



# Tunnelling Asia' 2023

International Conference on  
Climate Change Resilience and Sustainability  
in Tunnelling and Underground Space



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## Sustainability of Underground Works – Thoughts from a Designer

by

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## Overview

- Introduction and Concept of Sustainability
- Concept Phase
- Investigation and Design Phase
- Tendering Phase
- Execution Phase



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## Introduction

- Construction cost for Underground works is high, so underground works are perceived as costly
- Economic sustainability is defined by IRR on the “investment”
- Things which are not always taken into account
  - Land use – this resource is becoming scarcer over time
  - Carbon footprint – a concept which is gathering momentum



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## Introduction – 2

- Opportunities to work on the sustainability of a project can be allocated to all phases of the project
- Clarity on the final performance requirements including maintainability is required
- Identification and quantification of risks, ideally / mandatorily with the monetary consequences



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## Concept Phase

- Owner and his Consultant are the major players
- Basic performance requirements are defined here
- Conflict between quickly implementable and possible long-term benefits (and ecological benefits)
- System decisions
- Risk assessment



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## Concept Example – 1

- Alignment Options
  1. Bridge – tunnel alignment (tunnel length restricted)
  2. Longer tunnel alignments, eliminating some bridges
  3. Following the terrain, reducing tunnelling to a minimum
- Benefits and risks for options 1. / 2. / 3. in terms of cost, maintainability, vulnerability and ecological impact



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## Concept Example – 2

- Tunnel Options – one long tunnel or several “shorter” ones
  - Construction time (assuming the long tunnel has no adit)
  - Operational cost – e.g. ventilation does not increase in a linear manner
  - Cost of other structures (bridges)
  - Land use of portals and bridge abutments



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## Concept Phase - thoughts

- Go for the fresh (rock)
  - The closer to the surface, the higher the weathering
  - Minimum overburden might not be the only way to go
- Less disturbance = less efforts
  - Slope cutting – disturbance on the whole length, support required
  - Tunnel – disturbance restricted to the portals and the initial drive





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## Design Phase

- After the basic parameters and boundary conditions are defined, the first investigations start
- With the general design and implementation approach, also basic materials choices are made
- Here the Owner can impact by specifying / allowing new approaches and technologies



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## Opportunity examples – Design phase

- Steel fibre reinforced concrete
  - Durability benefits
  - Reduction of overall steel quantity (more than 50% in segmental lining)
  - Simplification of the construction process (caveat – “balling”)
- Unreinforced concrete (PCC)
  - Shape optimization to have primarily compressive loading



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## Opportunity examples – Design phase

- Single shell and composite linings
  - Sprayed liners, no formwork required
  - Reduction of overall thickness and material use
  - Avoidance of “fill” concrete due to larger excavation (optimized material use)
  - Caveats: primary support also subject to full durability requirements, bonding between layers, waterproofing system



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### Impact of overbreak – traditional liners

- Assumption is the overt quantity from springline upwards
- The average overbreak is the average depth of overbreak
- Opportunity to reduce “waste”

Description	Quantity	Unit		Notes
Inner dia	12	[m]		
Inner Lining Thickness	300	[mm]		
<b>Avg Overbreak</b>	<b>250</b>	<b>[mm]</b>		
Primary Support	250	[mm]		
Theor Excavation Dia	13.1	[m]		
with overbreak	13.6	[m]		Probability applied
<b>Inner Lining [Volume]</b>			<b>Excess</b>	
theoretical	11.6	[m3/rm]	0.0%	
with overbreak	21.7	[m3/rm]	<b>87.1%</b>	Risk



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## Tendering Phase – 1

- Tendering conditions
  - Reduce / eliminate unintended incentives for waste
  - Define clear rules for alternative material acceptance and approval
- Evaluation of execution plans
  - Use of existing infrastructure (wear and tear)
  - Disruption of existing infrastructure and its avoidance



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## Tendering Phase – 2

- Financial Recognition of sustainable practices
  - Positive recognition of practices which are resource-efficient
  - A mechanism similar to the Geological Baseline Report is thinkable, with an impact baseline in terms of vehicular movements (material transport and use), public road network use, etc. – also for subcontractors
  - An incentive to “safe” quantities as a counterweight to perceived “losses” due to lesser quantities, especially in item rate contracts



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## Execution Phase

- Detailed / execution design – opportunities
  - Clear objectives for Designer and Checkers (LDC, GC, etc.)
  - Avoidance of quantity increases through non-codified practices or codal interpretations (Note – no compromise on safety)
- Implementation planning
  - Short and well-planned “drastic” solutions or dragging compromises?
  - Optimization of construction sequences and their material requirement



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## Quality Control / Assurance

- Objectives like durability and structural safety to be reached
- Example grouted rock bolts – if not done properly, a piece of steel
- The treatment of the material “ground” in underground works – the less damage the excavation technology inflicts on the remaining material, the lesser material is required to support
- Sprayed Concrete – rebound (= waste)





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