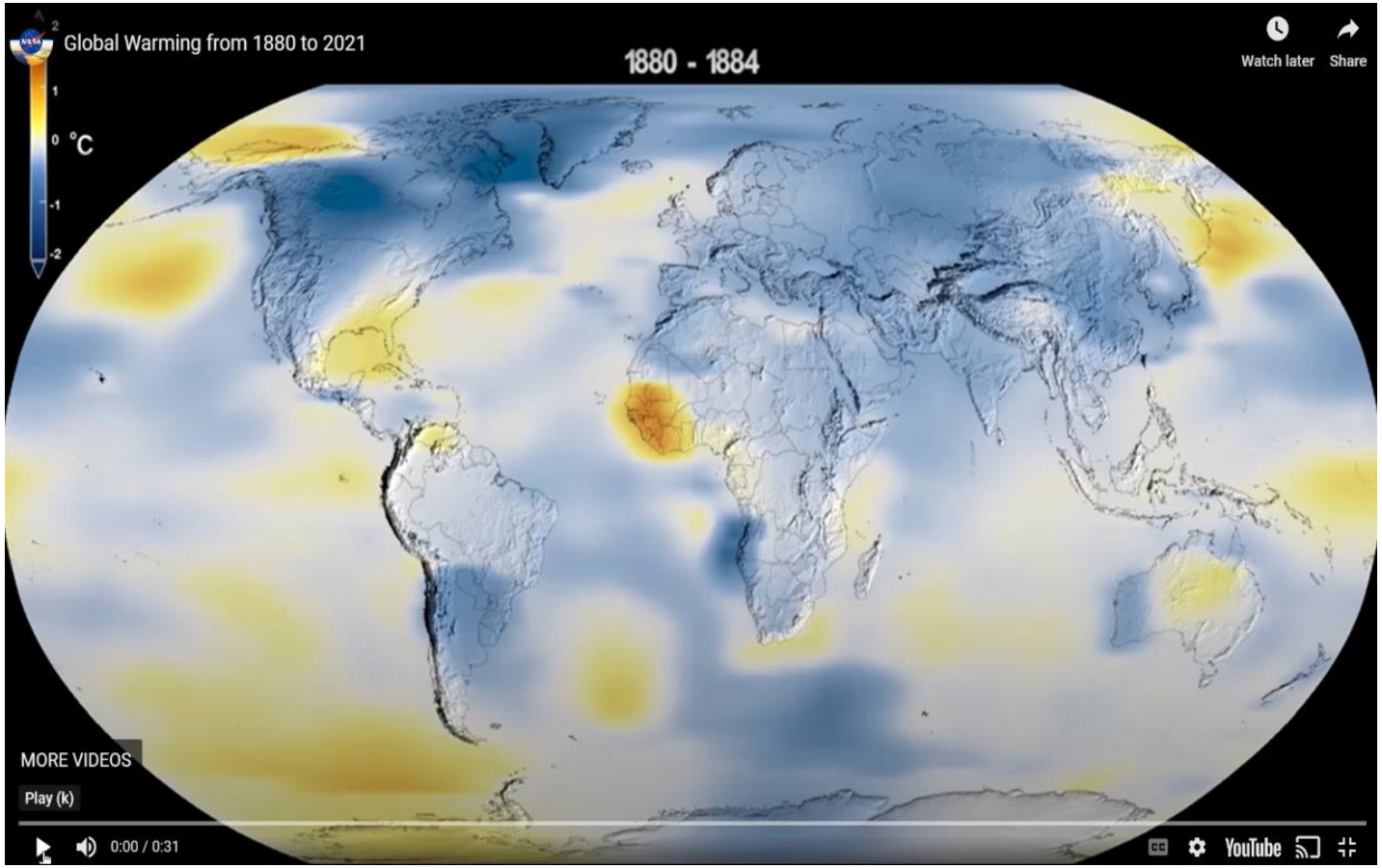
SUSTAINABLE SPRAYED CONCRETE TUNNELLING - A SUPPLIERS VIEW

Ross Dimmock

VP Tunnelling – Normet Group

“THE ERA OF GLOBAL BOILING IS HERE!”

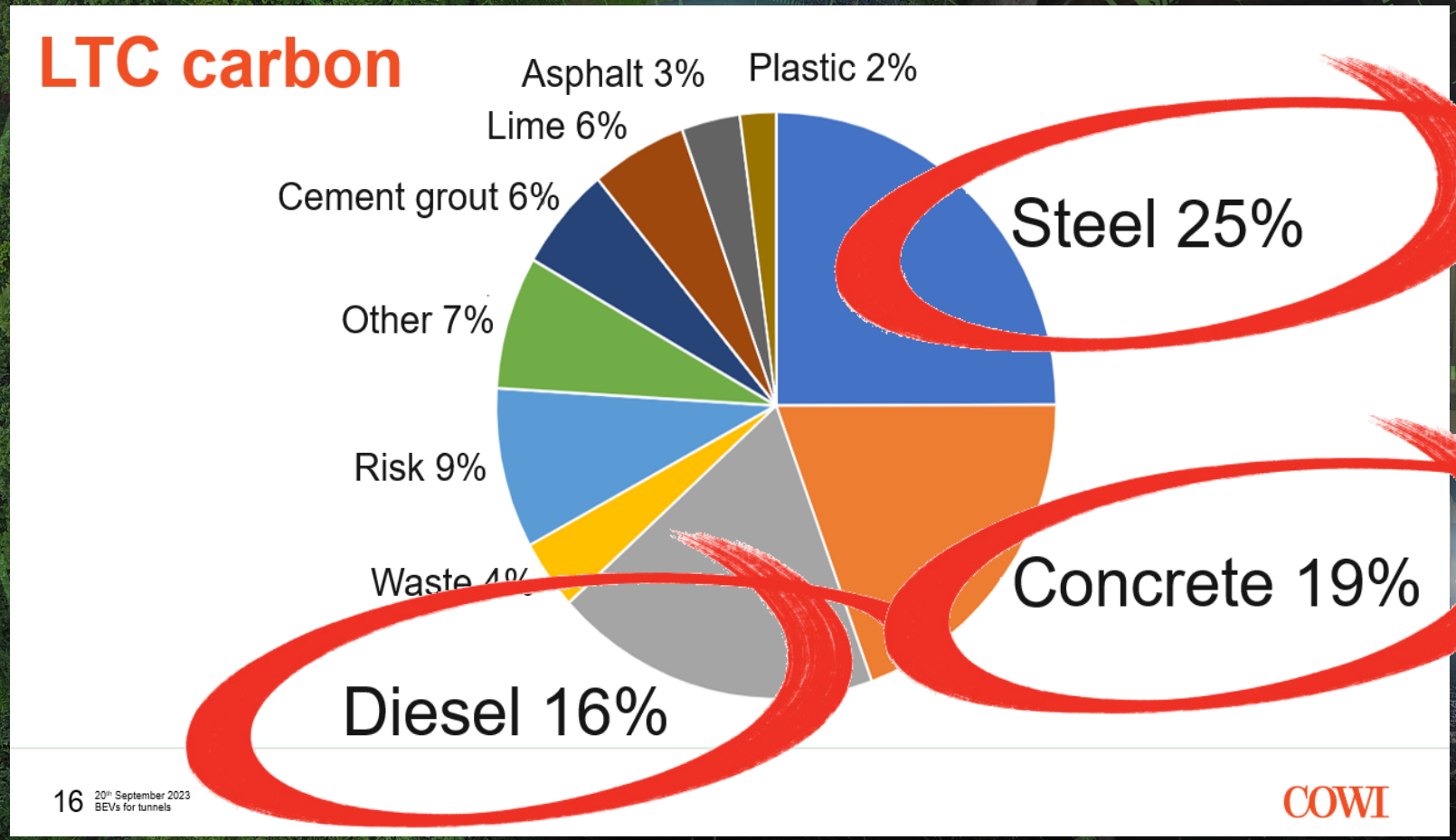
July 2023 - The United Nations Secretary General, António Guterres



WHO CAN IMPACT OUR TUNNEL BUILD?

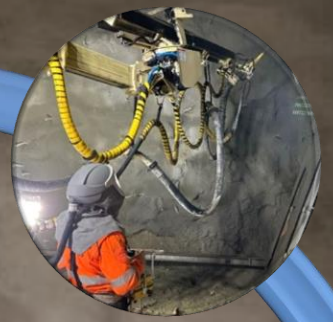
- United Nations
- Government
- Scheme Operators
- Designers
- Contractors
- Technology Suppliers

So, how can our industry keep global temperature rises under control?



Courtesy of Dr Keith Bowers, SubSpace Energy Hub Roundtable Event, Switzerland 2023

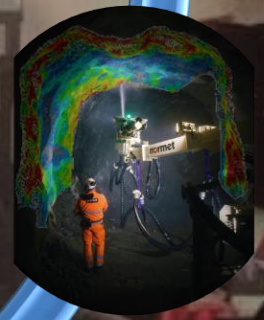
A HOLISTIC APPROACH



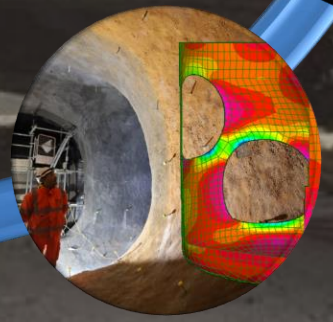
Lower carbon lining materials

Zero emission construction equipment

Sustainable Sprayed Concrete Tunnelling



Implementing digitalisation



New design approaches

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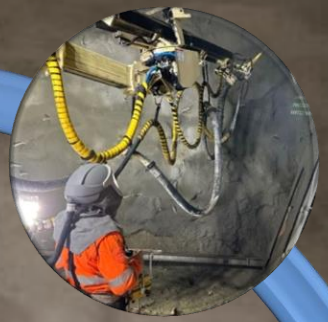

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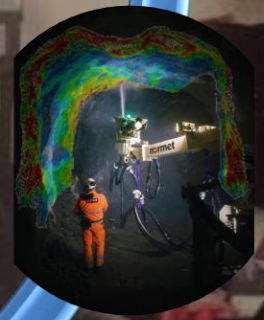

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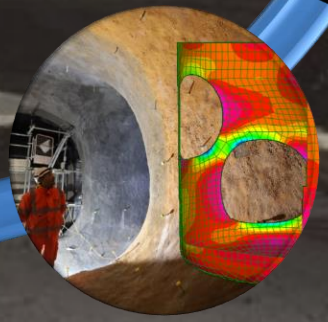

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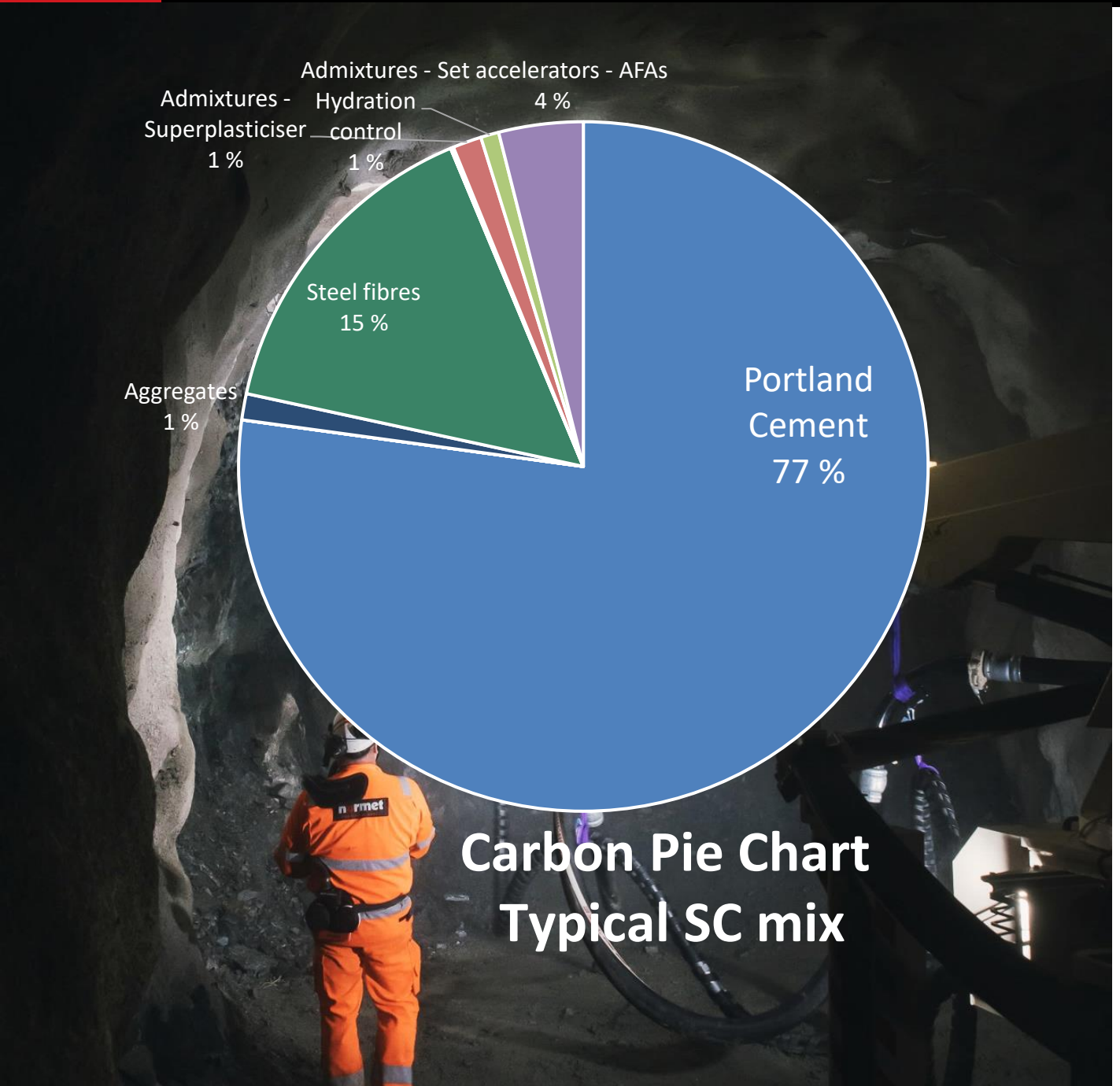
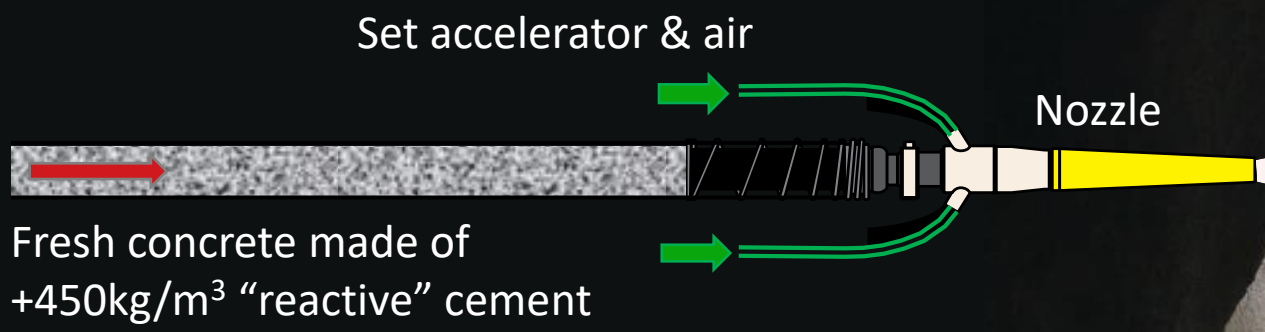


THE SPRAYED CONCRETE PROCESS IS QUITE CARBON RICH!

- High amounts of Portland Cement
- Steel girders, mesh, bolts
- Over excavation
- Over spraying
- Rebound
- Dumping of un-used or out of specification concrete
- Construction tolerances add up
- Diesel powered construction equipment
- Temporary support elements

YOU NEED RAPID ROCK SUPPORT

CEMENT AND CHEMICAL ACCELERATOR
THIS IS WHERE THE MAGIC HAPPENS !



Immediate impact
on **safety!**

Whatever cement/binder we use in the concrete, it must react quickly to be safe for the tunnel team and the structural concrete!

REPLACING CEMENT IN SPRAYED CONCRETE TUNNELLING

Types	Cement products
CEM I	OPC – Portland cement
CEM II	Portland & slag
	Portland & silica fume
	Portland & pozzolana
	Portland & fly ash
	Portland & burnt shale
	Portland & limestone
	Portland & all above
CEM III	Blast furnace slag & Portland
CEM IV	Pozzolanic cement
CEM V	Composite cement

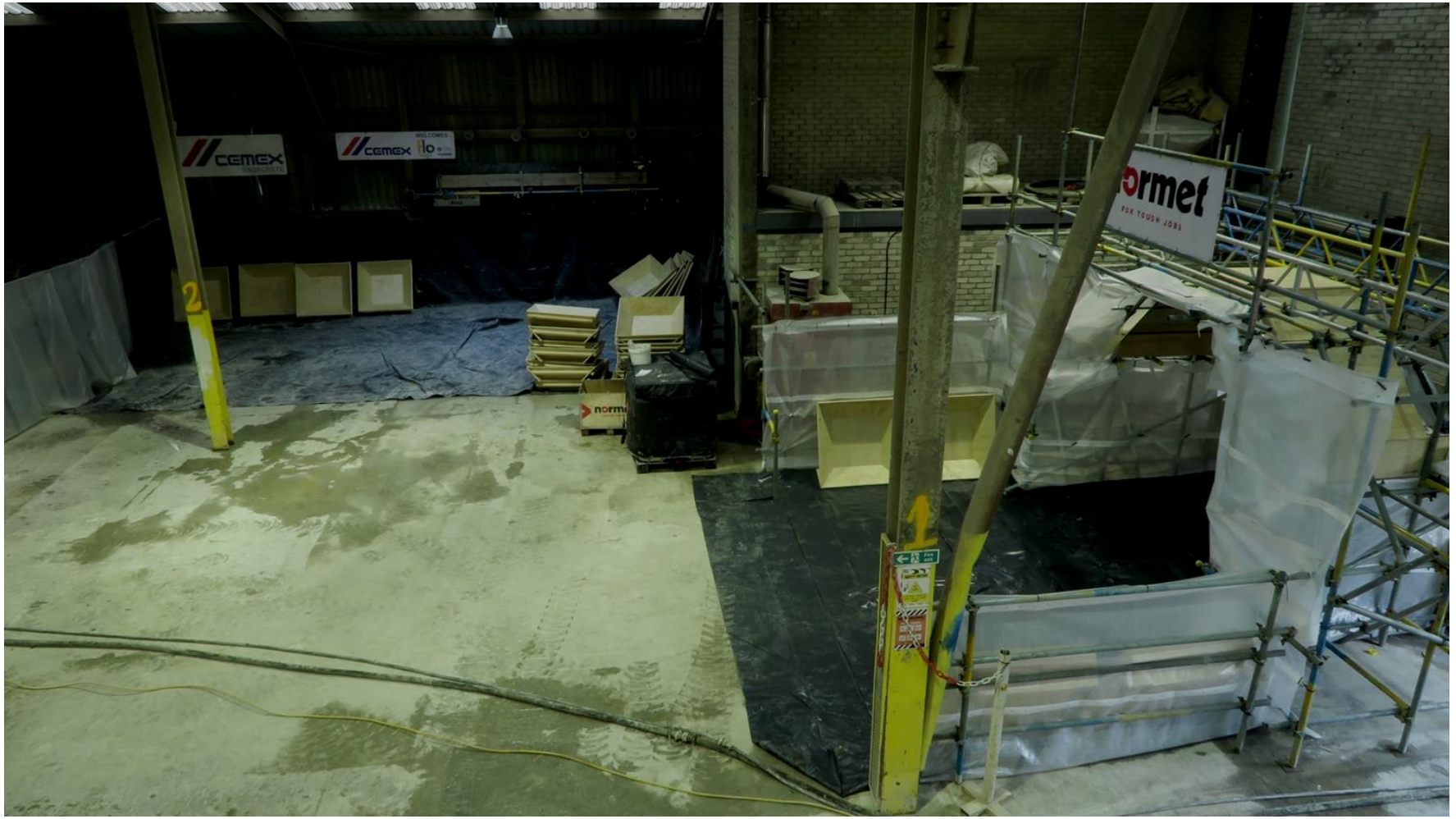
Best spraying performer

Generally speaking, more challenging to attain early strength

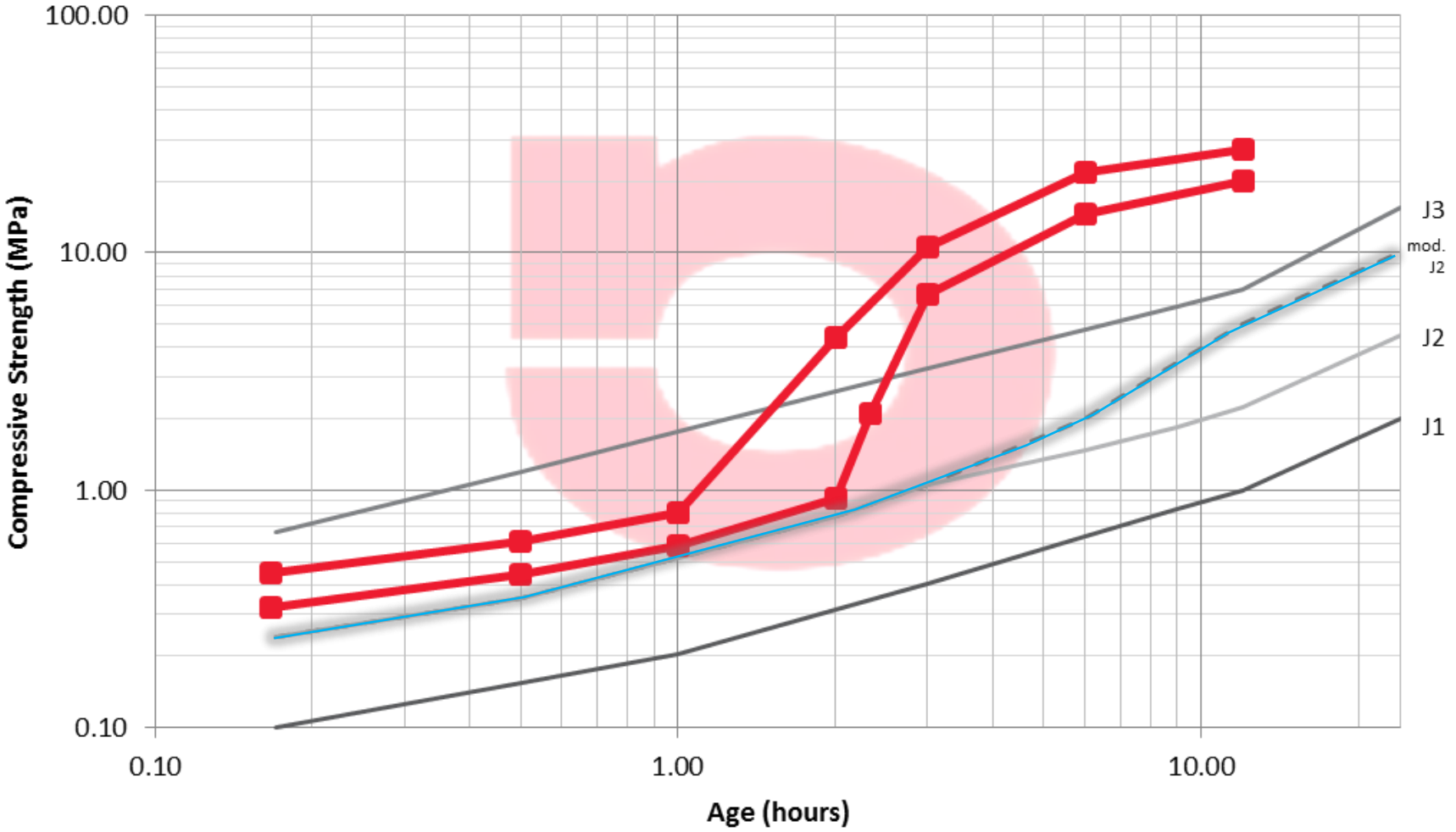
“ Eco cements”

Cement classification to EN197-1

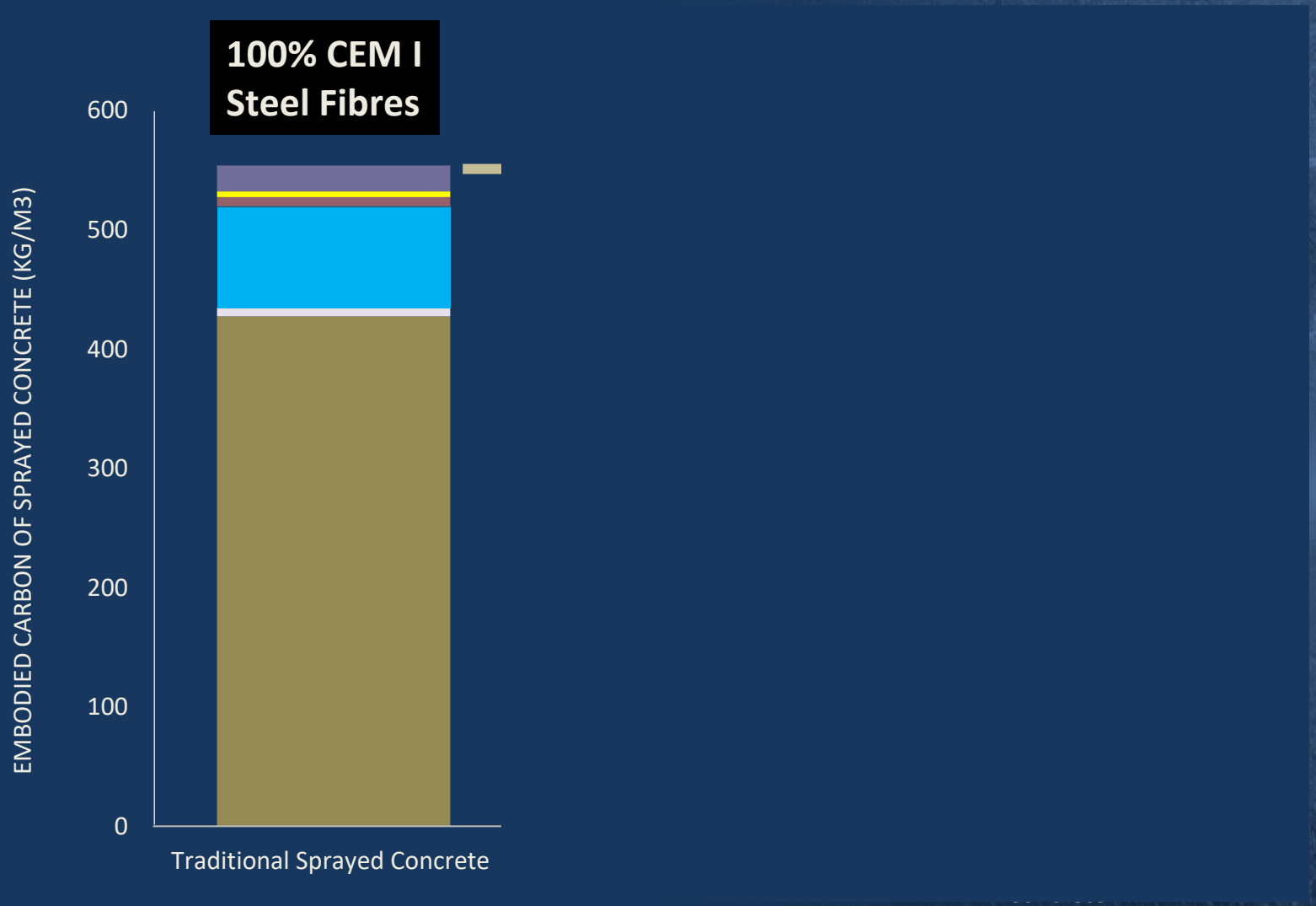
LOW RISK APPROACH - SCALING UP FROM LAB TO SPRAY TRIALS TO TUNNEL USE



SPRAYED CONCRETE EARLY AGE STRENGTH IS KEY



Low and Ultra Low Carbon Sprayed Concrete Mixes

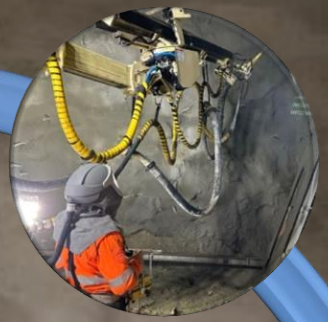


LAB TOOLS TO FAST-TRACK DEVELOPMENT OF NEW SPRAYING TECHNOLOGIES

- Labmec - Mini Lab Sprayer
- No need to test spray at sites
- 20-30 test sprays per day!

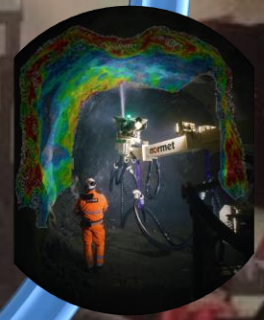
A HOLISTIC APPROACH

Sustainable Sprayed Concrete Tunnelling



Lower carbon lining materials

Zero emission construction equipment



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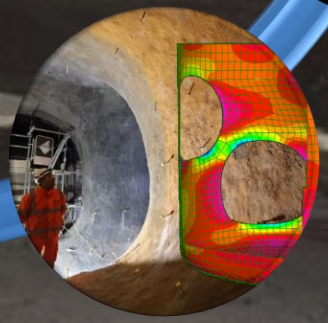
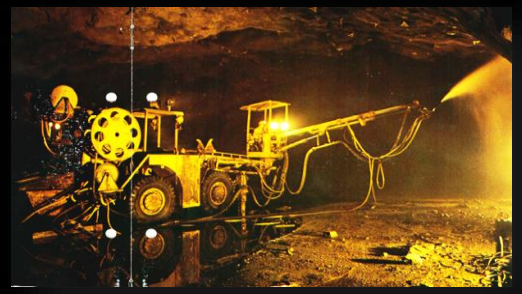
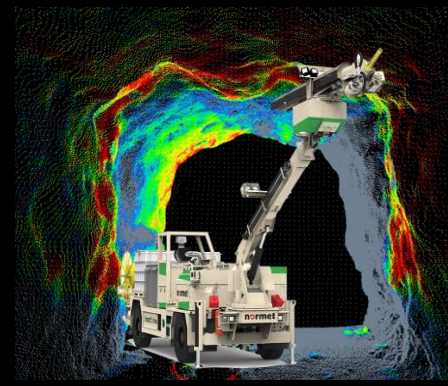


New design approaches

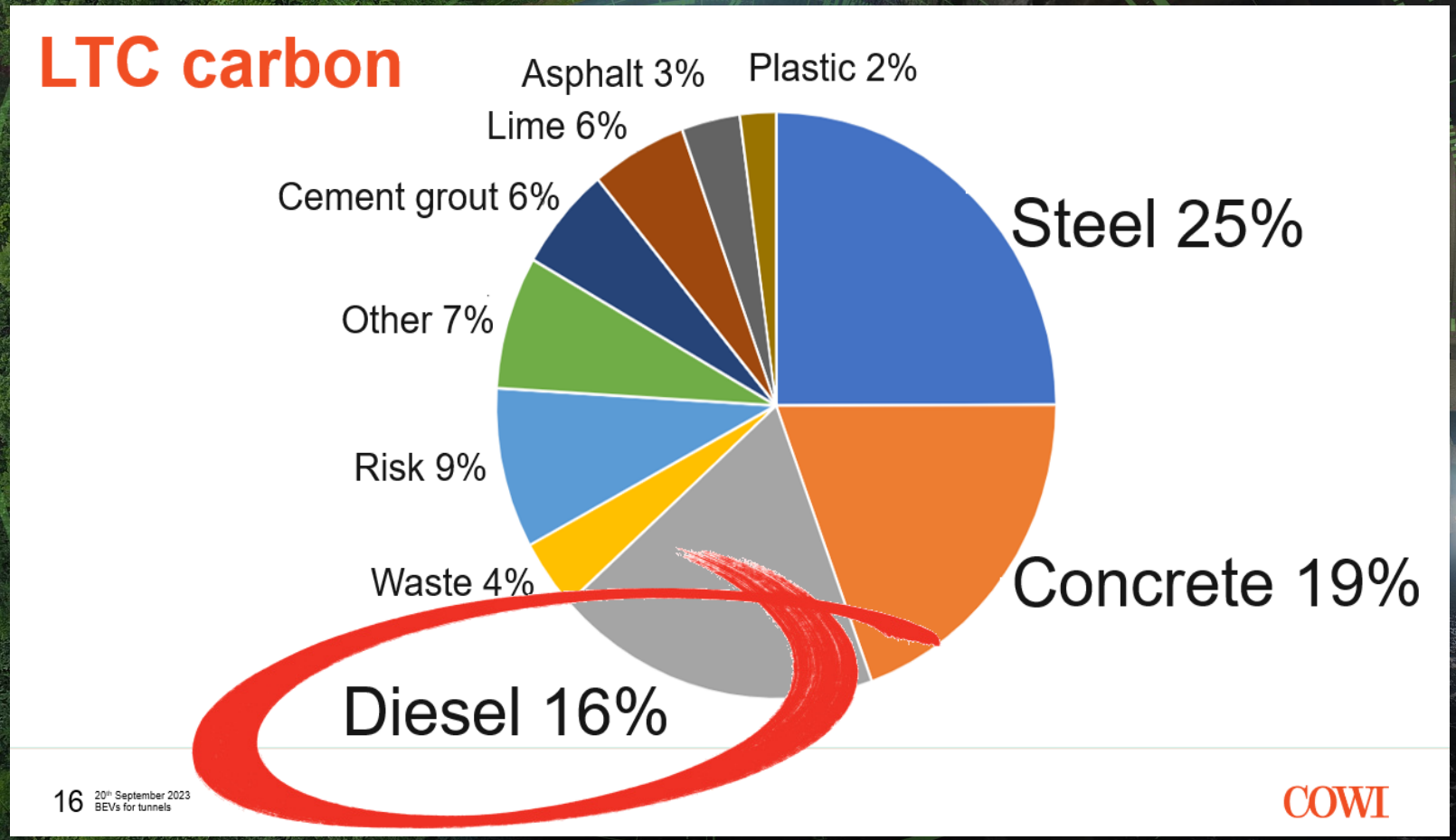
TUNNEL SPRAYING EQUIPMENT
MAIN EVOLUTIONARY STEPS!

1907 — 1960s — 1970s — 1980s — 1990s — 2000s — 2020s



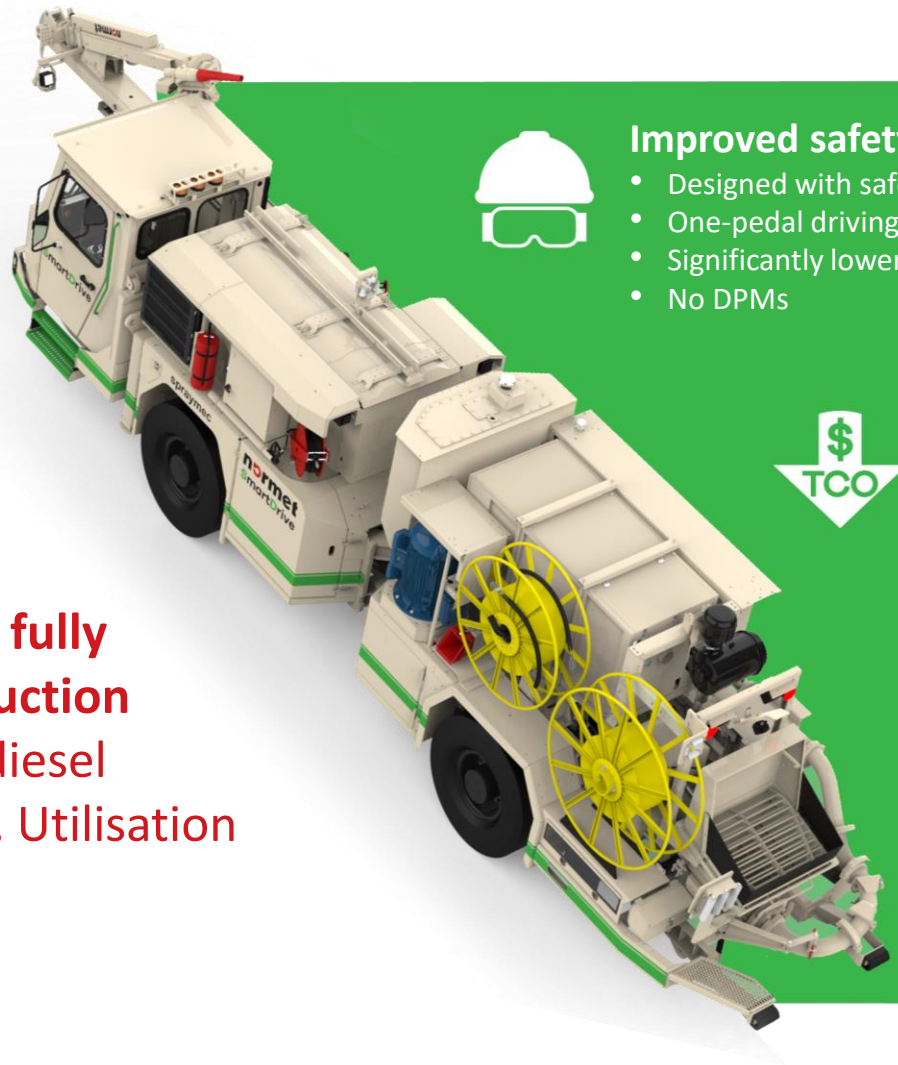


So, how can our industry keep global temperature rises under control?



Courtesy of Dr Keith Bowers, SubSpace Energy Hub Roundtable Event, Switzerland 2023

KEY TAKEAWAYS FROM MINING WITH BEVS



Improved safety and health

- Designed with safety as a #1 priority
- One-pedal driving + many driving assistance functions
- Significantly lower noise levels
- No DPMs

Reduced total cost of ownership

- Lower operational costs
- Even 30 % less maintenance costs
- Significantly reduced service brake wear

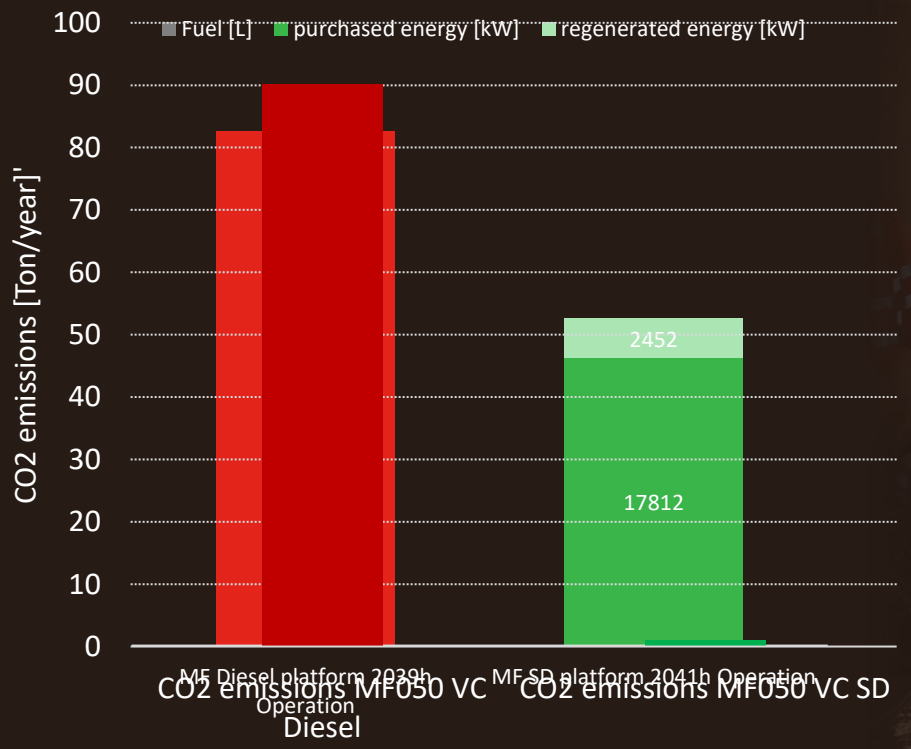
Increased efficiency and productivity

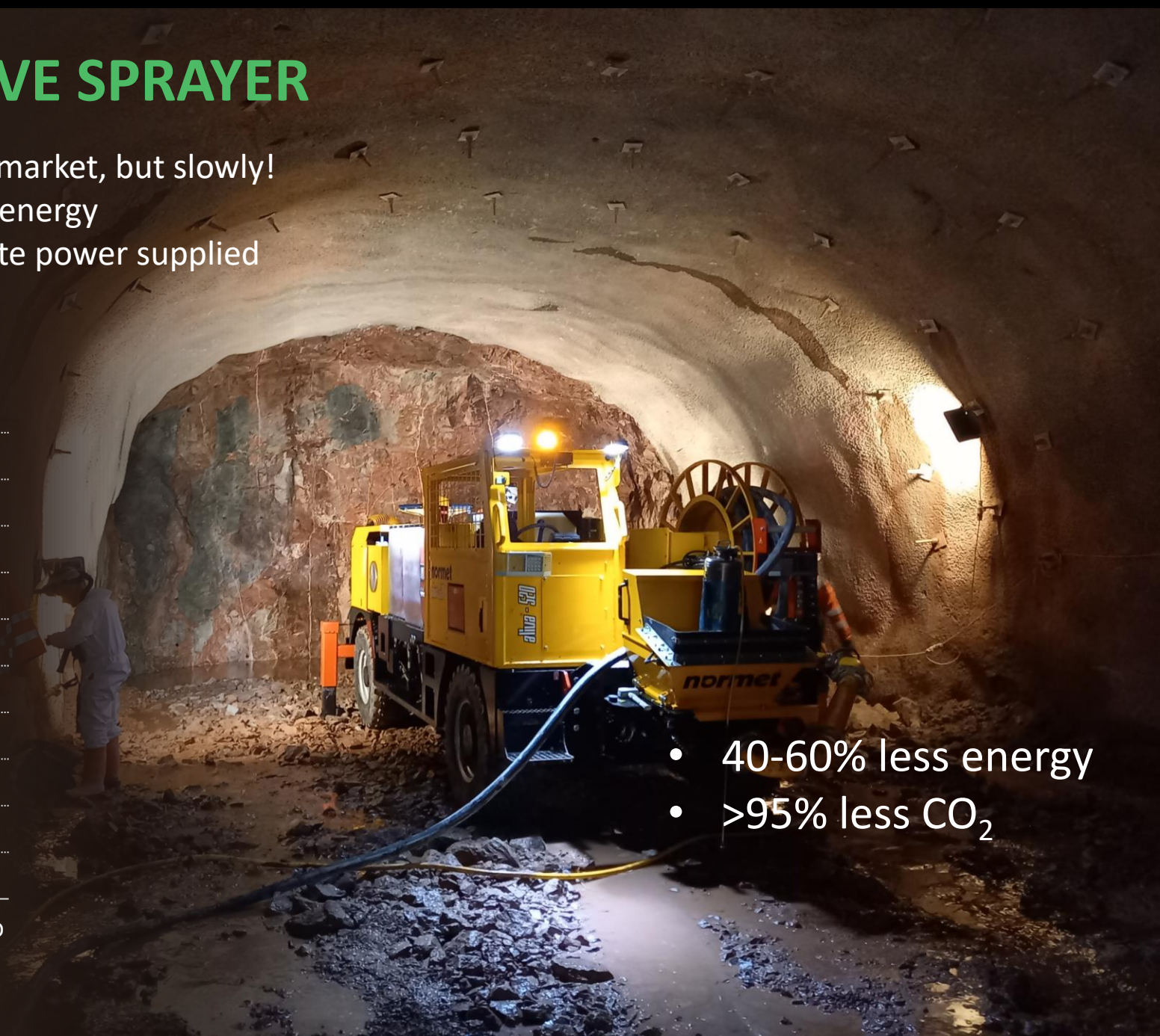
- Up to 50 % energy recuperation
- Fast charging capable
- Modular design. Less need for spare parts
- 100 % increase in uphill tramming speed

1. **Global mining houses are fully committed to carbon reduction**
2. More cost effective than diesel alternatives – TCO, Speed, Utilisation
3. Safer – no DPMs, no heat

BATTERY ELECTRIC DRIVE SPRAYER

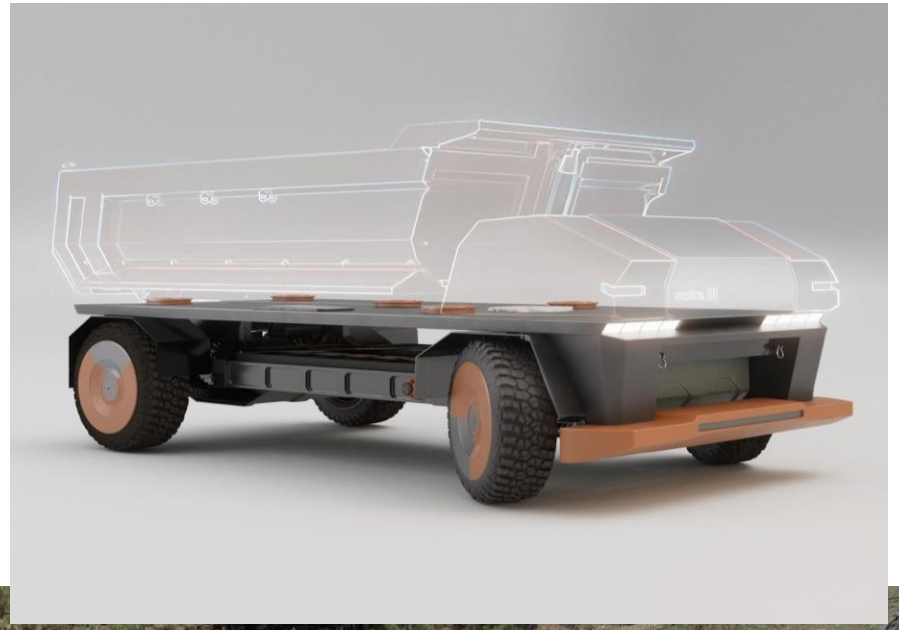
- Electric vehicles are coming onto the market, but slowly!
- Replacing diesel power trains – clean energy
- >95% CO_2 emission reduction using site power supplied from renewable energy sources





- 40-60% less energy
- >95% less CO_2

HOWEVER, THE MAIN BEV FOCUS SHOULD BE ON EQUIPMENT THAT MOVE MATERIALS



ELECTRIC WHEEL LOADER REVOLUTION

- LiuGong wheel loader
- 423kWh battery
- Fast charging at 240kWH
- Up to 70% lower operating costs

SANY WIDE BODY TRUCK, WBT

- Sany SKT 60/70-ton payload
- 422 and 564kWh battery packs
- Fast charger, 300kW
- Up to 90% lower operating costs

TUNNEL INDUSTRY BEST PRACTICE AND STANDARDS FOR TUNNEL BEVS

SUBSPACE ENERGYHUB

ITAtech

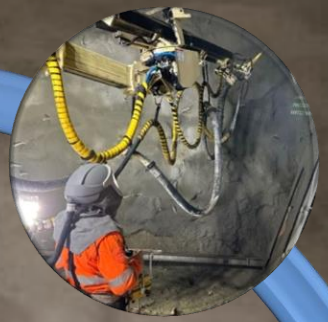
Net Zero Tunnelling group

BRITISH TUNNELLING SOCIETY

cen EUROPEAN COMMITTEE FOR STANDARDIZATION

A HOLISTIC APPROACH

Sustainable Sprayed Concrete Tunnelling



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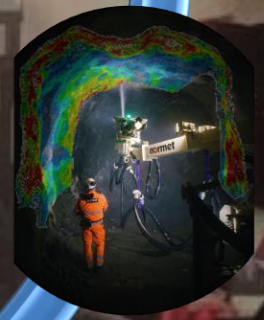

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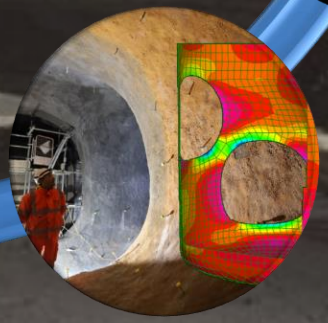


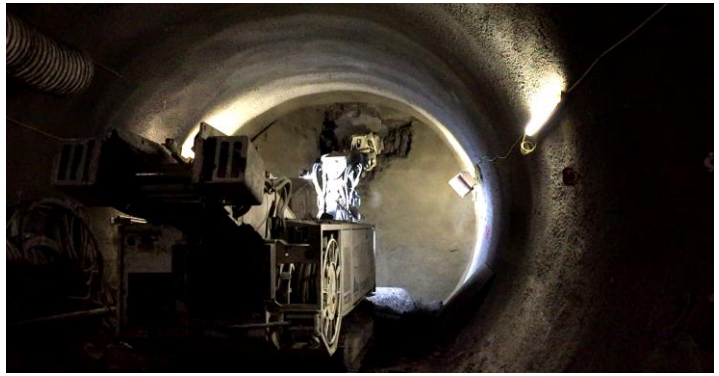
New design approaches

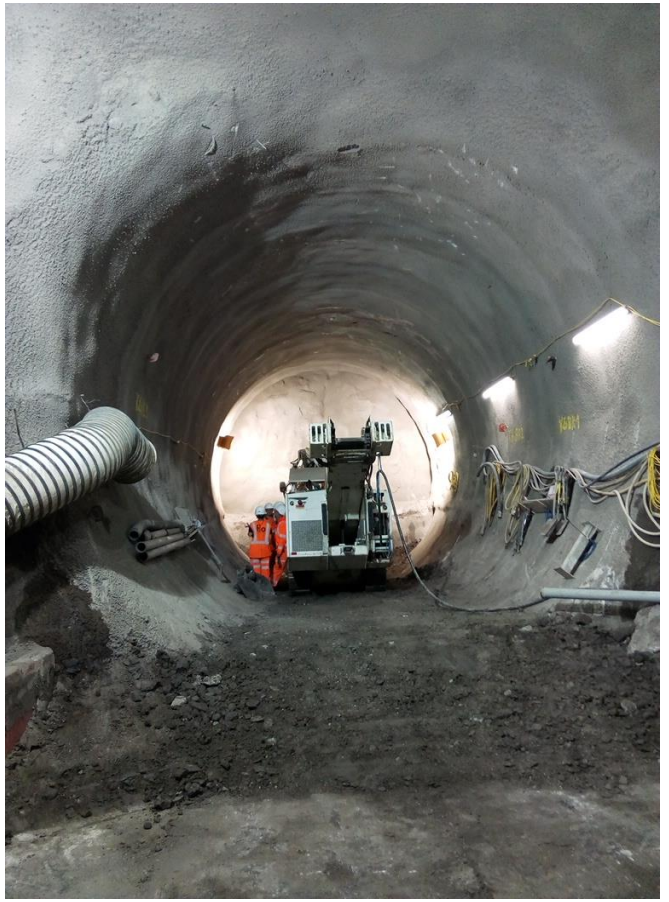
DIGITALISATION IN SPRAYED CONCRETE TUNNELLING

SPRAYING TO THE REQUIRED THICKNESS AND PROFILE

- Optical control of profiles
- Excavation and spraying processes
- Often removes need for lattice girders/steel profiles
- Fibres instead of mesh and all round safer!

PROFILE CONTROL ON LONDON TUNNEL PROJECTS



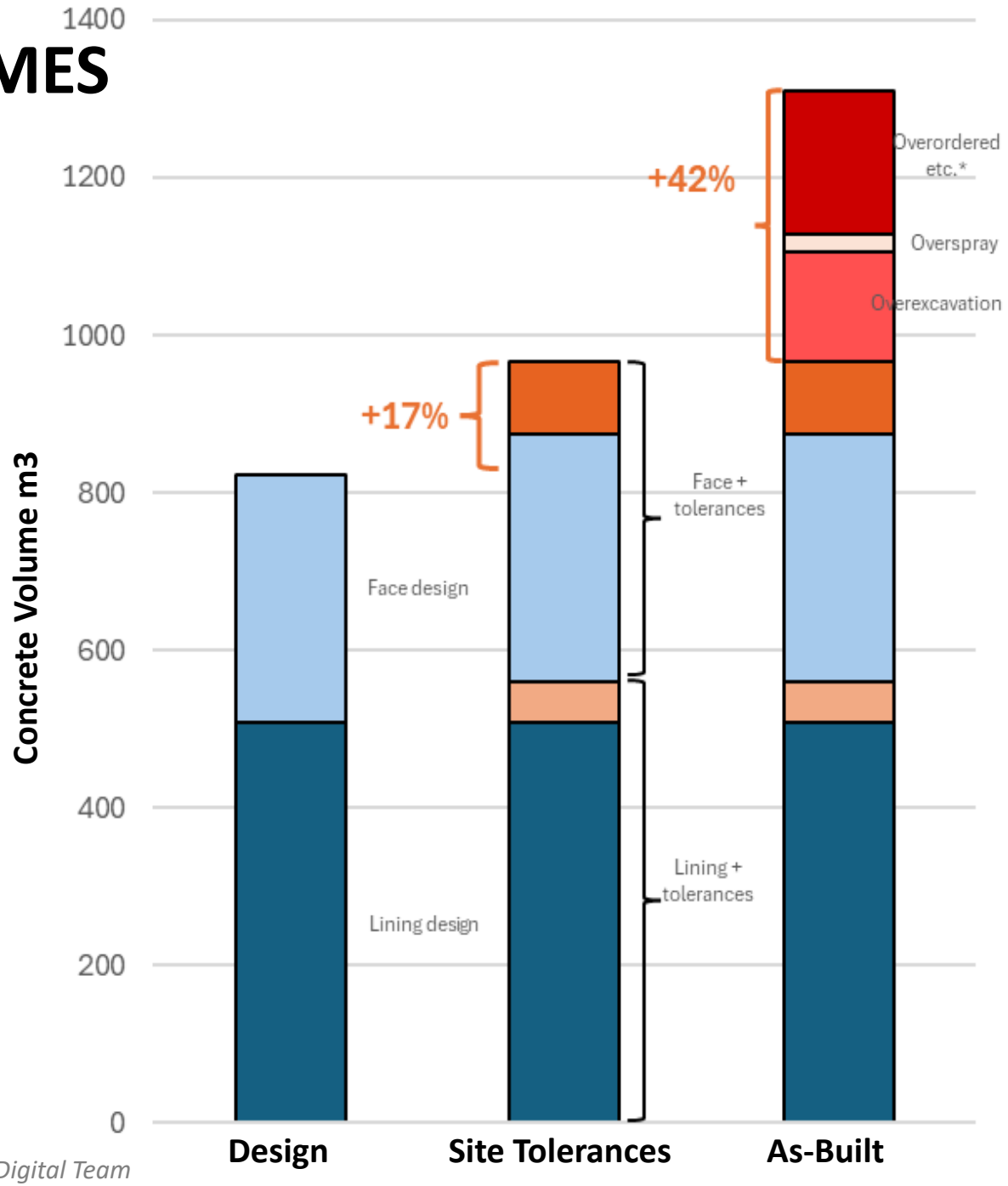


SPRAYED CONCRETE – EXCESS VOLUMES

- As a general statement, in tunnelling we use approx. 1.5 to 2 X the design amount of sprayed concrete
- This would be unacceptable in most infrastructure projects!

- On a recent project we have measured the processes and profiles with main culprits being:
  - Tolerance build up
  - Over excavation
  - Over ordering of concrete

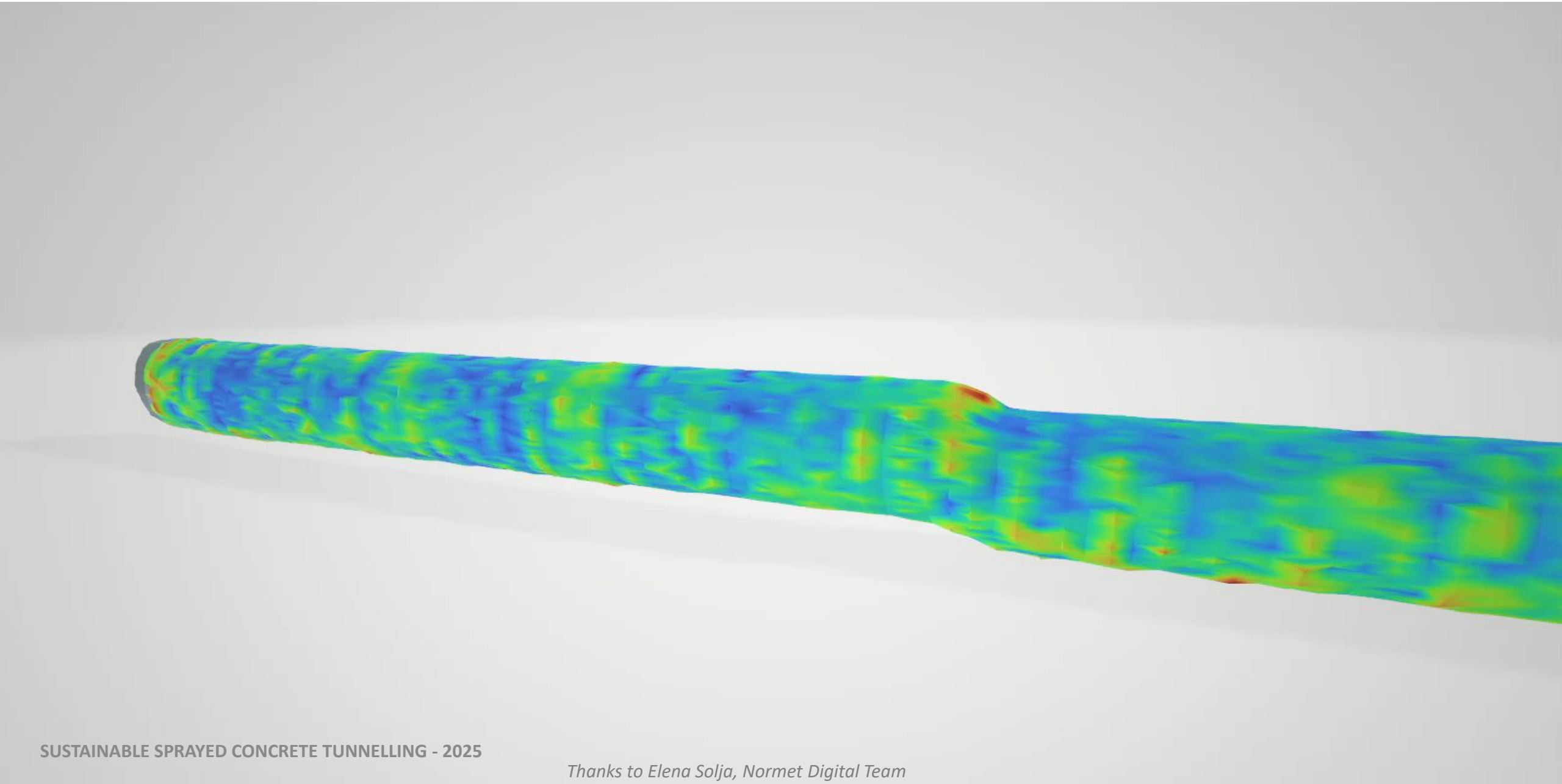
- We must be focused to reduce these waste factors going forwards if we want to reduce carbon and cost



Thanks to Topias Moisa, Normet Digital Team

SmartScan Align

EXCAVATION AND SPRAYING TO THE DESIGNED TUNNEL PROFILE



Thanks to Elena Solja, Normet Digital Team

DIGITAL TWINS – ASSESSING 1M SLICES OF TUNNEL

ADV004: Ref. HS = 10.596 m

Tunnel Meters:
Ref. HS: 10.596 m
Start: 9.398 m
End: 10.596 m
Length: 1.198 m
No data: 0.138 m

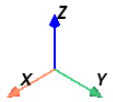
Excavation:
Volume:38.910 m³
Over: 2.422 m³
Under: 0.000 m³
Surf. Area:24.775 m²
Prof. Area:32.484 m²

Concrete:
Volume:
Sprayed: 9.318 m³
Remaining:29.591 m³
Over: 0.721 m³
Under: 0.026 m³

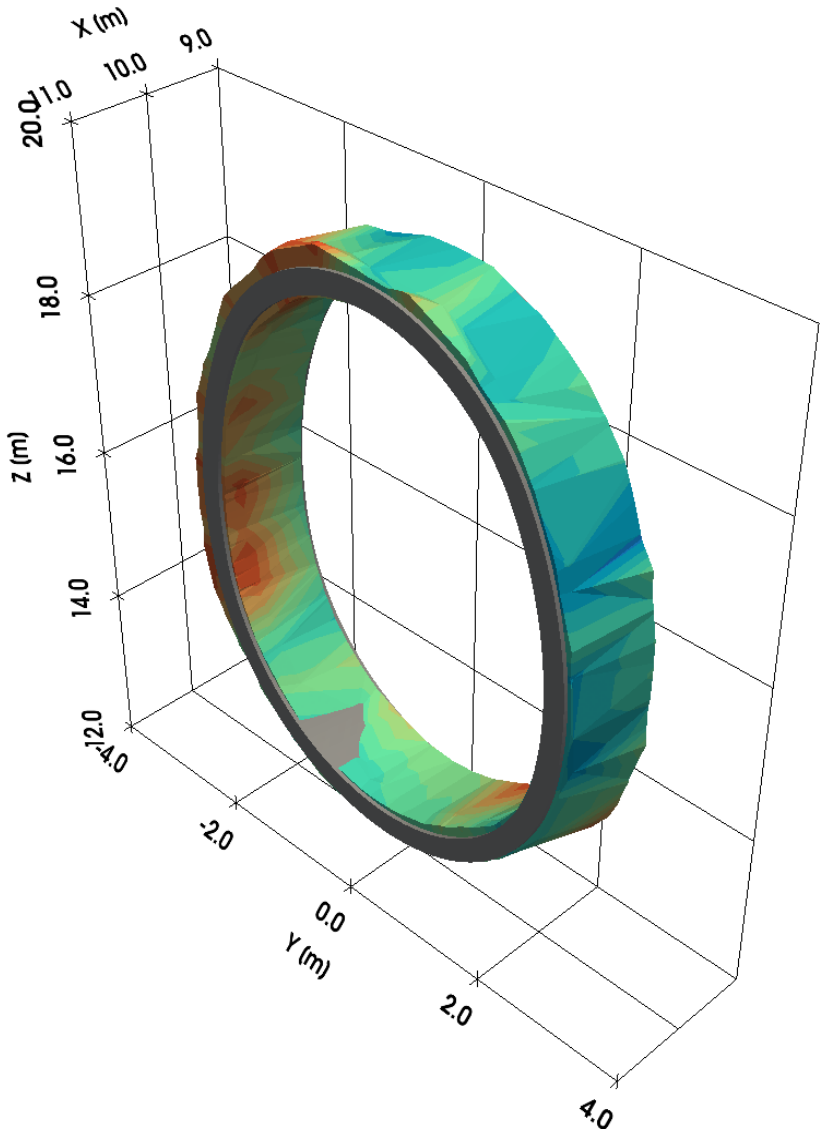
Area:
Surface: 21.355 m²
Profile: 24.704 m²

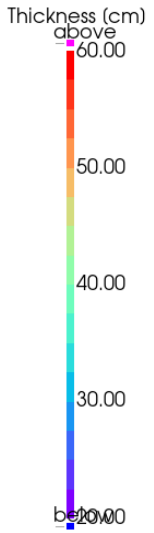
Thickness:
Min: 29 cm
Max: 57 cm
Mean: 40 cm

ADV004



☑ Show Design





Thanks to Elena Solja, Normet Digital Team

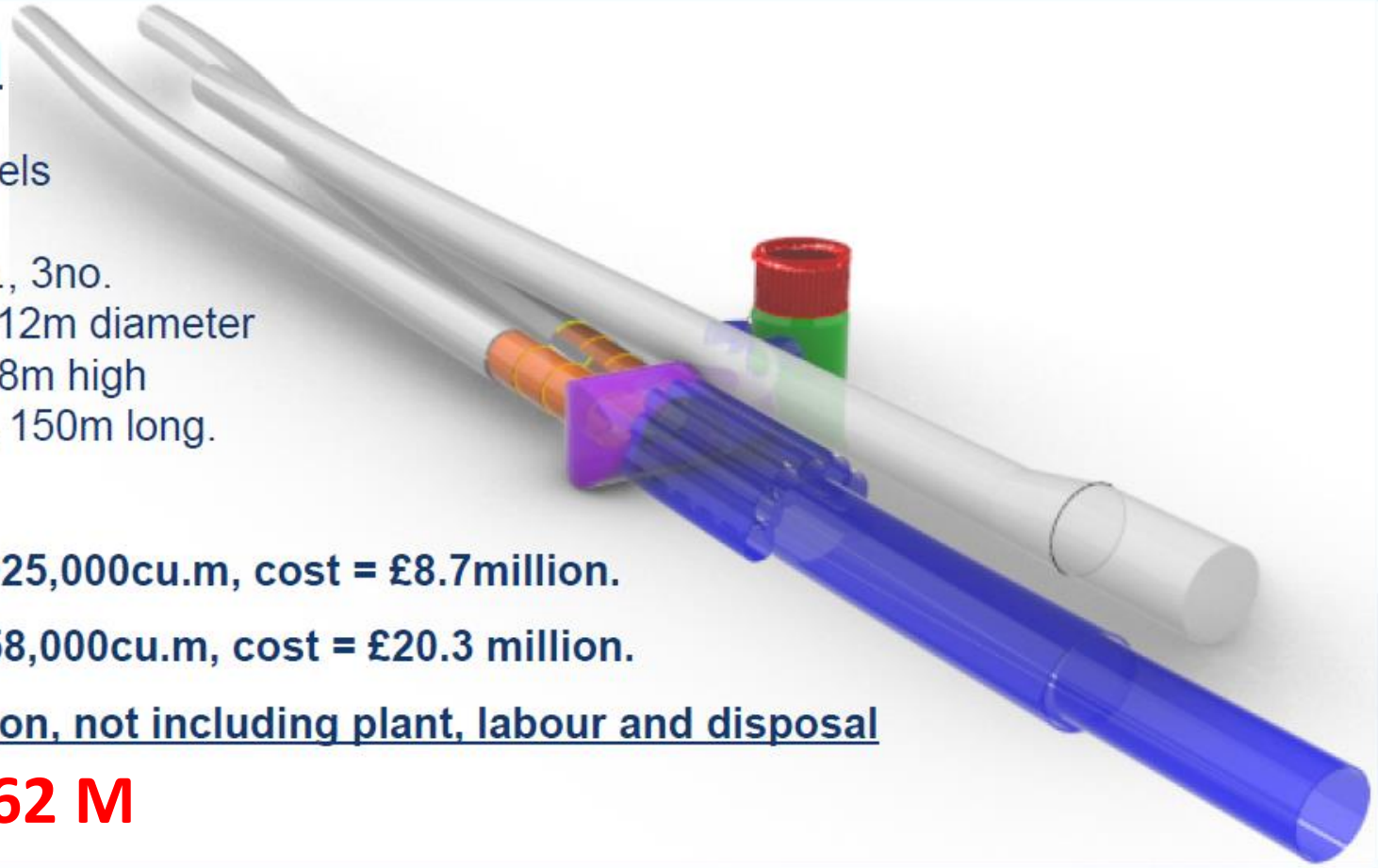
CONTRACTORS ASSESSMENT FOR NEXT TUNNELLING PHASE

One Team Challenge

SKANSKA COSTAIN STRABAG Working on behalf of HS2

Making the problem real

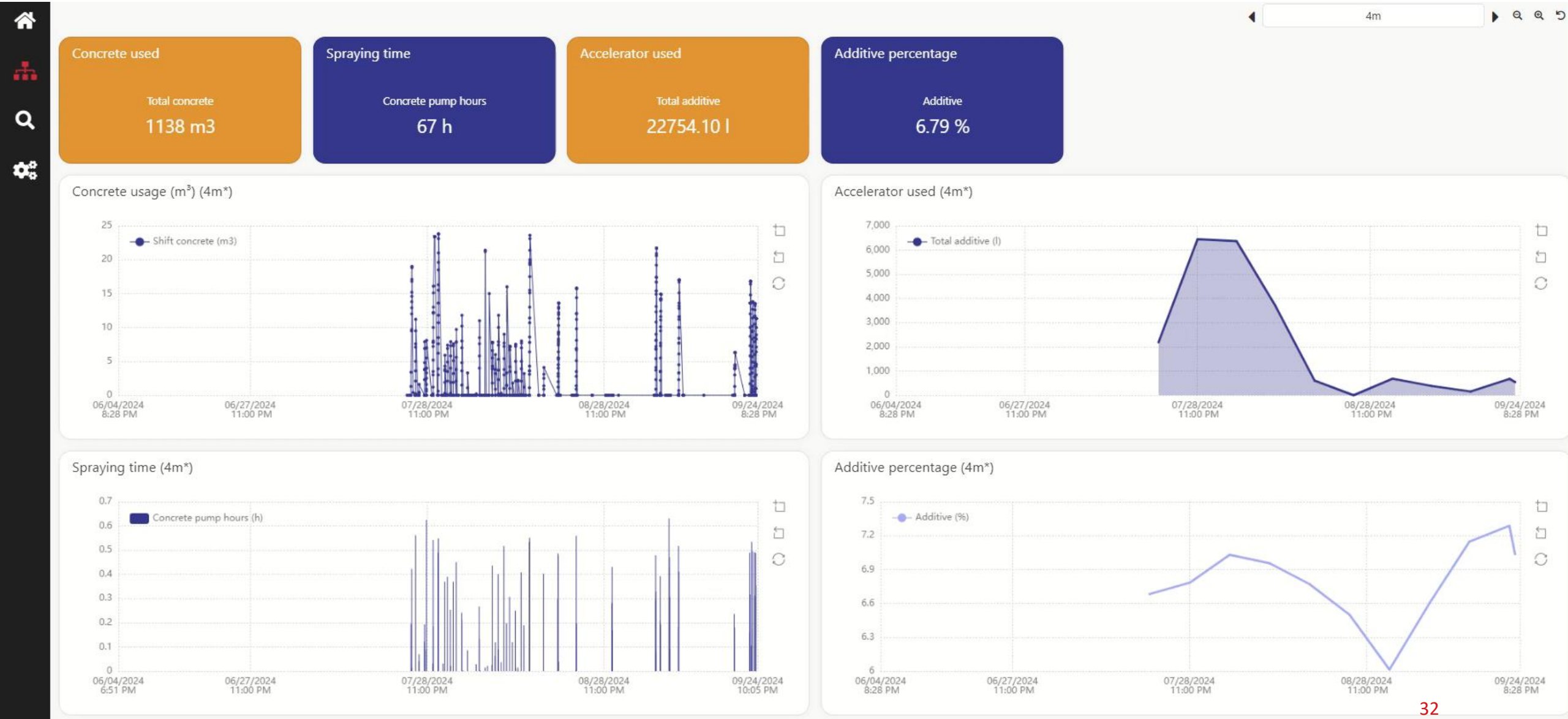
- Euston SCL Approach Tunnels
  - Crossover tunnels
    - 300m long, 9m dia., 3no.
    - Shaft - 30m deep, 12m diameter
  - Crosscut - 30m high,18m high
  - Cavern - 11-15m wide, 150m long.



- **Theoretical volume = ~25,000cu.m, cost = £8.7million.**
- **Predicted volume = ~58,000cu.m, cost = £20.3 million.**
- **Waste SCL = £11.5million, not including plant, labour and disposal**

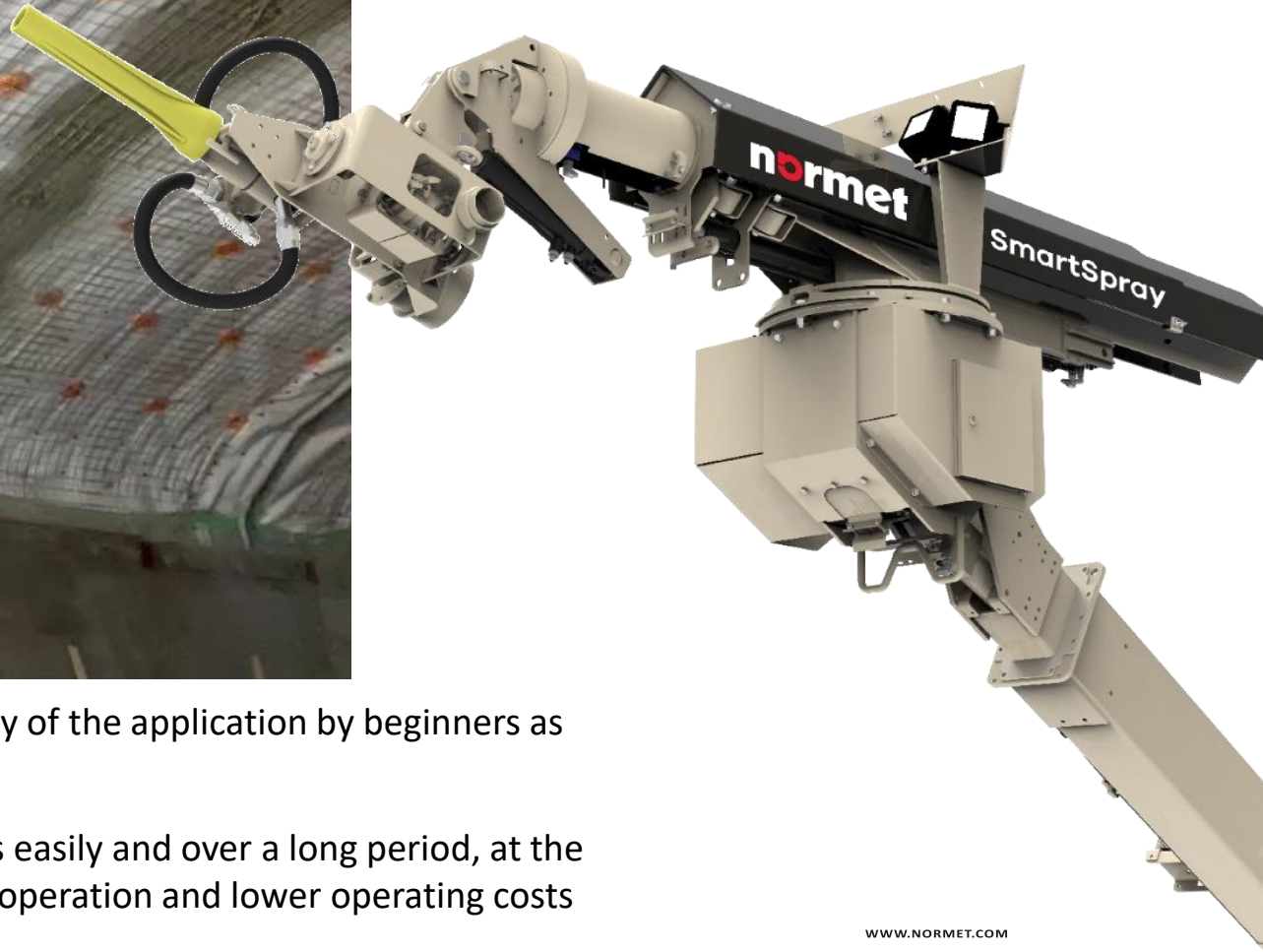
NOK 162 M

DIGITALLY CONNECTED SPRAYED CONCRETE ROBOTS
TUNNEL PROCESS HEALTH DASHBOARDS



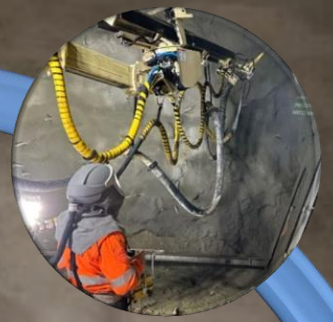
Thanks to Pekka Jaarinen, Normet Digital Team

SMARTSPRAY TOWARDS FULLY AUTOMATED SPRAYING



- Decreases the ergonomic strain and helps to improve the overall quality of the application by beginners as well as experienced operators
- Supports the operator to achieve the target sprayed concrete thickness easily and over a long period, at the same time reducing concrete waste for more environmentally friendly operation and lower operating costs
- Three levels of automation available from nozzle distance control to fully automated spraying

A HOLISTIC APPROACH



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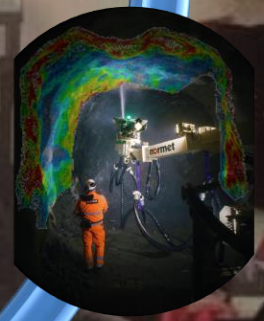

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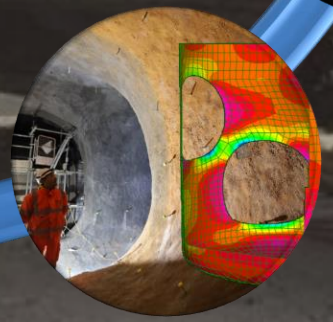


New design approaches

NORWEGIAN TUNNELLING APPROACHES

Rock support SC and bolts, sheet membrane, cast in-situ linings

Courtesy Karl Gunnar Holter – Gevingåstunnelen (www.tu.no)

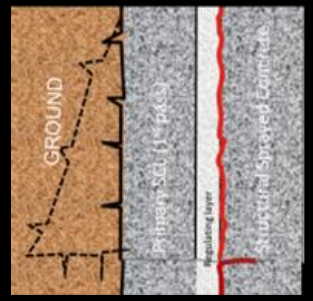
Rock support SC and bolts, spray membrane, final thin SC shell

MUMBAI METRO – CROSSOVER CAVERNS

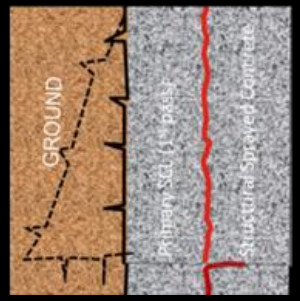
SPRAY WATERPROOFING MEMBRANES IN SCL TUNNELLING AUSTRALIA

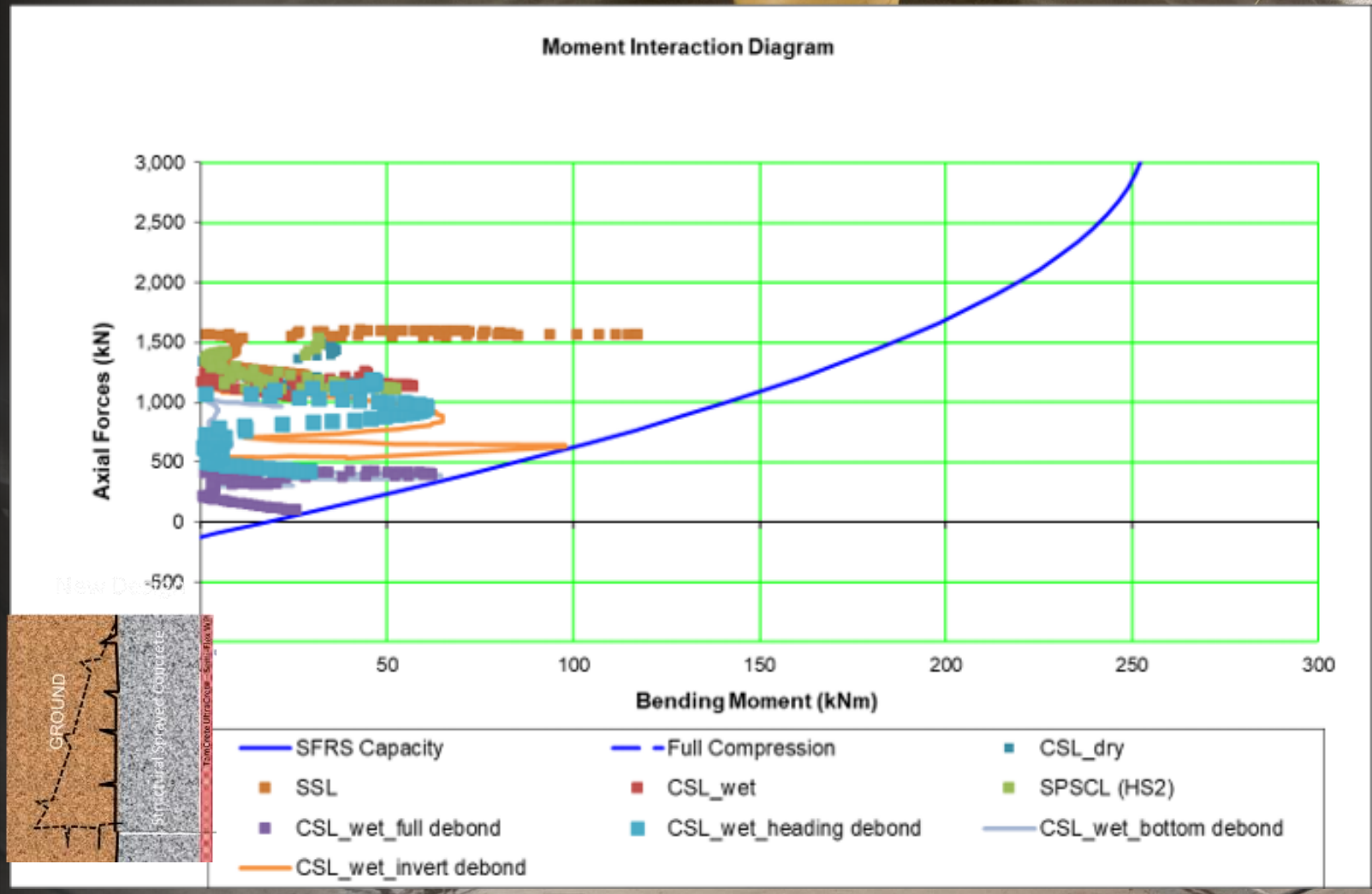
TAKING CROSSRAIL PLATFORMS TUNNELS AS A DESIGN EXAMPLE

Original Design



Optimised Design

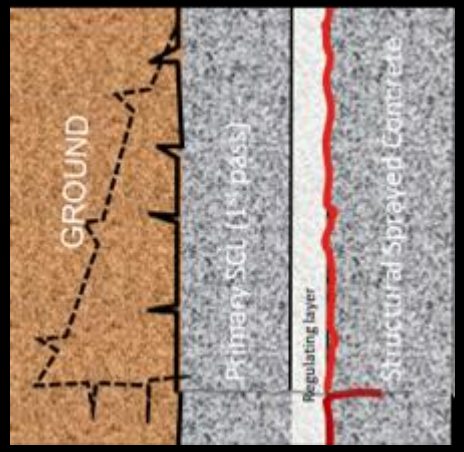




BEDI CONSULTING normet

AND WE CAN DREAM . . . FLEXIBLE WATERPROOF SPRAYED CONCRETE

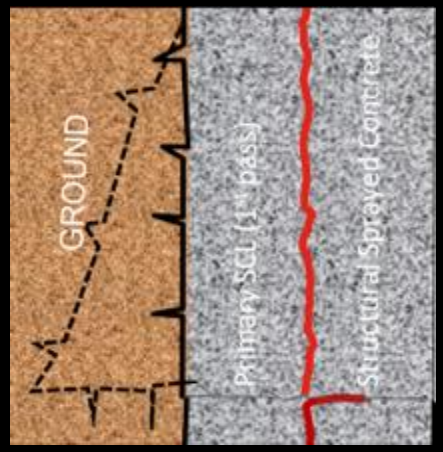
Original Design



4 – 5 Layers – 700mm

Separate construction processes

Optimised Design



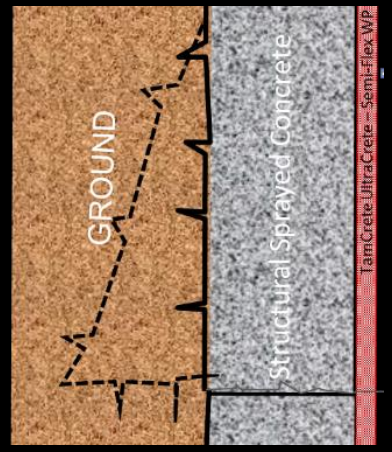
3 Layers – 450mm

Separate construction processes, but simpler

Composite lining

30% CO_2 Saving

New Design



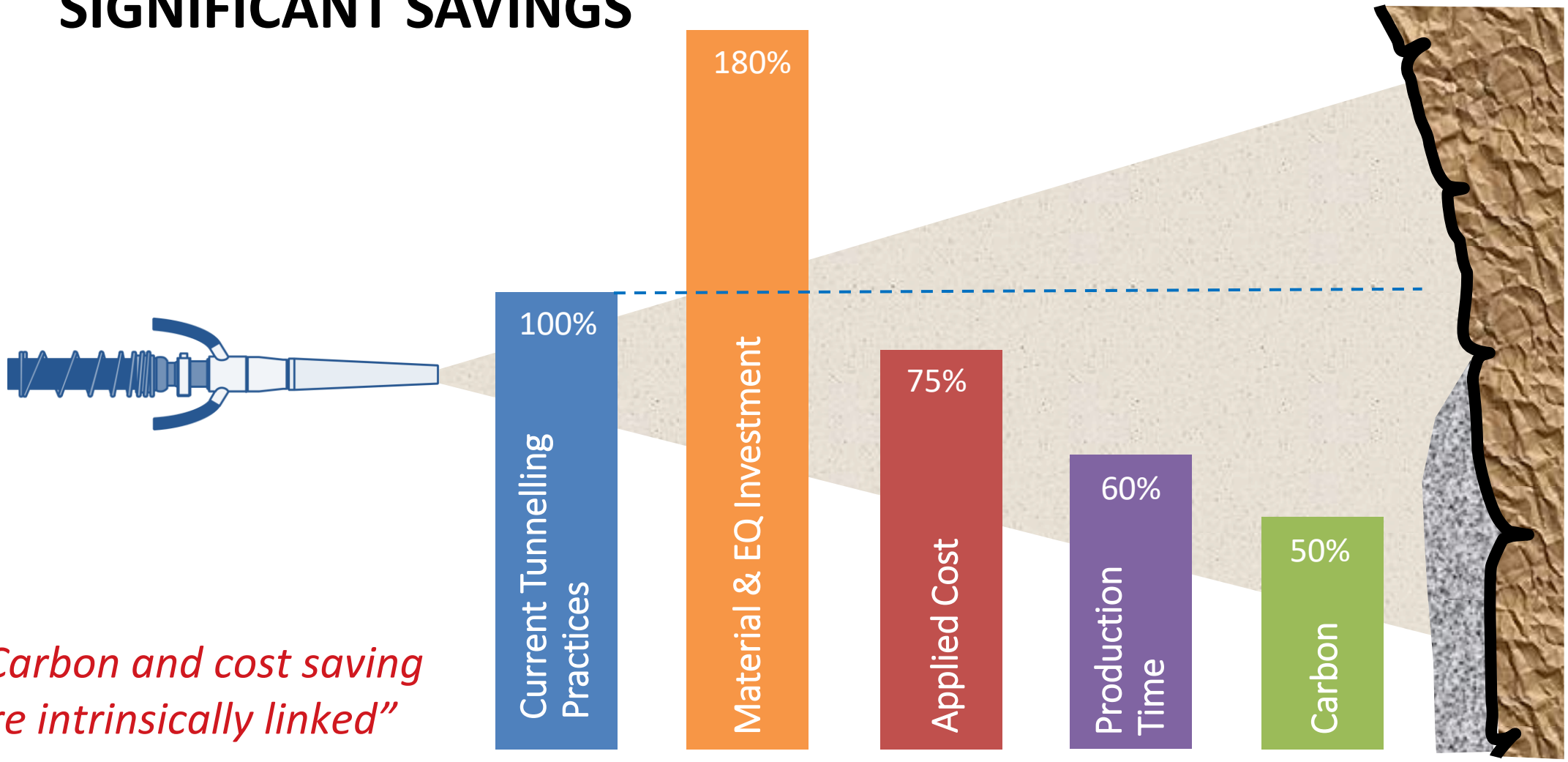
2 Layers – 375mm

Fast, one sprayed concrete structural layer with sprayed wp coating

45% CO_2 Saving

Even without using more environmentally friendly cement!

INVEST IN LOW CARBON TECHNOLOGY TO MAKE SIGNIFICANT SAVINGS



"Carbon and cost saving are intrinsically linked"

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Any thoughts or questions?