

Rinnovare senza consumare

Circular Economy and Sustainability in the Refurbishment of the Manfreida Tunnel

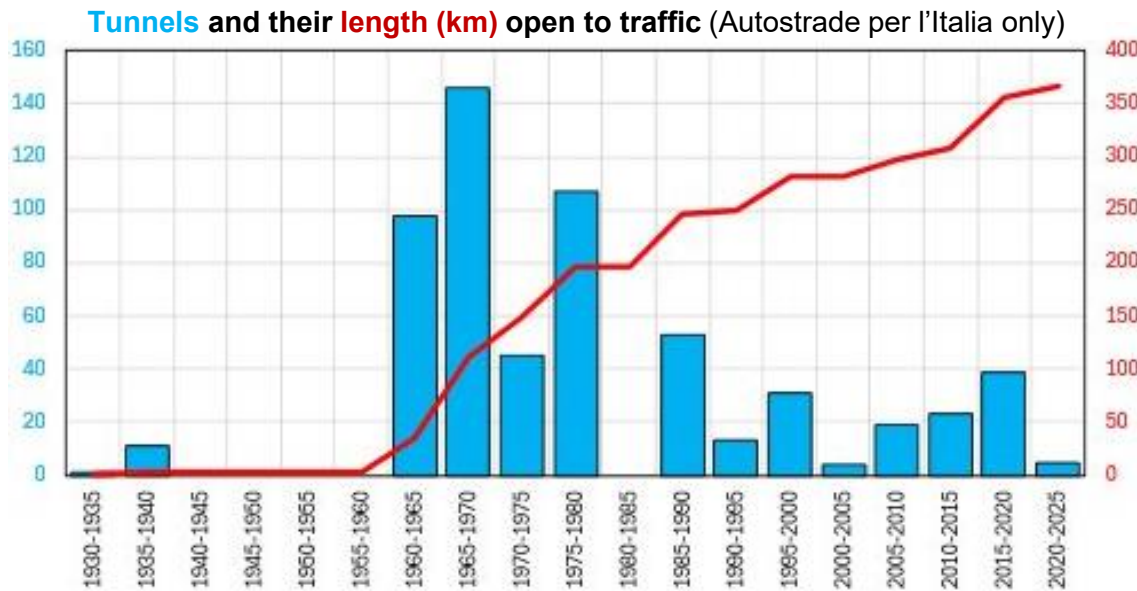
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An extraordinary assessment plan for the refurbishment of Autostrade per l'Italia's existing tunnels

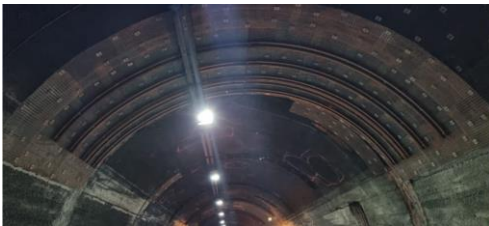
- Significant infrastructural development in Italy between 1960s and 1970s
50% of tunnels were built before 1980s
- Since 2020, Autostrade per l'Italia has embraced an extraordinary tunnel assessment plan, based on the following intervention strategies:
 1. Relining (TRS – Tunnel Renewal Strategy)
 2. Structural reinforcement (IRS)
 3. Extraordinary maintenance (IMS)
- Ensuring the safety and continuous improvement of the asset



Treatment strategies for refurbishing existing tunnels

“Ordinary Maintenance”

These are temporary measures to address defects that could increase the risk of local mechanisms in the short term.



Treatments:

- Steel wire mesh
- Sheeting to prevent water leaking onto the platform
- Steel ribs

IMS – “Extraordinary Maintenance Intervention”

Reduce vulnerability with no impact on structural behaviour.



Treatments:

- Shallow refurbishment using steel net and shotcrete
- Joints drainage installation
- Crack sealing

IRS – “Structural Reinforcement Intervention”

Reduce vulnerability increasing strength.



Treatments:

- Permanent bolts
- Deep refurbishment using a steel net and shotcrete + drainage
- Invert reinforcement

TRS – “Tunnel Renewal Strategy”

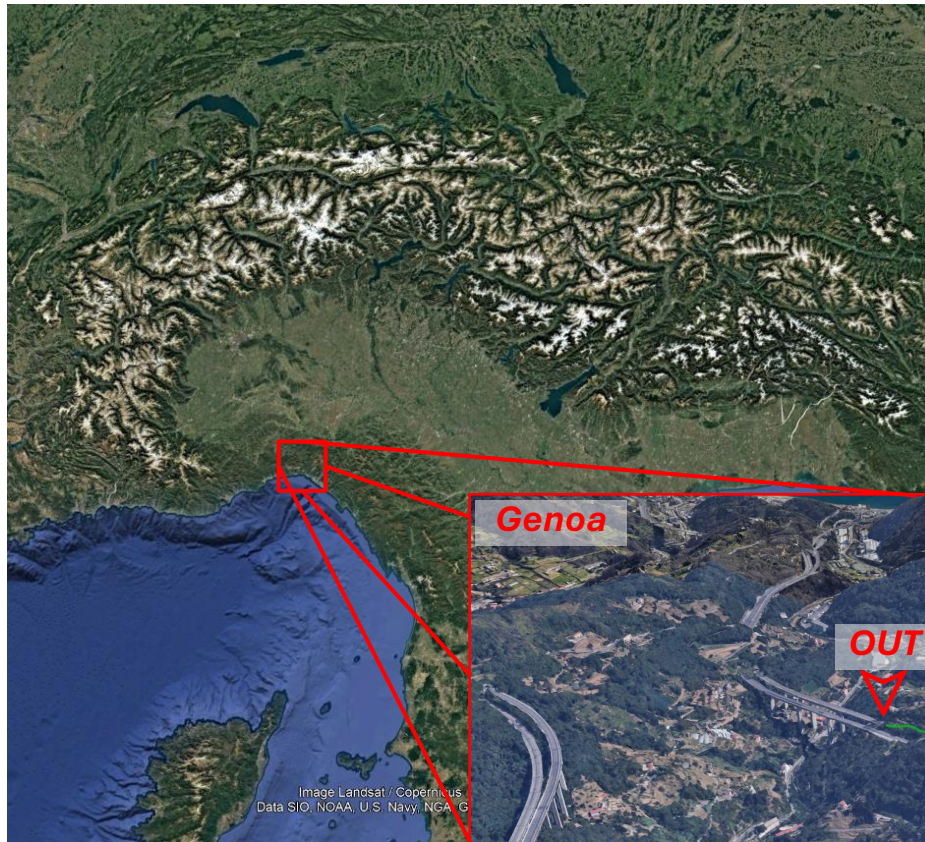
Relining and restoration of the useful life



Relining by:

- Cast in place concrete
- High performance shotcrete
- Pre-cast elements + backfilling
- Liner plates

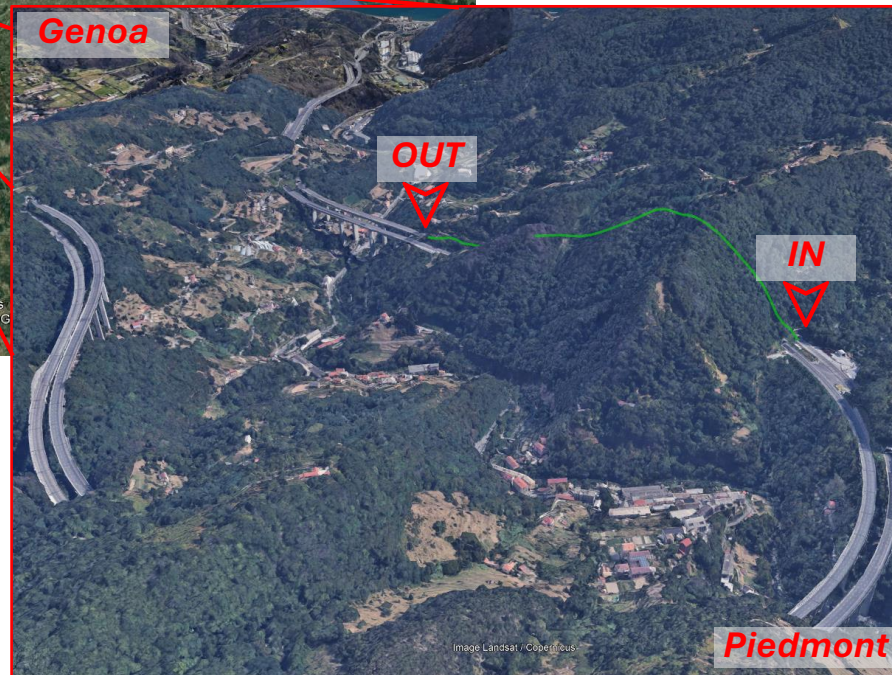
Context of the Manfreida Left Tunnel



Location: A26 Genoa-Gravellona Toce motorway – Liguria Region – Genoa.

Geometry: Monocentric twin tunnel, 787 m long and 15.5 m wide.

Material: Plain concrete (exception made for inlet/outlet where reinforced concrete was adopted). Invert is present for the entire length. Concrete strength (before renovation) < 20 MPa.

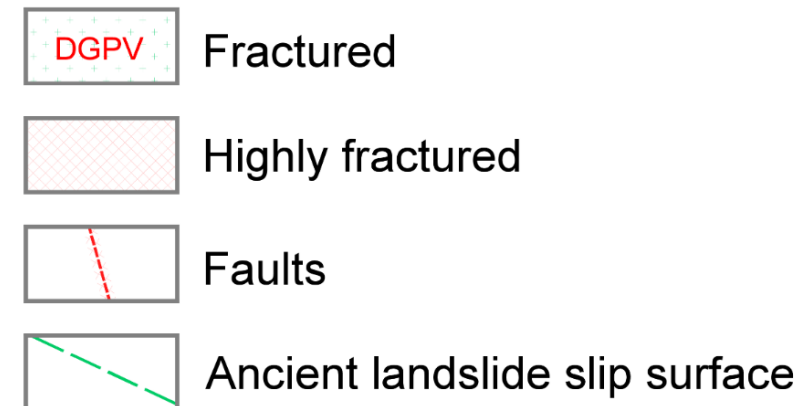
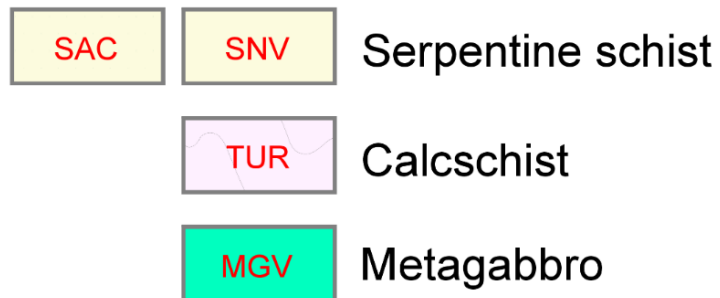
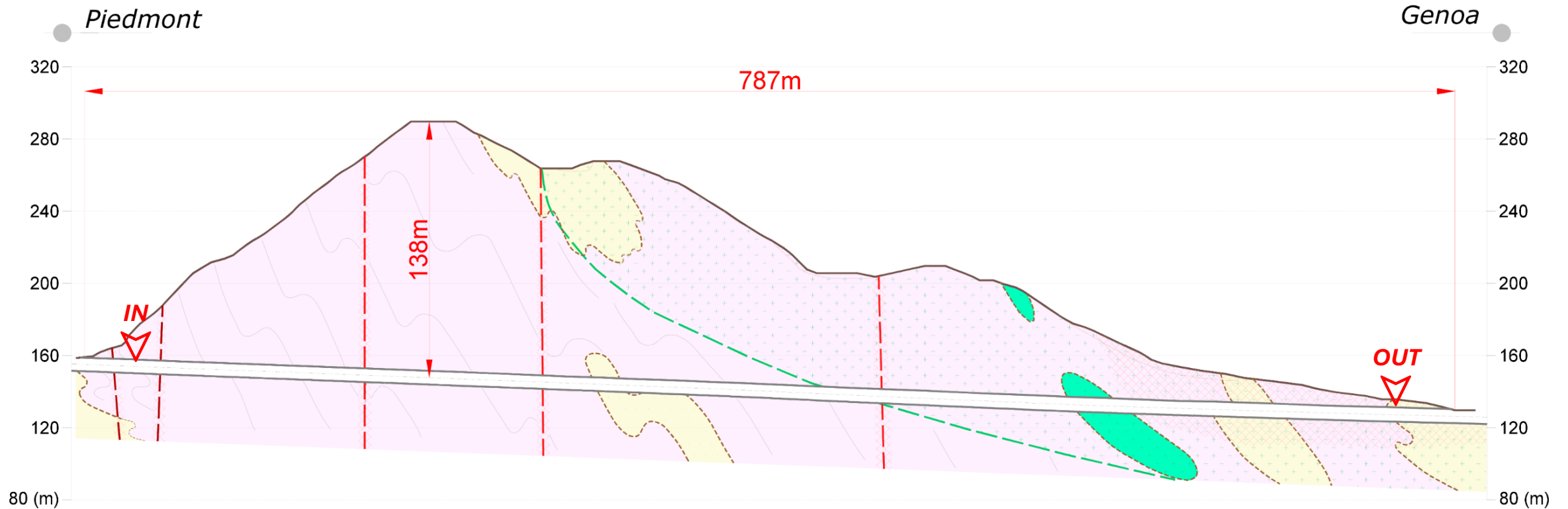


Construction year: 1976 (in operation since 1977).

Traffic: about 22'000 vehicles per day, 25% of which are heavy goods vehicles.

Conditions: A notable deficiency in the lining's thickness at the crown was observed. The results of the flat jack tests showed that the stress in the liner was not solely dependent on the weight of the lining.

Context of the Manfreida Left Tunnel



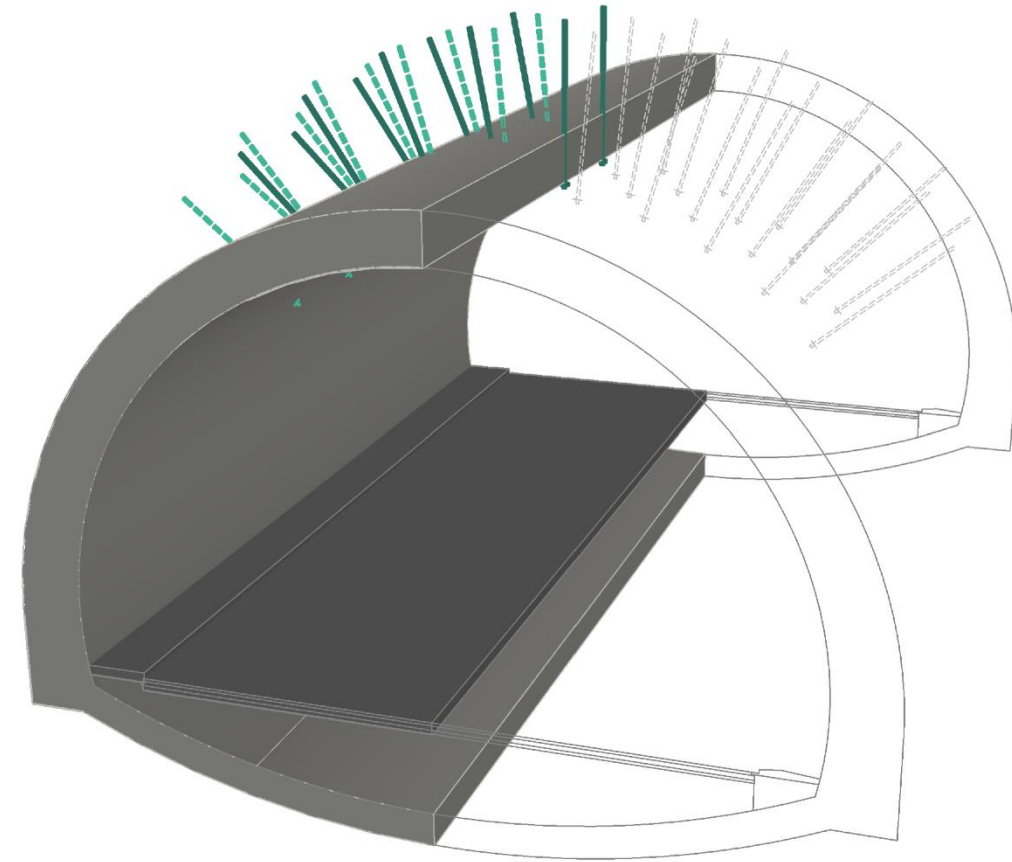
The Technical Solution – Preliminary Activities

The existing lining was thoroughly inspected and tested to evaluate its condition and determine the most suitable refurbishment strategy.

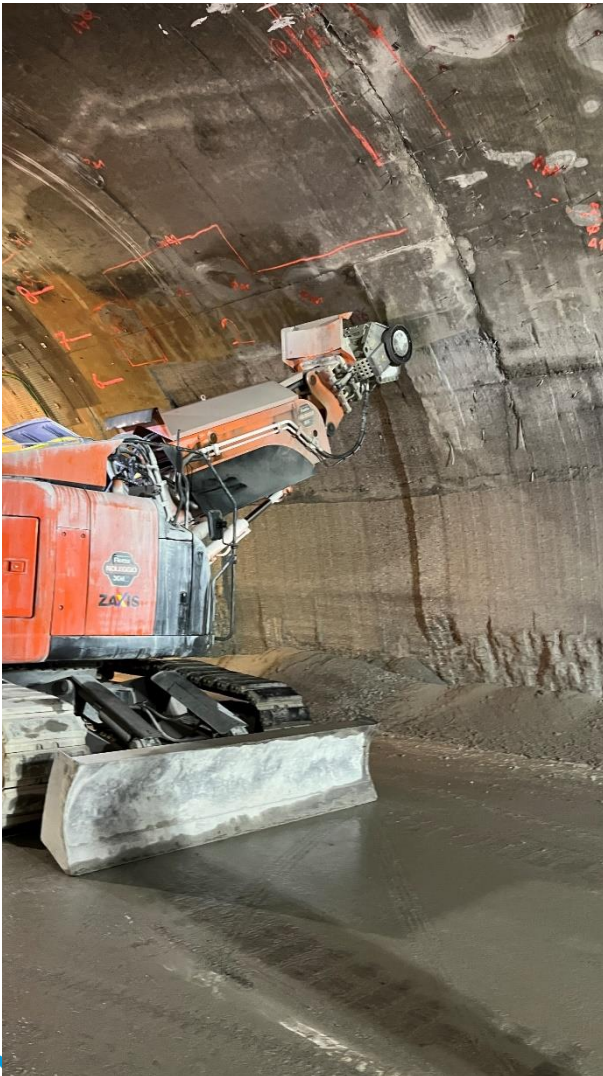
The 90 cm thick original liner was deteriorated mainly due to the lack of a waterproofing system and to the poor construction technologies adopted at that time. The concrete casting technologies used at the time of construction unquestionably resulted in the creation of several hidden cavities in the tunnel lining.

The design of the solution was based on the consolidation of the voids by means of nailing and grouting, in order to safely proceed with the refurbishment and relining of the tunnel in the subsequent phases.

- **GFRP grouted bolts ($D \geq 90$ mm, $L = 4.0$ m)**
- **Voids grouting (compressive strength ≥ 18 MPa, weight = 1100 kg/m³)**



The Technical Solution – Existing Lining Demolishing

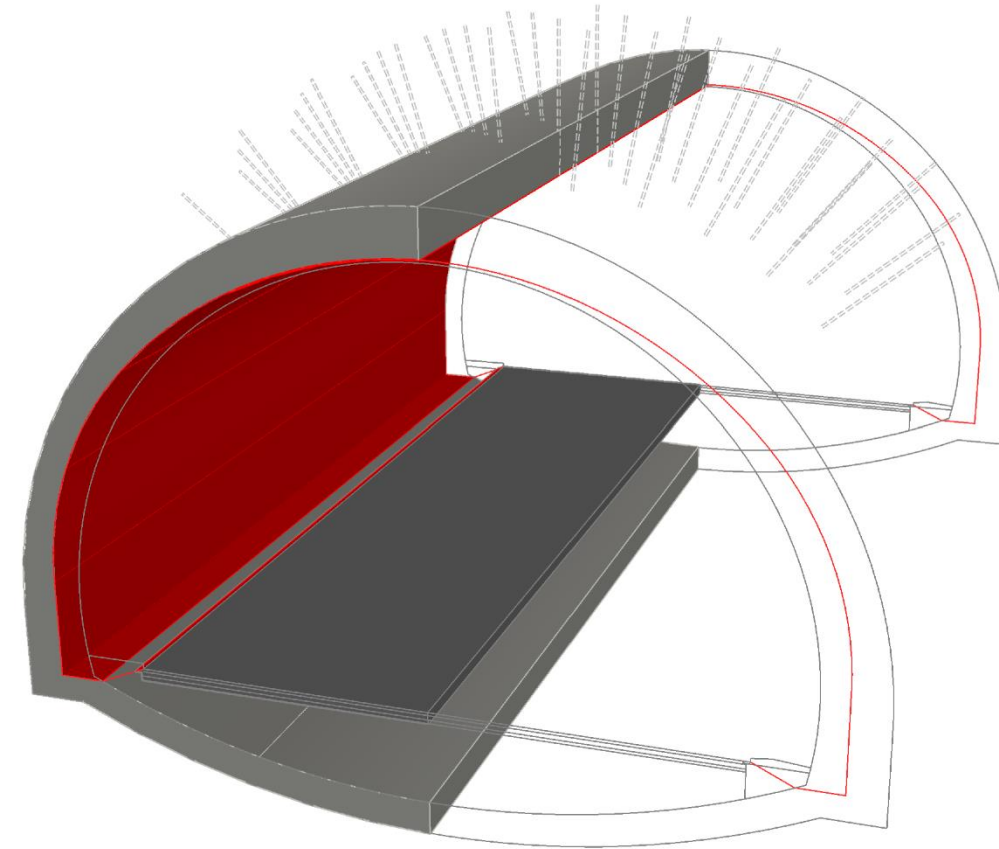


Milling and hydro milling were used as appropriate, depending on whether the original lining was reinforced or not.

The polycentric milling shape was designed to minimise demolition at the crown and maximise it at the sidewalls.

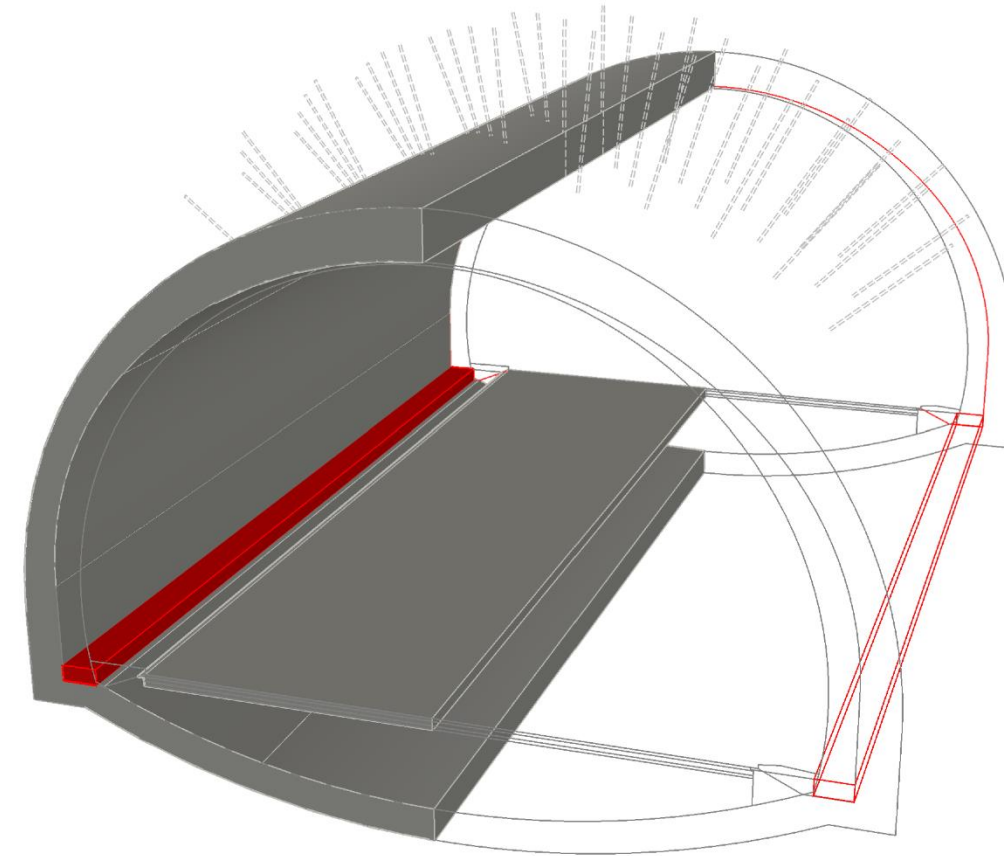
This system provides the highest level of operational safety, ensuring the necessary clearance for vehicles in lateral lanes.

- ***Min milling depth 5 cm at crown***
- ***Max milling depth 65 cm at sidewalls***
- ***7 m³/m of demolition waste***



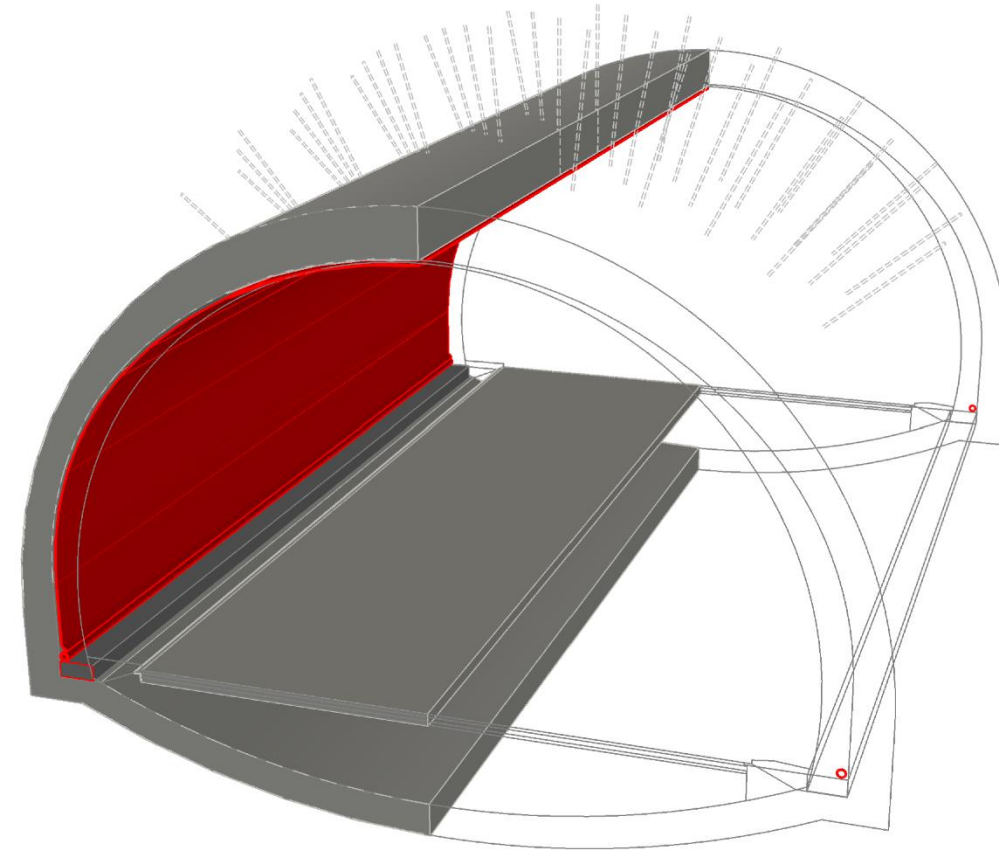
The Technical Solution – Side Beams Installation

The supporting beams were designed on both sides with anchors to provide a proper foundation and connection for the new reinforced lining.



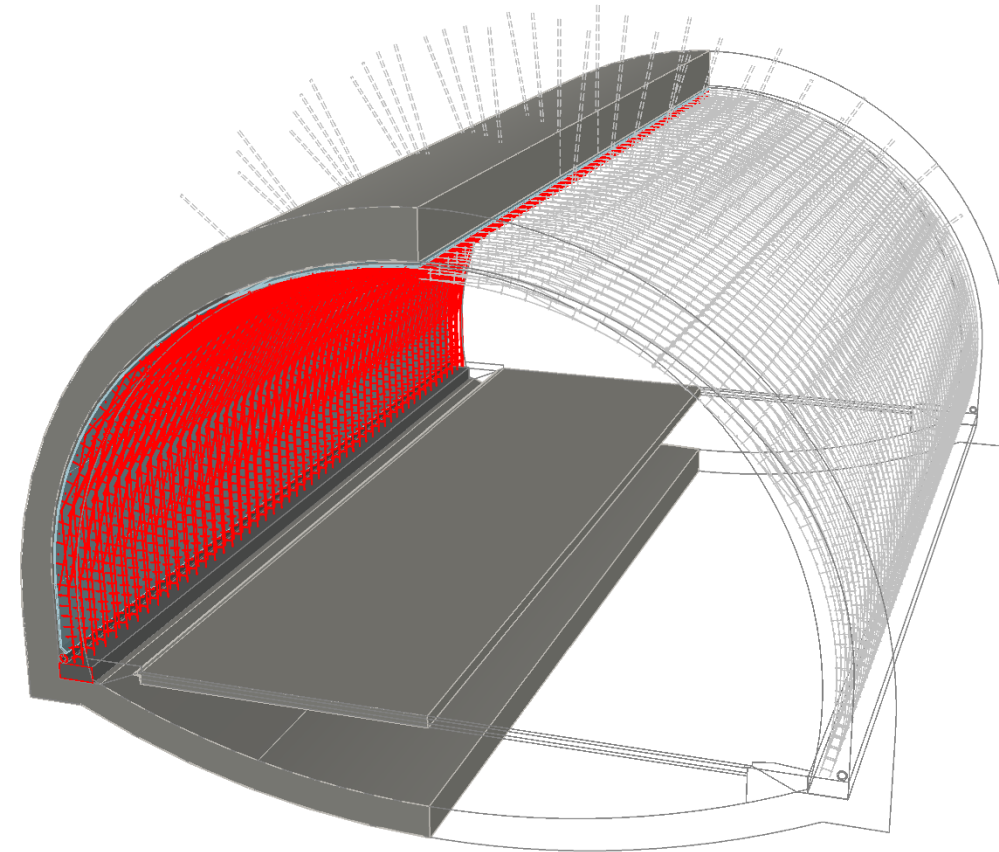
The Technical Solution – Waterproofing

The innovative waterproofing system is made of three preassembled layers and installed on the existing lining by velcro strips.



The Technical Solution – Reinforcement Installation

The cages were designed to be delivered on site in three preassembled modules with proper bolted joints and few additional rebars to be installed.



The Technical Solution – Sprayed Concrete Relining

The decision was made to re-line with high-performance sprayed concrete due to its unparalleled flexibility from both a geometrical and operational standpoint.

The tunnel's unique shape made it clear that any other alternative relining solution, such as precast segments or cast-in-place concrete, would have been impractical.



Concrete strength:

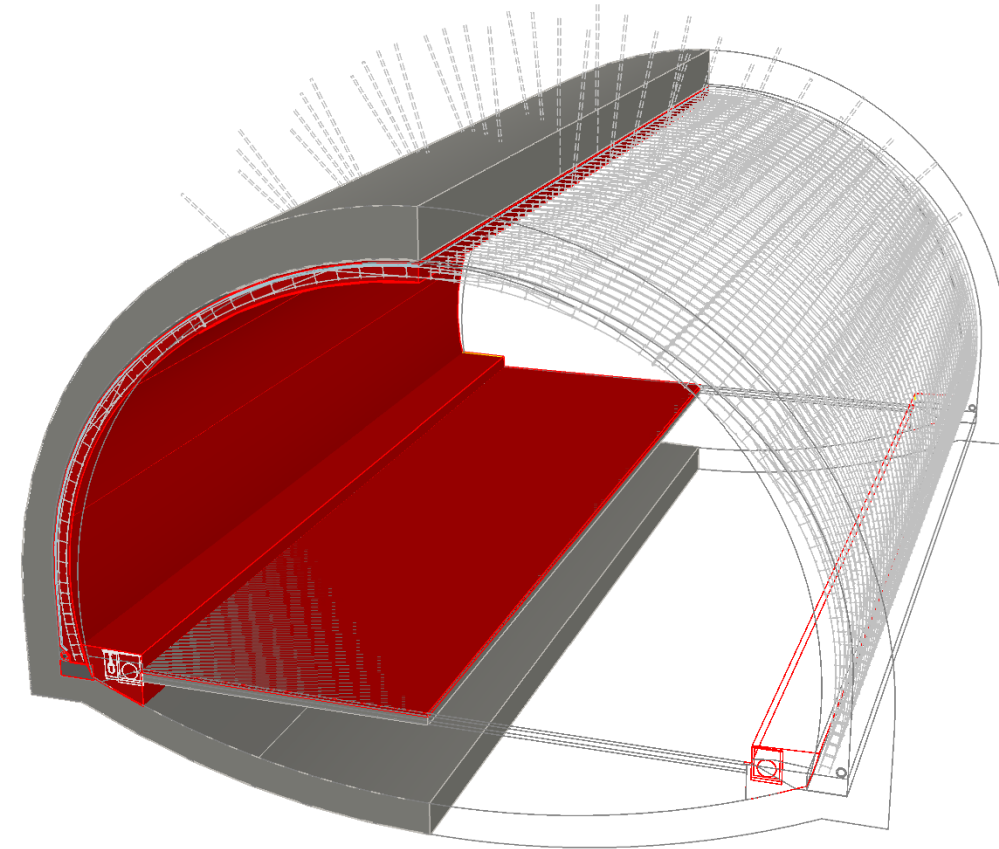
≥10 MPa after 24 h

≥20 MPa after 48 h

≥30 MPa after 7 days

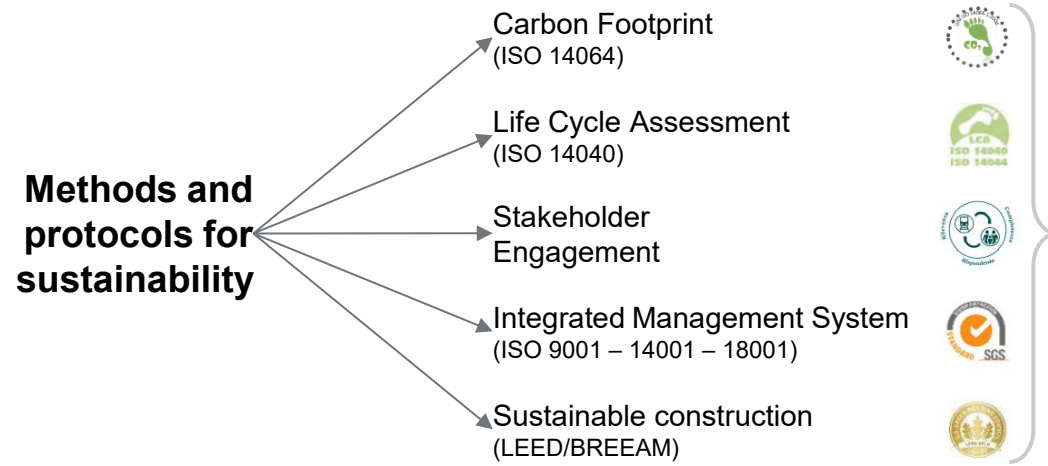
≥40 MPa after 28 days

C35/45 after 90 days

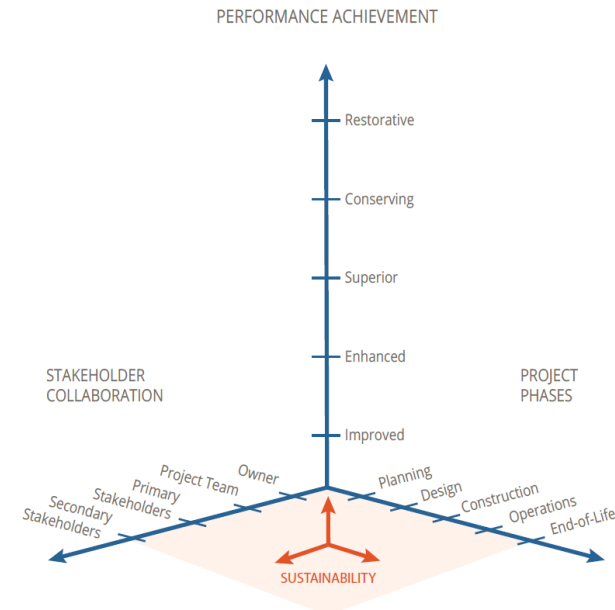
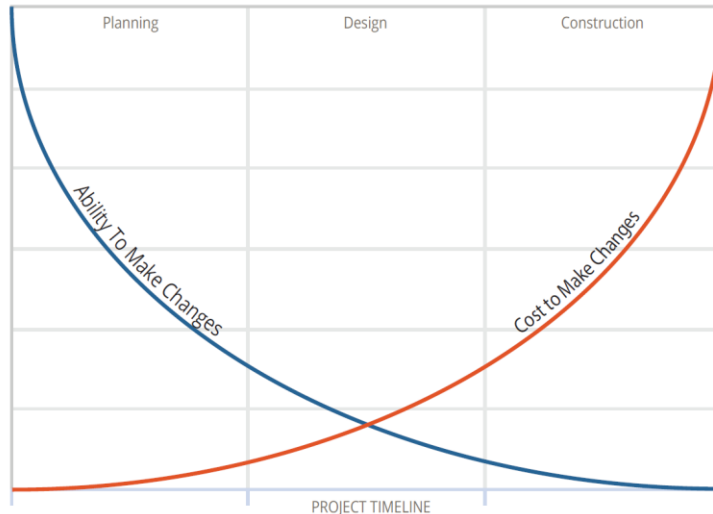


Measuring infrastructure sustainability

Why ENVISION?



Sustainability in any phase of the project



Infrastructure and Sustainability – Envision

Sustainability and life cycle approach



ENERGY

- Geothermal
- Hydroelectric
- Nuclear
- Coal
- Natural gas
- Oil
- Wind
- Solar
- Biomass



WATER

- Drinking water distribution
- Collection and storage
- Reuse
- Rainwater treatment
- Flood control



WASTE

- Solid waste
- Recycling
- Hazardous waste
- Collection and management



TRANSPORT

- Airports
- Roads
- Motorways
- Sustainable mobility
- Railways
- Public transport
- Ports
- Canals



LANDSCAPE

- Public realm
- Parks
- Ecosystem services



INFORMATION

- Telecommunications
- Internet
- Satellites
- Data centers
- Monitoring stations



Highways
20-50
years



Bridges
30-75
years



Pipelines
50-100
years



Dams
50-100
years

Envision Protocol

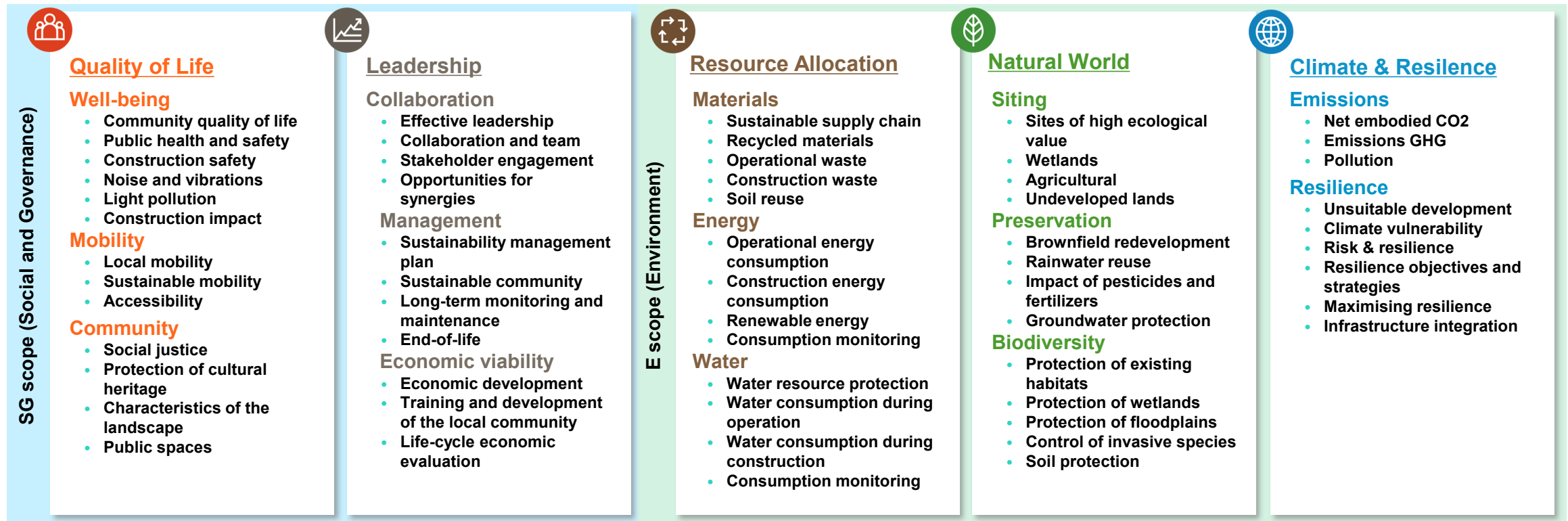
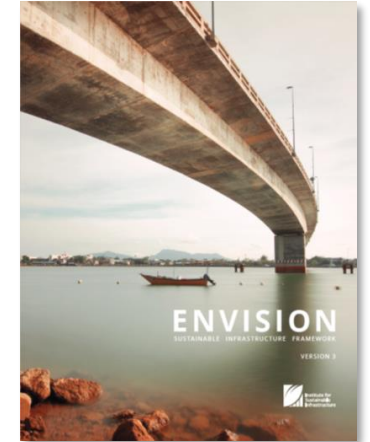
Framework, categories and credits



ENVISION

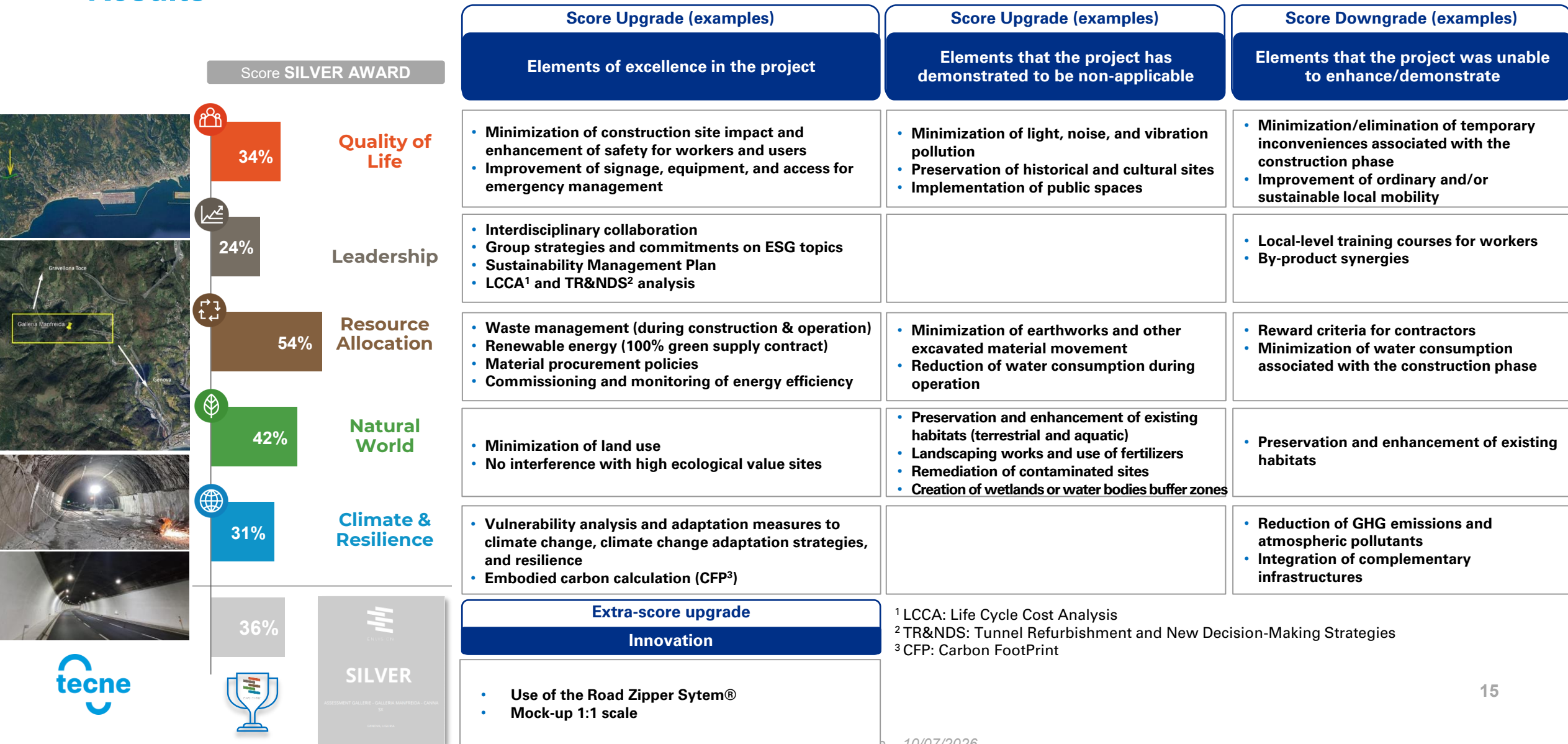
Envision is an independent assessment tool that provides practical support to businesses, designers, public administrations and citizens in infrastructure design, in terms of investment effectiveness, respect for the ecosystem, climate and environmental risk, functional durability, leadership and improvement of quality of life.

The framework is consisting of 64 credits organized under five key categories:



ENVISION certification of Manfreida Left Tunnel

Results



Road Zipper – the project's traffic management system

Tested for the first time in Liguria as part of the Manfreida Tunnel rehabilitation project, this technology helps to manage the impact of a construction site on users. Barriers are quickly moved, creating a dynamic working area and an optimal number of lanes for separated two-way traffic. The aim is to avoid disruption, reduce duration of works inside the tunnel and increase safety for both workers and users.



This advanced technology made it possible to swap a central physical barrier separating the two-way motorway with a special machine that works continuously using a system of conveyors belts (without stopping the traffic flow).

The barrier is made of modular “new jersey” elements. The machine follows the direction of traffic and changes the number of lanes in real time according to traffic demand minimizing the users’ time lost when passing through the site area.



Are we still throwing sustainability away?

THE SCALE

787 m

of tunnel length

7,000+ m³

of demolished lining

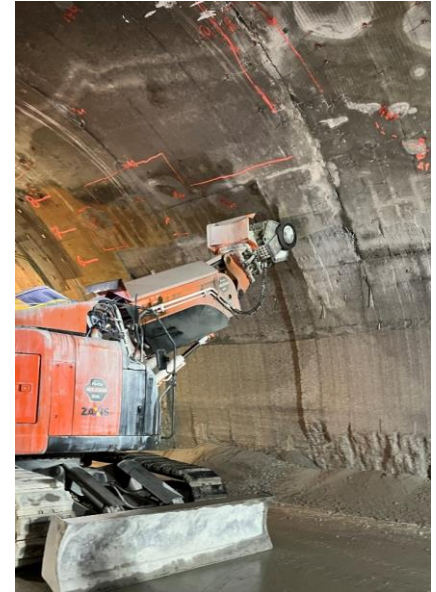
The technology to recover these materials already exists.

The question is no longer:

“Can we reuse them?”

but:

“Why do we still treat them as waste?”



Concrete-based resource

A material mainly made of concrete that, in many cases, could be used as:

- road sub-bases
- embankments
- recycled aggregates
- backfilling and geotechnical works

Barriers in Italian practice

The bottleneck is execution and incentives:

- **Fragmented actors & timing:** hard to align owners, worksites and recovery campaigns.
- **Unclear second cycle:** reuse rules and checks are not yet harmonized.
- **Variable permits:** regional timelines require early, design-stage planning.
- **Weak price signal:** price lists can make quarry vs. recovered supply and disposal vs. recovery economically equivalent.

THANKS FOR YOUR ATTENTION

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