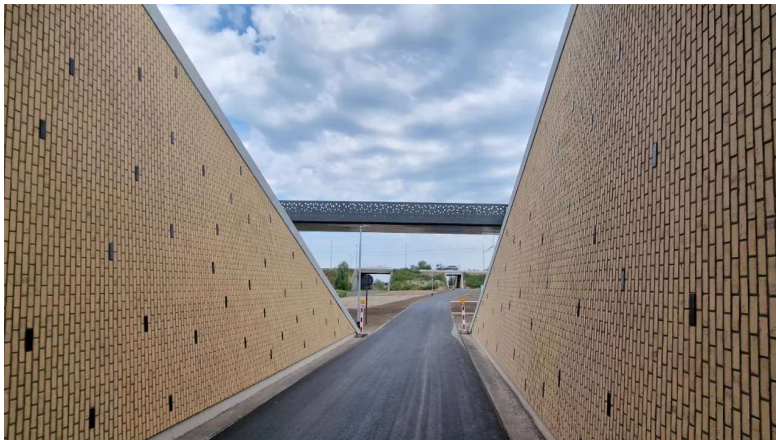
ViaCon – bicycle tunnel Rieme (BE)



Altena – bicycle tunnel Beveren (BE)

Trade-off

Esthetics



Key take-aways

1. Corrugated sheet steel have a considerable number of advantages (although less used)
→ Sustainable alternative for bicycle tunnels above groundwater level
2. Include sustainability in all its facets as an aspect in trade-offs:
 - Durability
 - Environmental impact
 - Circularity potential
3. Materials evolve, so regular update necessary
4. Dare to question what is common practice

Questions



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