Building around existing tunnels

Seminar

Design of the Cross River Rail station caverns for future over tunnel development

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Sydney, 27 April 2023

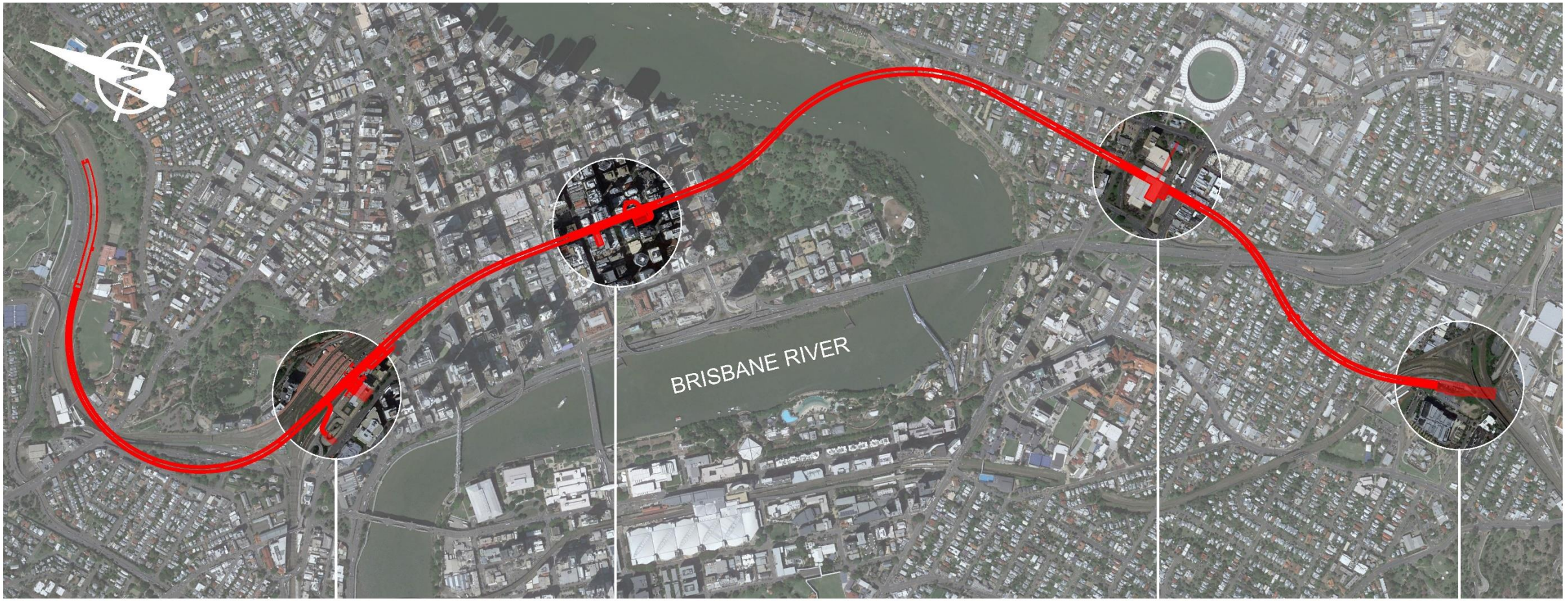
ENGINEERS AUSTRALIA | AUSTRALIAN TUNNELLING SOCIETY 50 years 1972 - 2022 | AUSTRALIAN GEOMECHANICS SOCIETY

Presentation outline

- Cross River Rail project overview
- Ground conditions
- Metro tunnels
- Project Scope & Technical Requirements (PSTR)
  - Notional development allowances
  - Specific developments
  - Ovalisation scenario
- Impact of basement excavations on tunnel linings
- Design of permanent tunnel linings
  - Ground load assessment (including future development)
  - Structural design
- Application of the ovalisation scenario
- Conclusions & recommendations

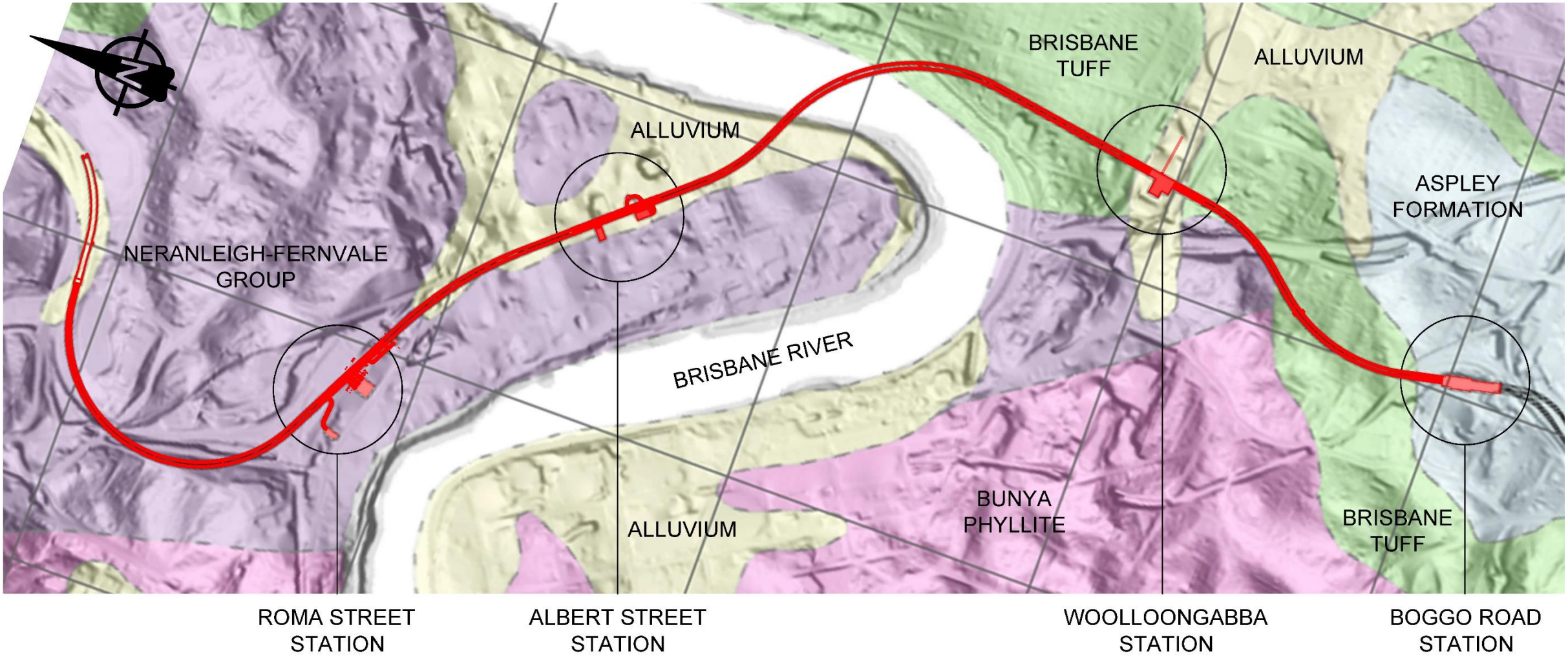
Cross River Rail project

Tunnel alignment and stations



Cross River Rail project

Ground conditions



Cross River Rail project

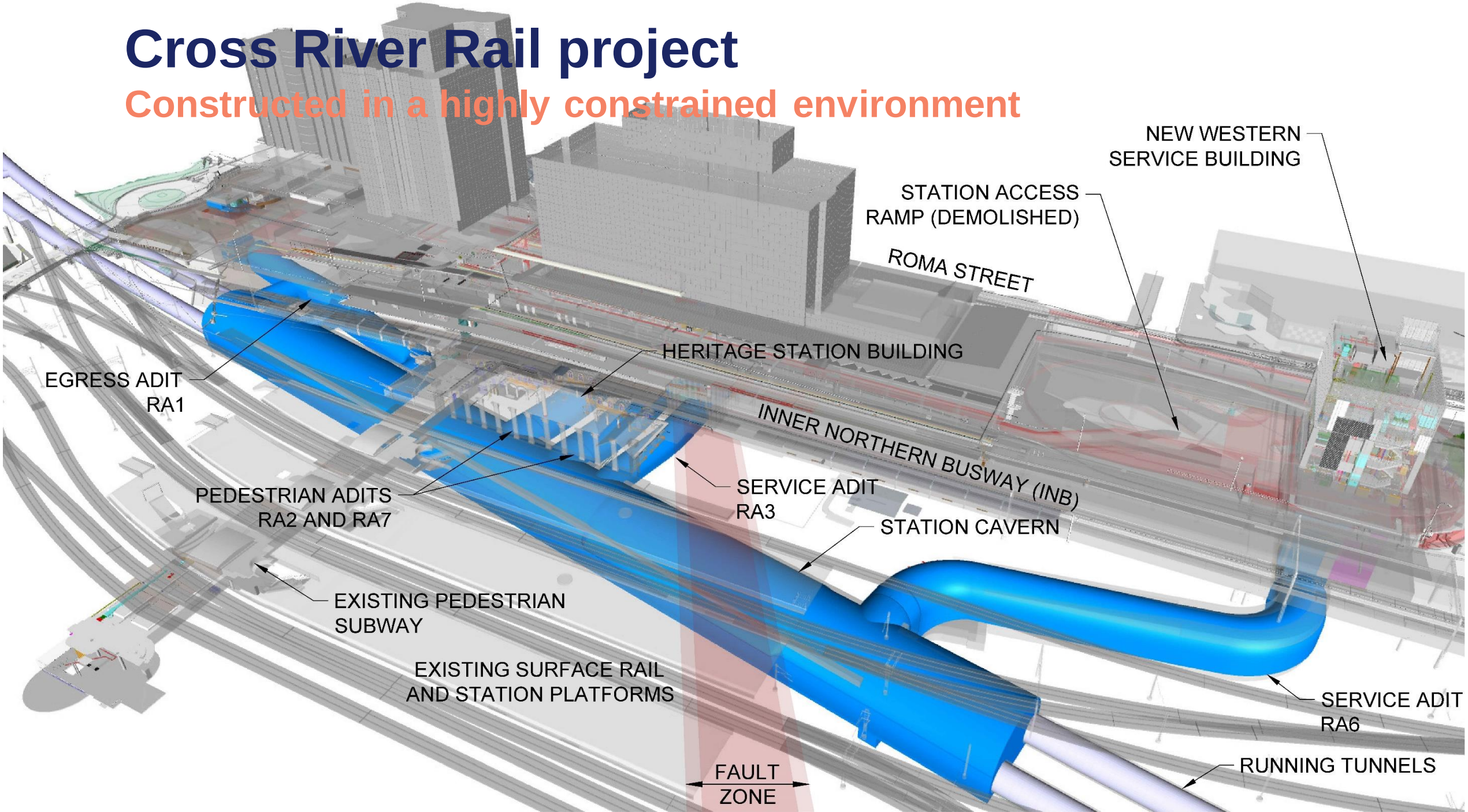
Ground conditions

HIGH STRENGTH NERANLEIGH-FERNVALE GROUP
(ALBERT STREET ACCESS ADIT)

WEATHERED TUFF
(BOGGO ROAD CAVERN)

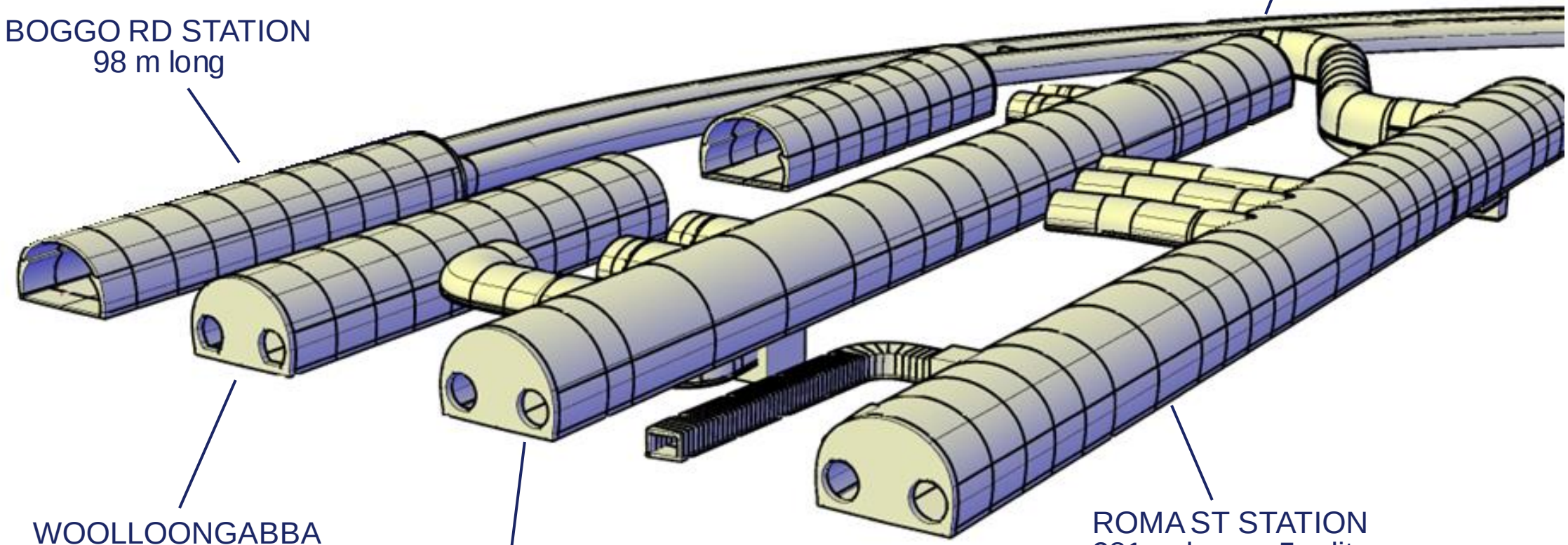
Cross River Rail project

Constructed in a highly constrained environment



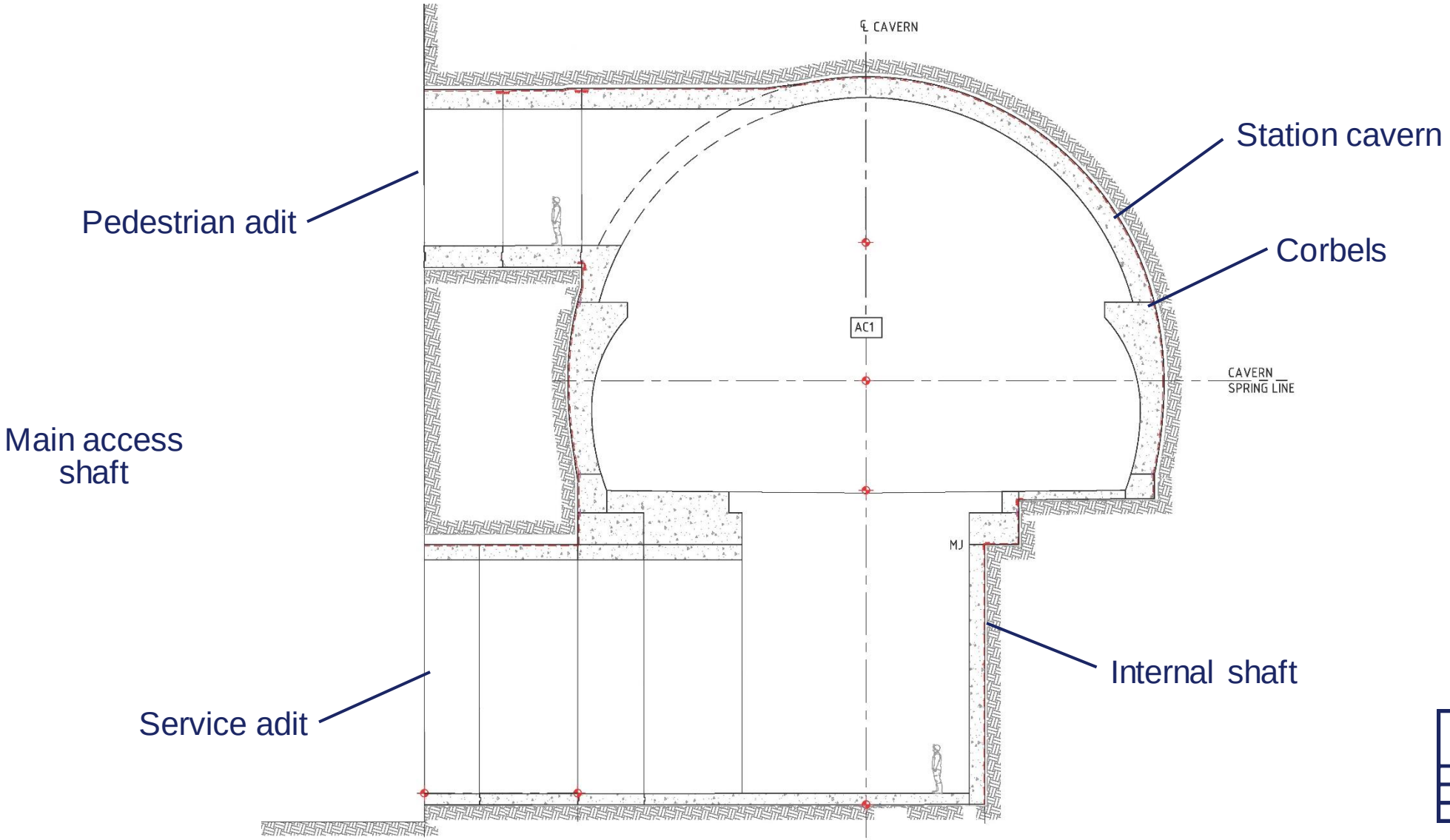
Cross River Rail project

Station caverns (compilation)



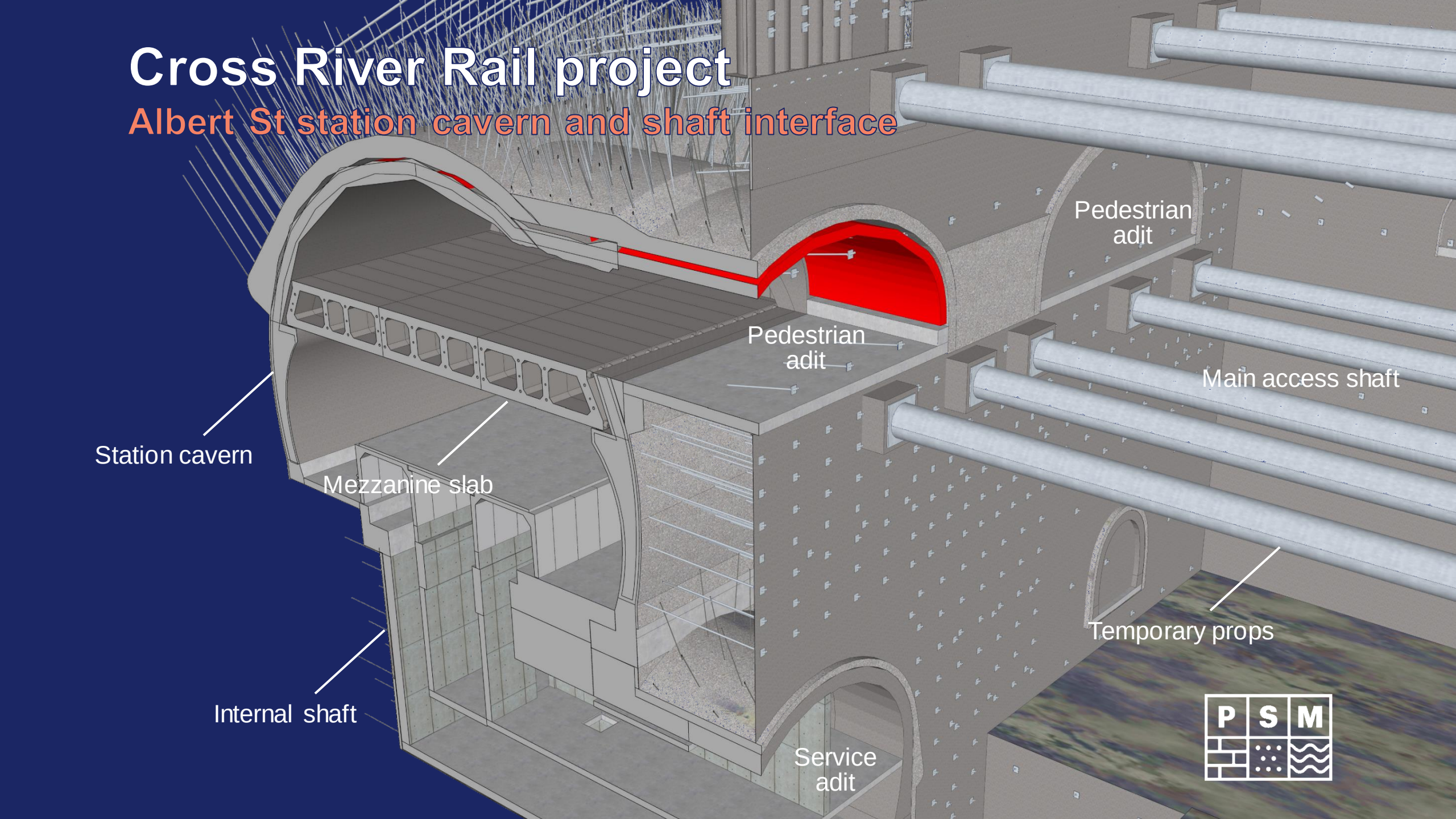
Cross River Rail project

Complex cavern structures



Cross River Rail project

Albert St station cavern and shaft interface



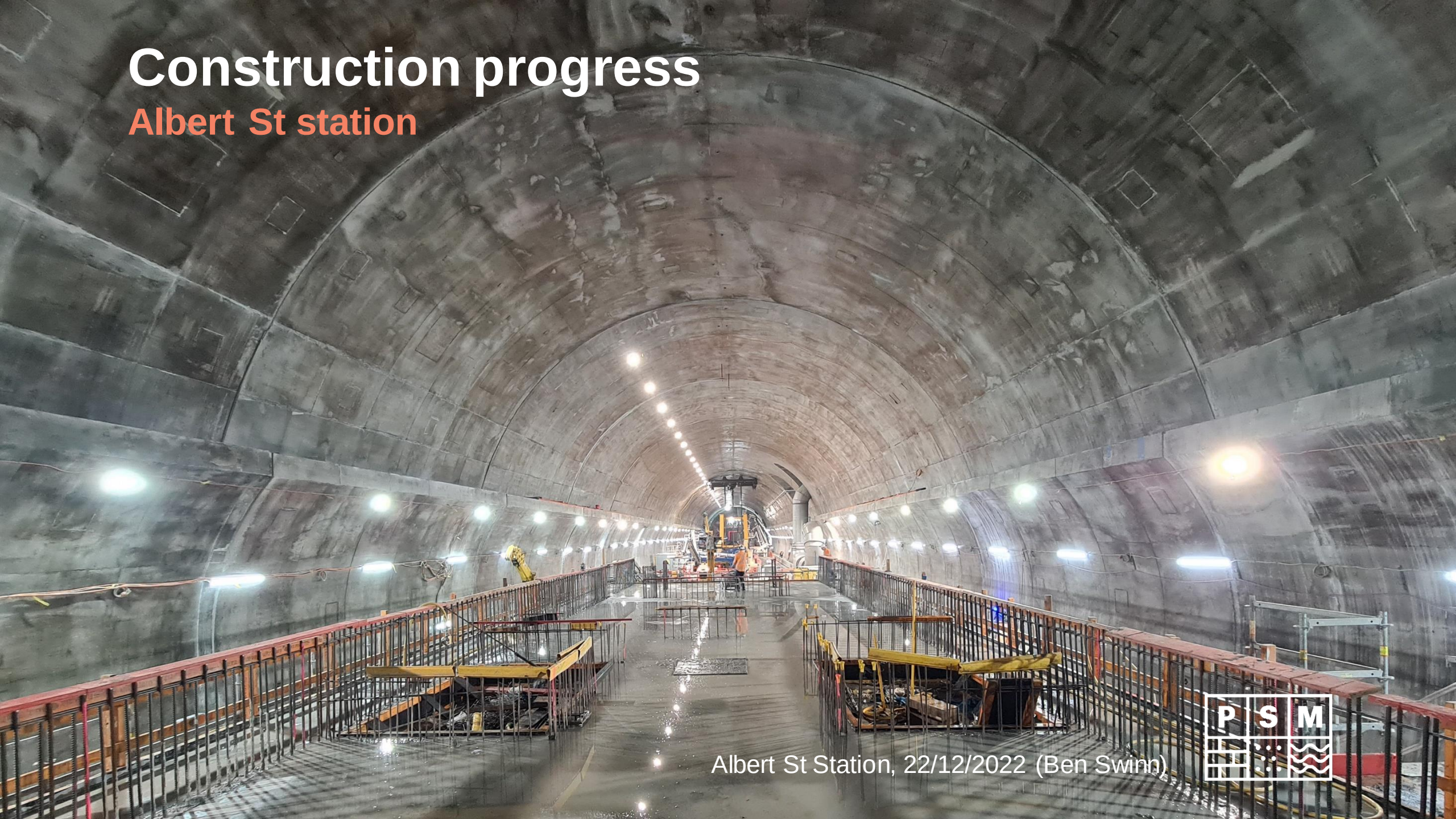
Construction progress

Albert St station

Albert St station, 21/09/2022 (Ben Swinn)

Construction progress

Albert St station



Albert St Station, 22/12/2022 (Ben Swinn)

Construction progress

Roma St station

Roma St station, 23/02/2023 (BS)

Construction progress

Albert St station

Albert St station, 24/02/2023 (ACR)

Construction progress

Boggo Rd station

Boggo Rd station, 24/02/2023 (BS)

Construction progress

Albert St station

Albert St station, 31/03/2023 (ACR)

Development impacts

Metro tunnels

Metro tunnels typically involve alignments located at shallow depth in poor ground conditions, with large station caverns required for railway lines, mechanical and electrical plant, platforms, and passenger access.

These factors, combined with the need for stations to be constructed in heavily developed city centres, result in the near certainty of being impacted by future development.

Project Scope & Technical Requirements

Purpose

Project Scope & Technical Requirements document is essentially a specification prepared by the owner (Queensland Government) which describes the details of the project:

- Alignment
- Tunnel profiles
- Design standards and criteria (e.g. design life)
- Loads (e.g. future development allowances)
- Performance requirements

Other projects use different names, for example “Scope of Work and Technical Criteria”, “Project Specification”

Project Scope & Technical Requirements

Future development

“the design shall allow for future development of the land above and adjacent to the Tunnel and Underground Structures by designing and constructing for loading and unloading in addition to the applicable design loads”.

Project Scope & Technical Requirements

Future development

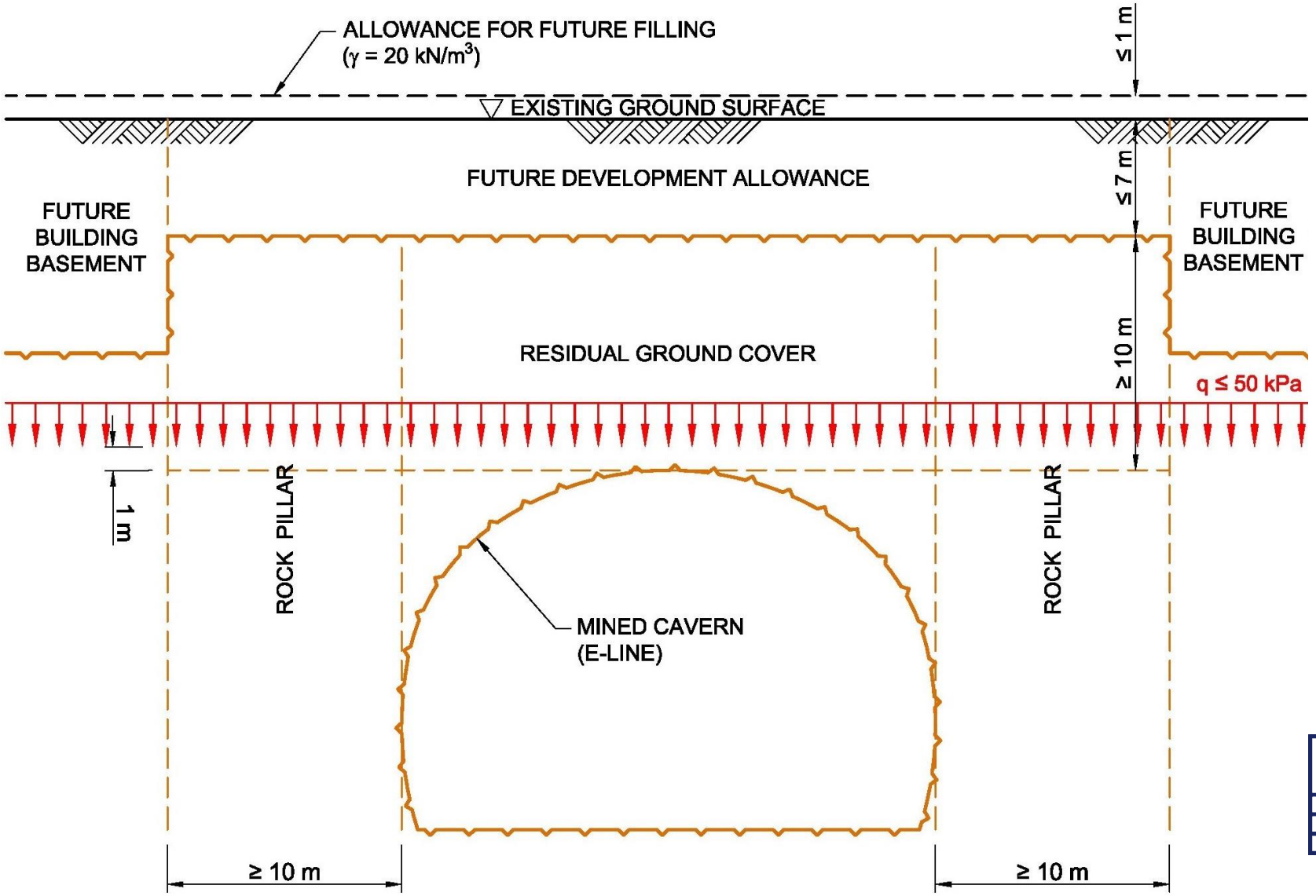
PSTR required that permanent linings designed to consider a range of future over tunnel development scenarios:

1. Notional development configurations defined by:
   - Excavation exclusion zones around the tunnels
   - Excavation geometries (e.g. depths)
   - Surface surcharge and building loads
2. Specific development proposals (i.e. approved by Council / State government)
3. Additional ‘ovalisation’ case (induced distortion), including prescribing how this was to be analysed.

These were applied to portions of the alignment which passed beneath or adjacent to developable land.

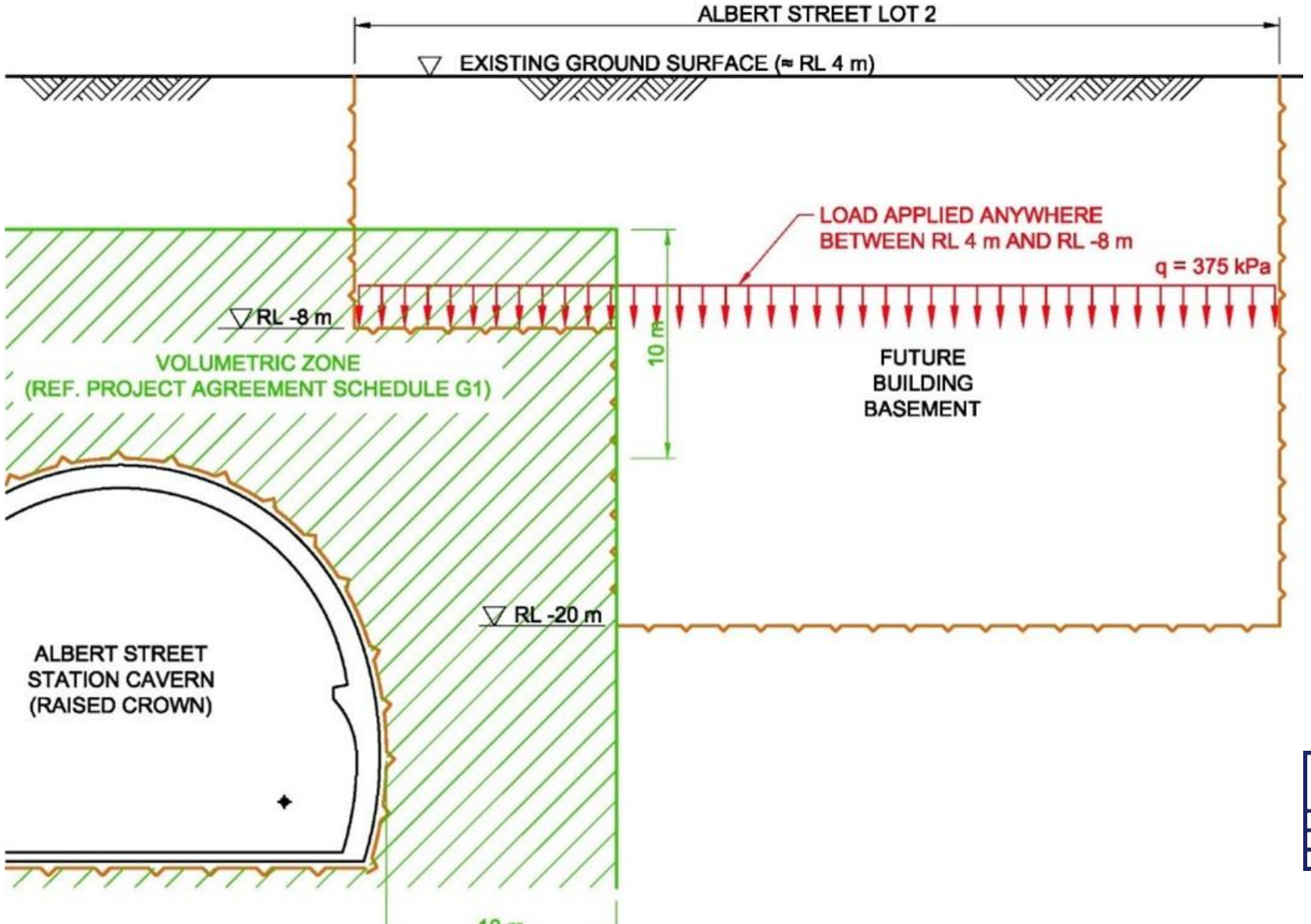
Project Scope & Technical Requirements

Notional developments - Excavation & loading scenarios



Project Scope & Technical Requirements

Specific developments – Albert St “Lot 2”



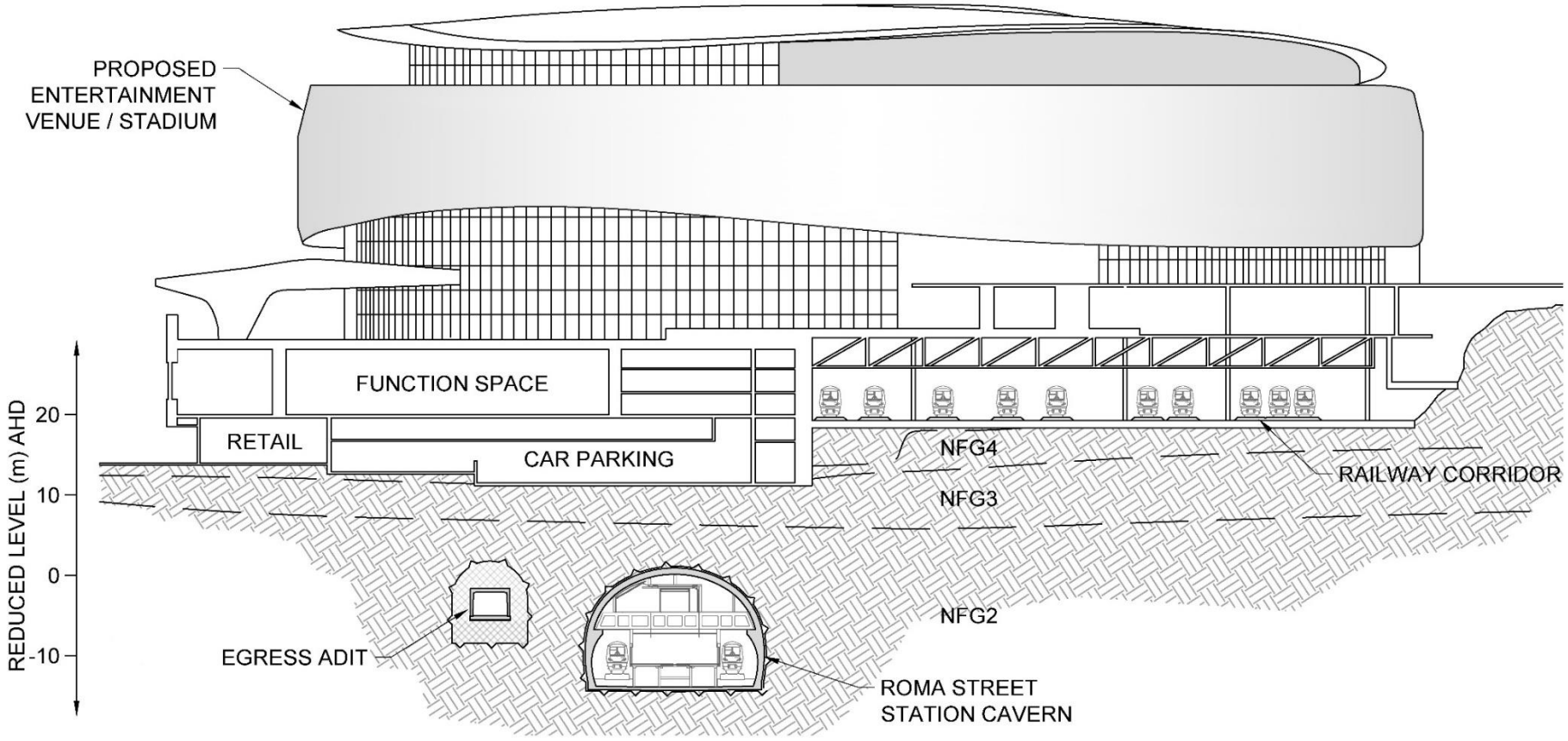
Project Scope & Technical Requirements

Specific developments – Albert St "Rainforest tower"

(FORMERLY KNOWN AS "LOT 2")

Project Scope & Technical Requirements

Specific developments – Roma St “Brisbane live”

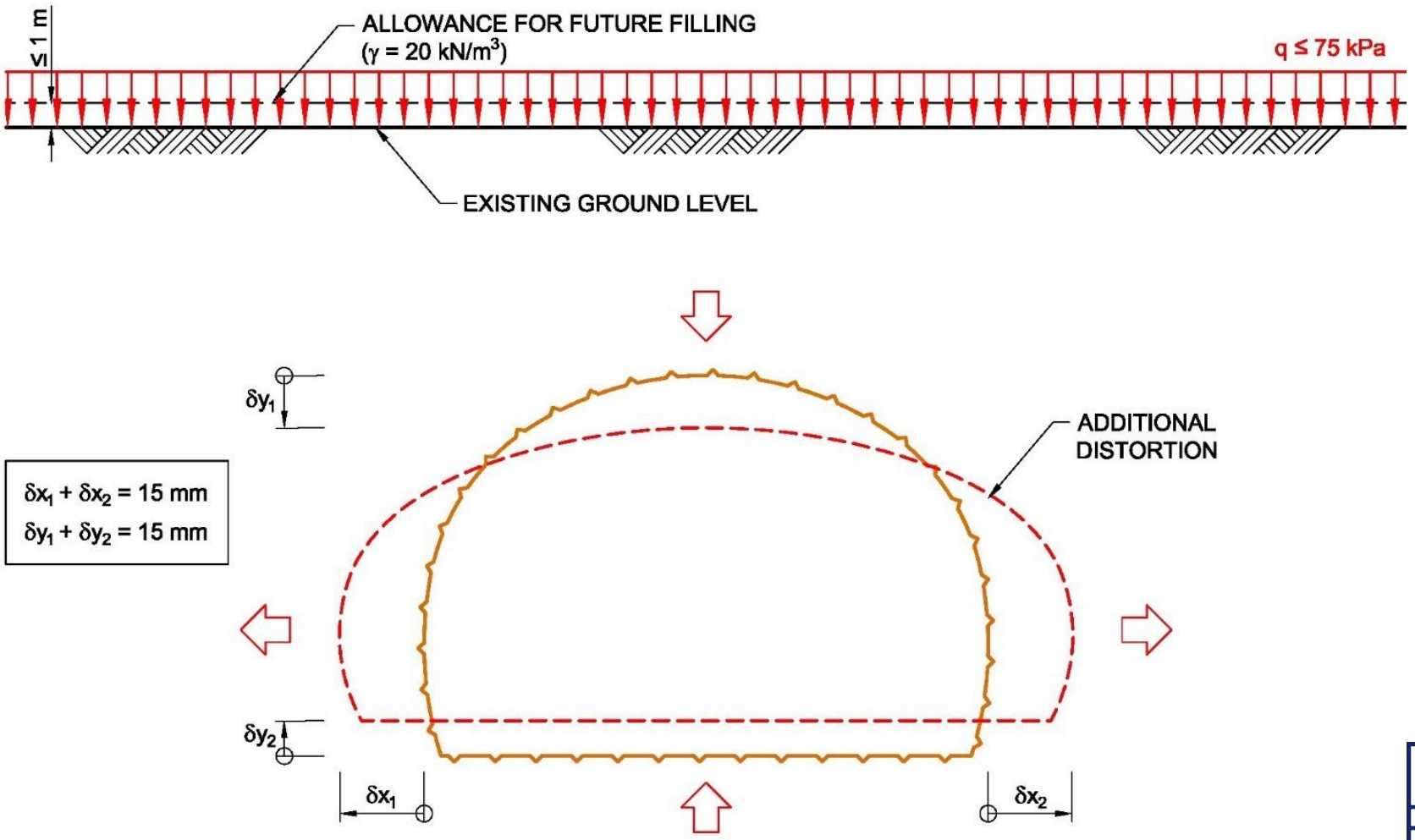


Project Scope & Technical Requirements

Specific developments – Roma St “Brisbane live”

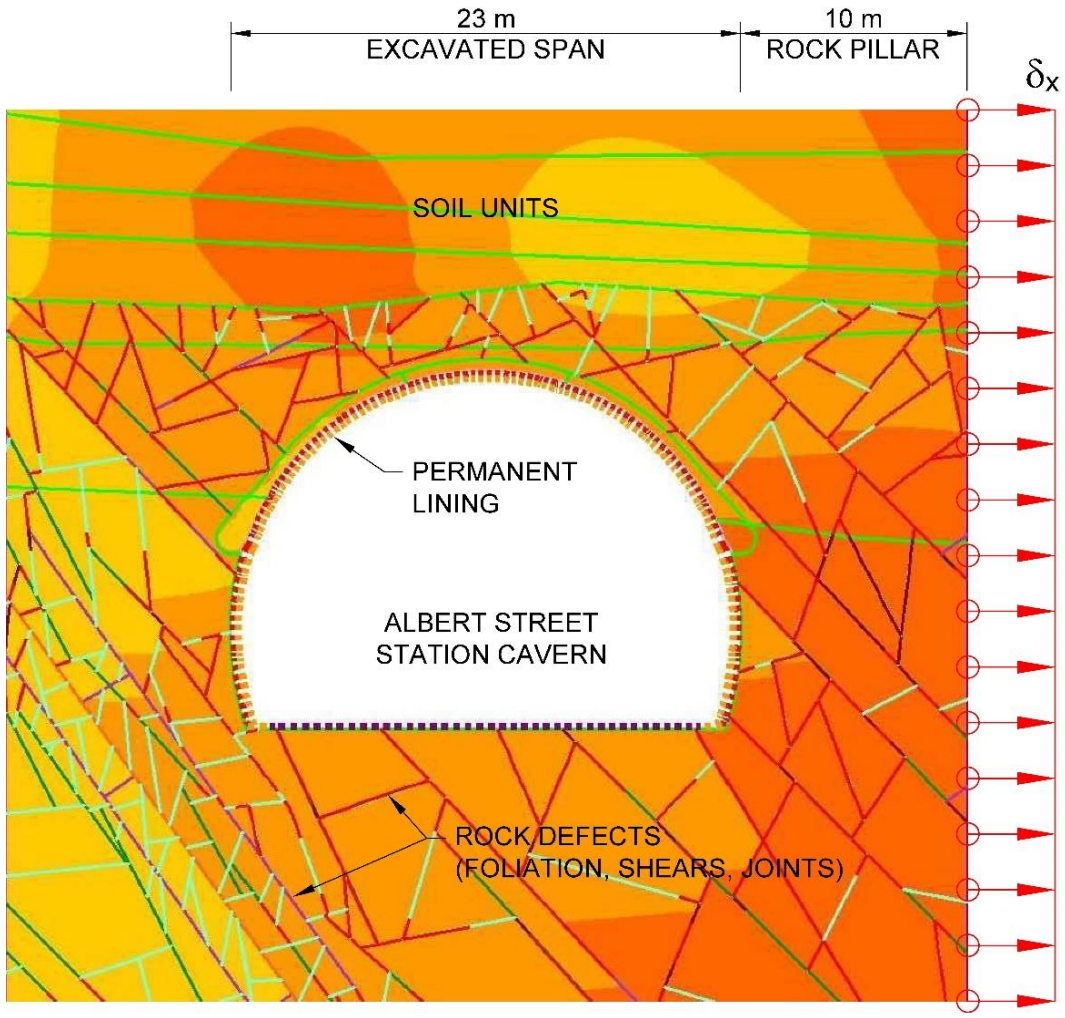
Project Scope & Technical Requirements

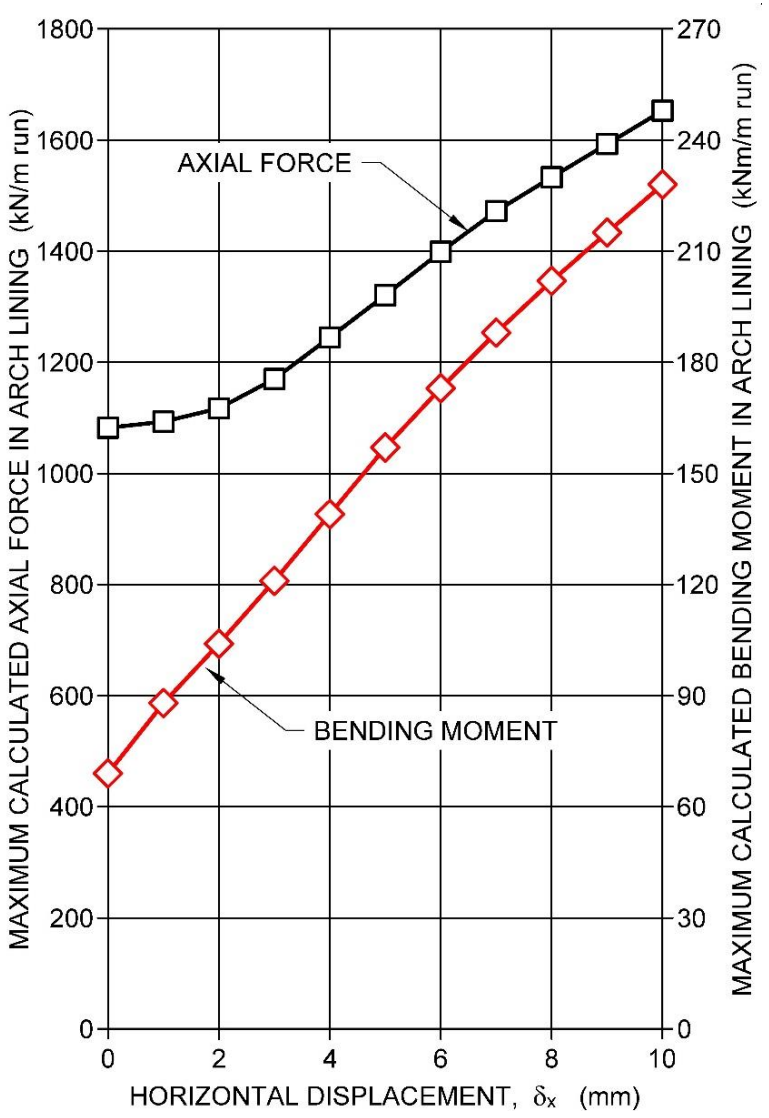
Ovalisation induced distortion allowance



Basement excavations

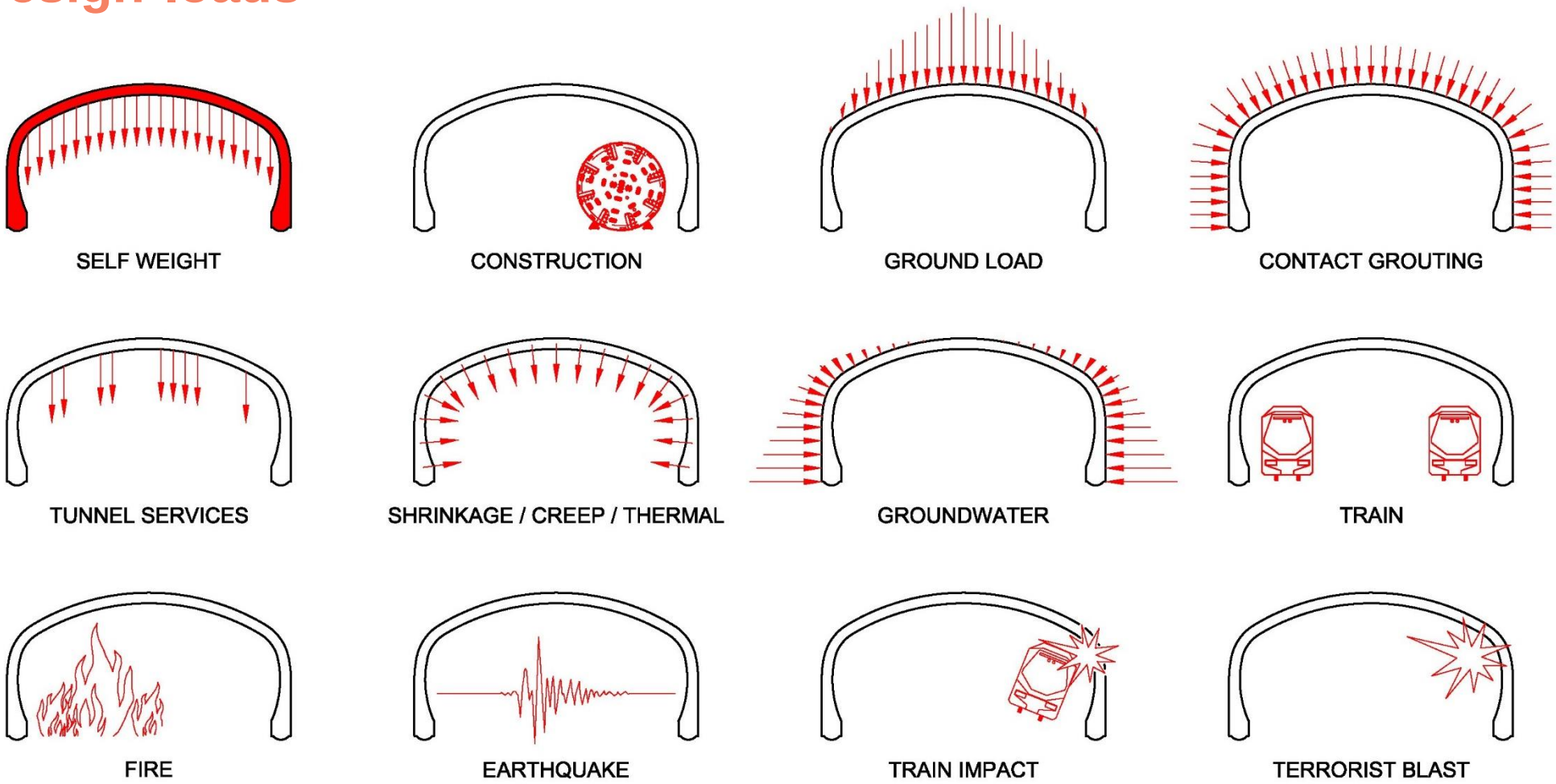
Impact on tunnel linings





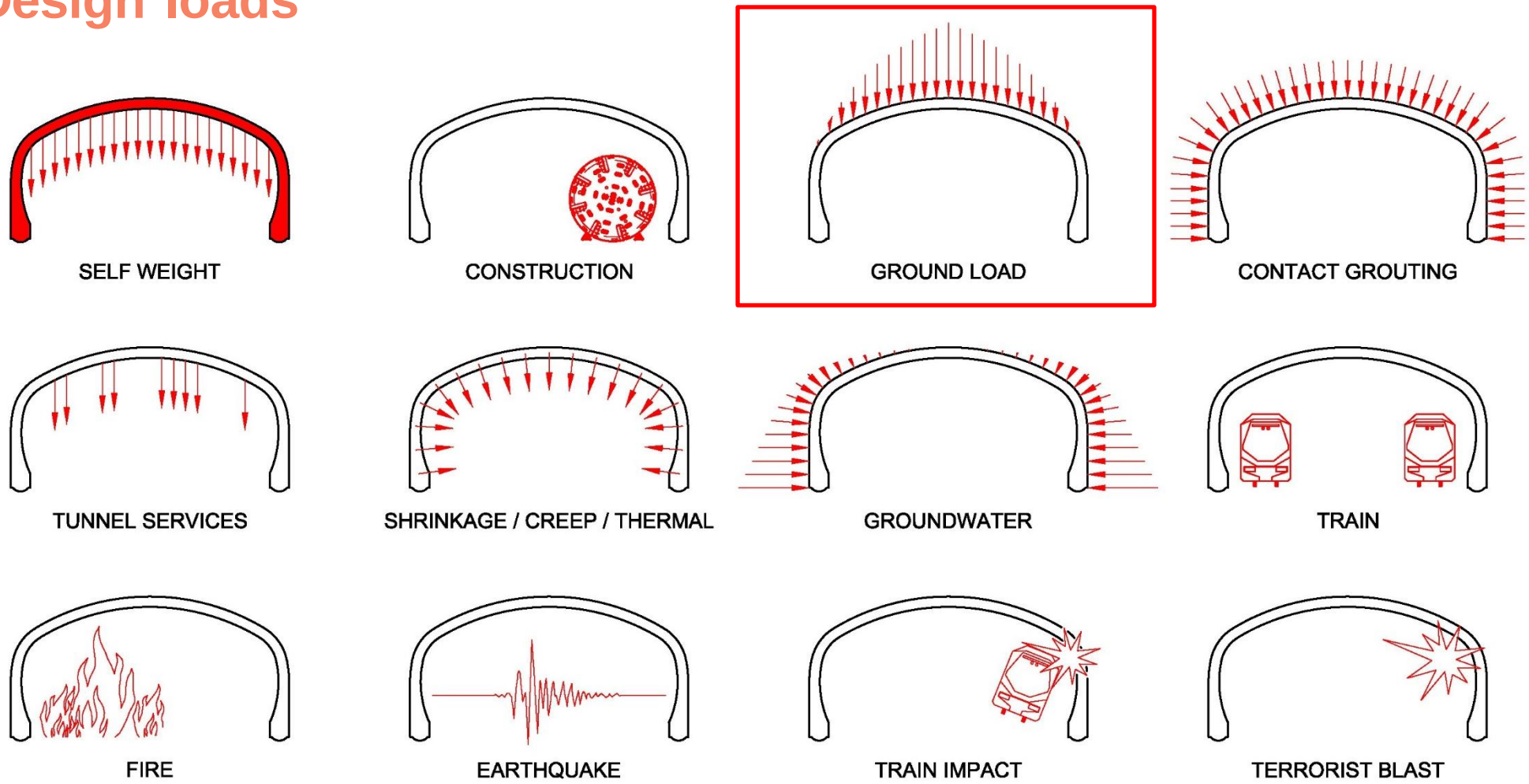
Structural design of tunnel linings

Design loads



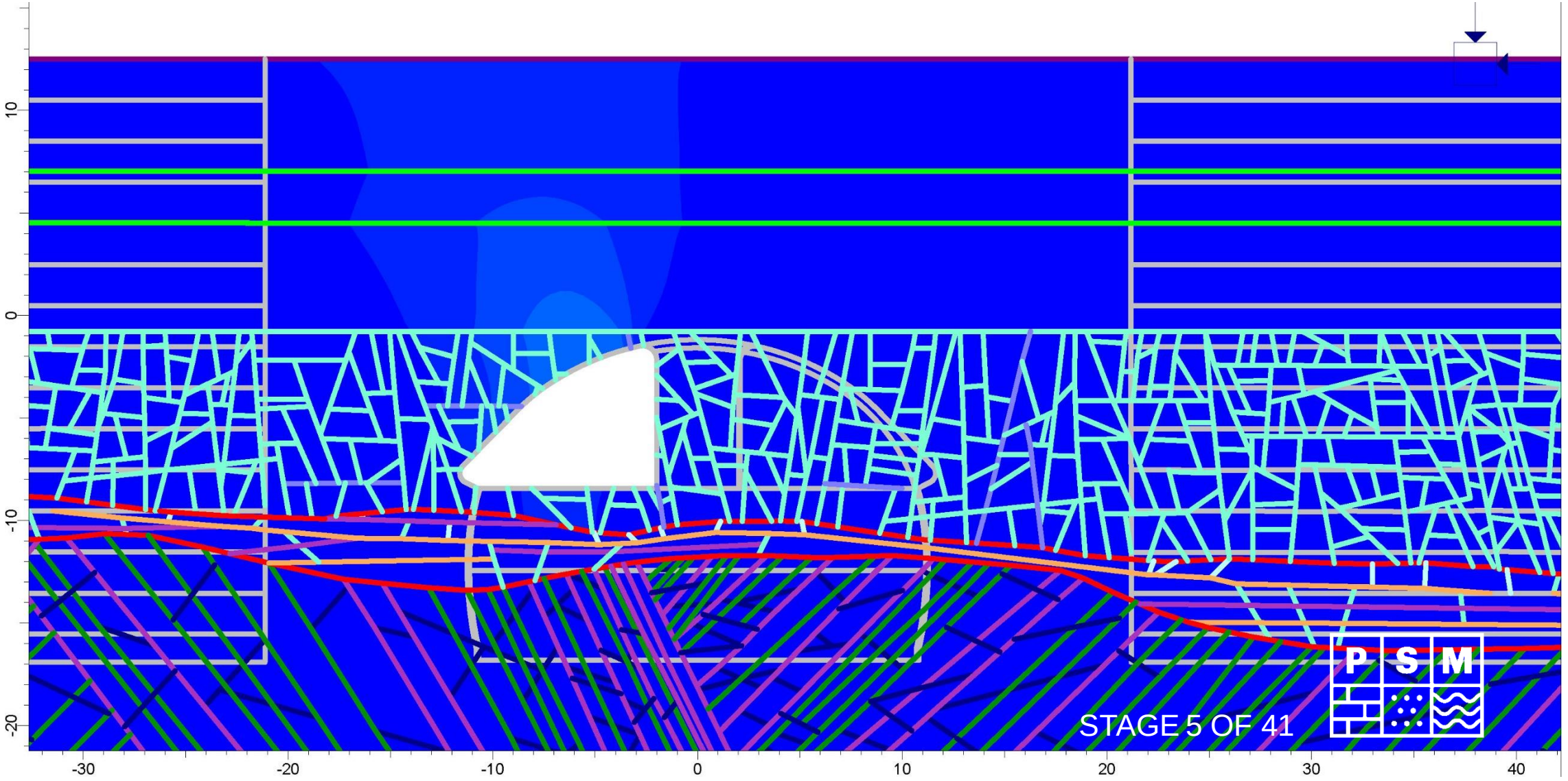
Structural design of tunnel linings

Design loads



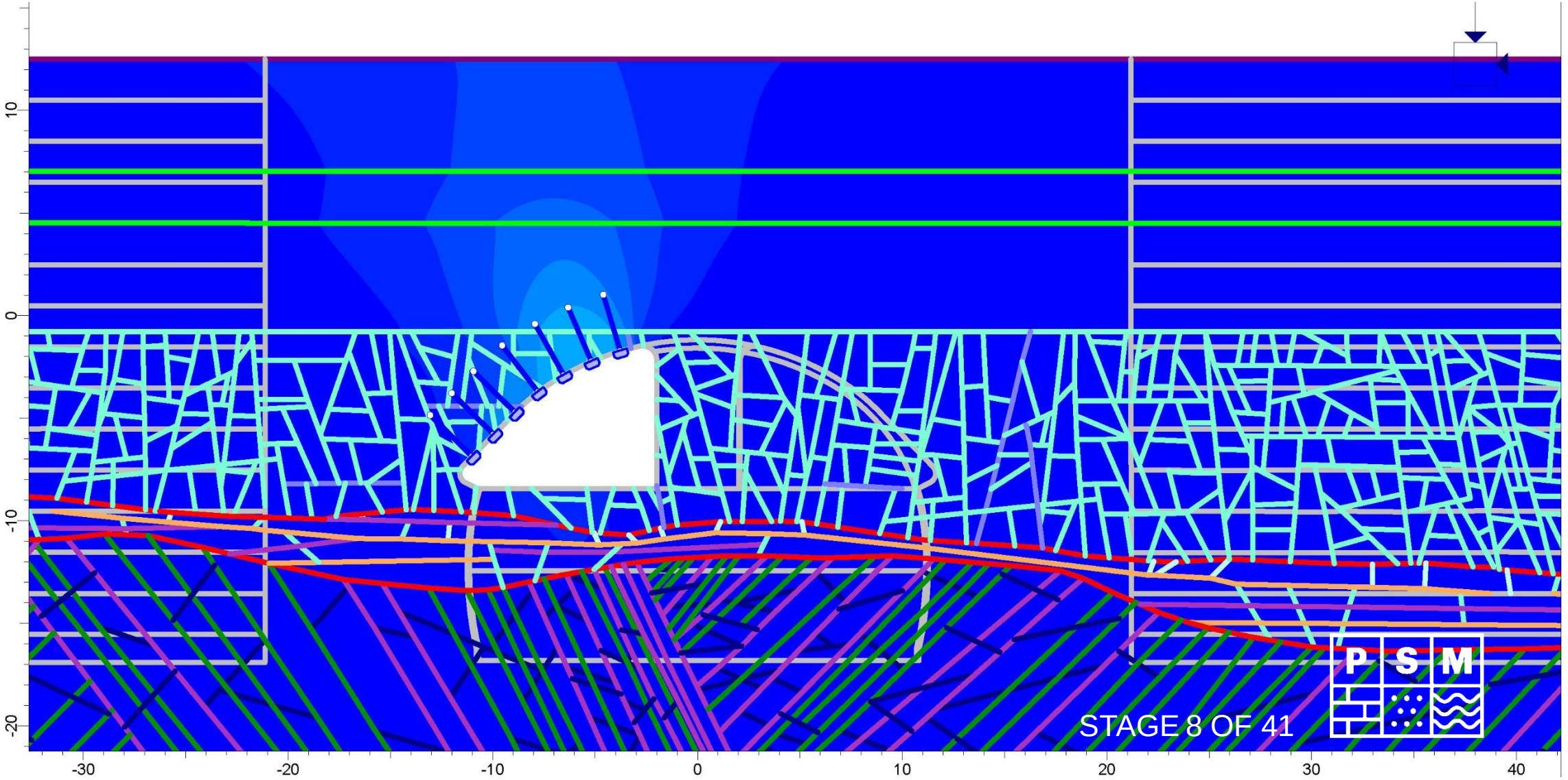
Structural design of tunnel linings

Ground load assessment example



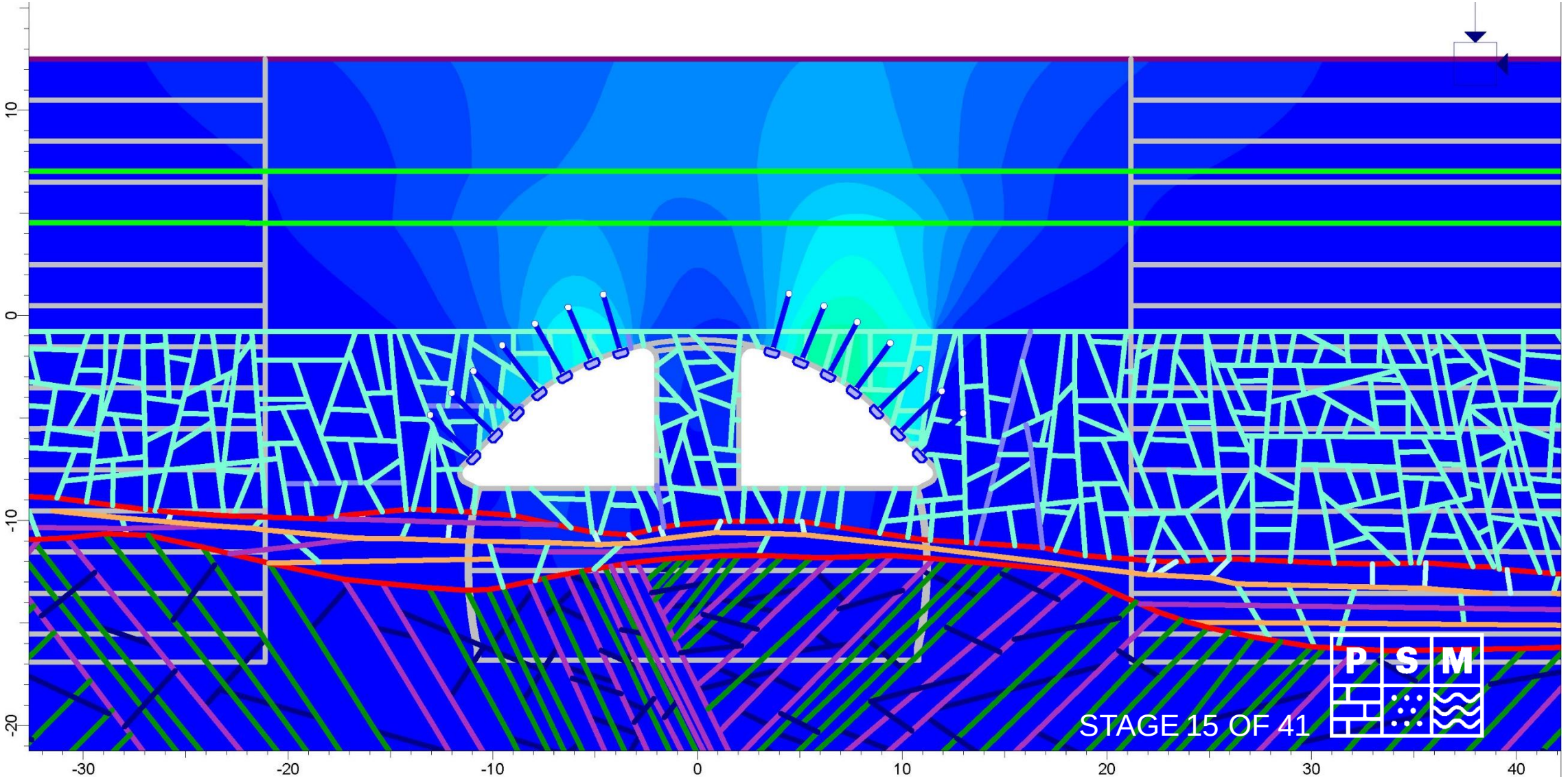
Structural design of tunnel linings

Ground load assessment example



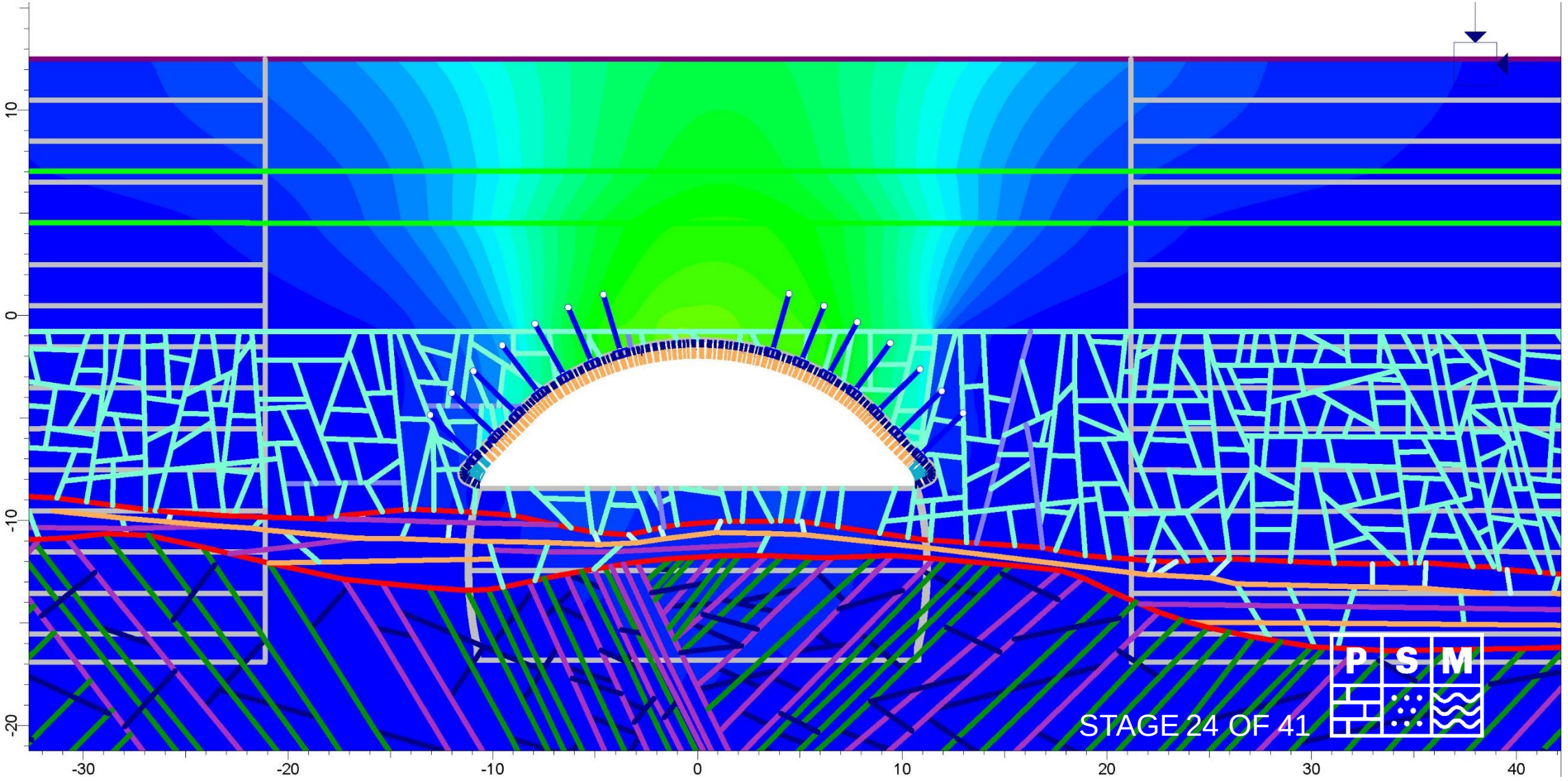
Structural design of tunnel linings

Ground load assessment example



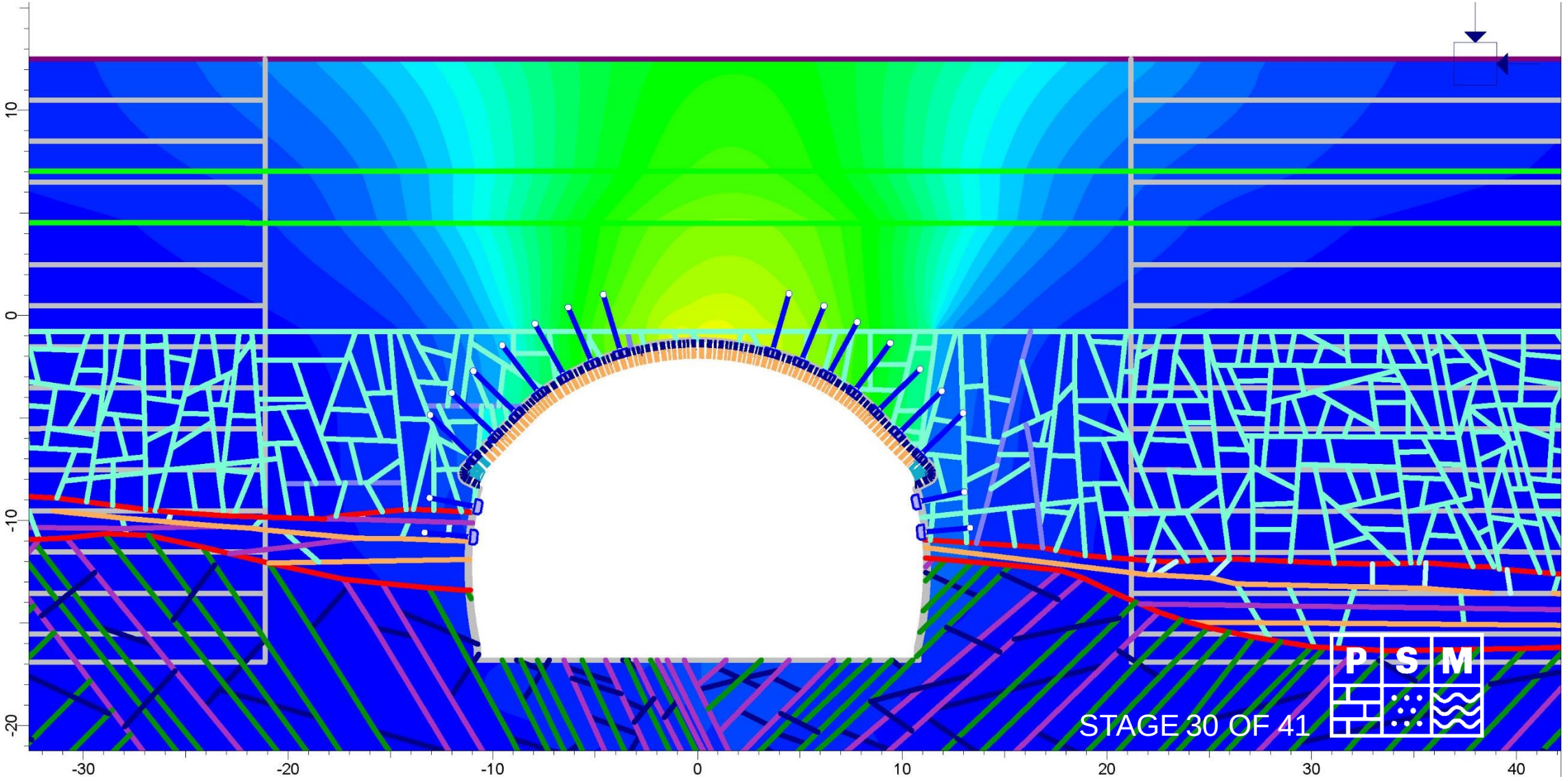
Structural design of tunnel linings

Ground load assessment example



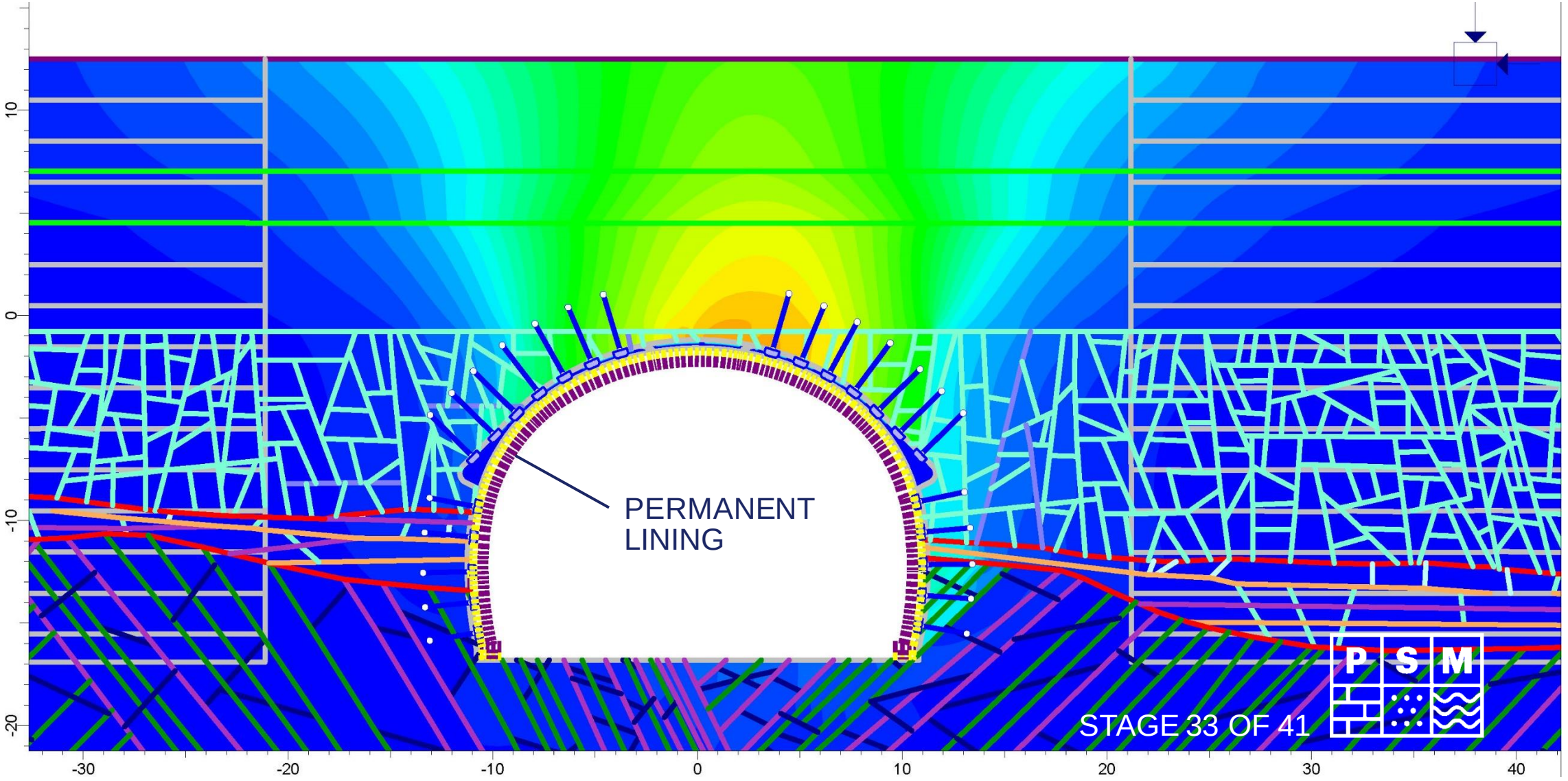
Structural design of tunnel linings

Ground load assessment example



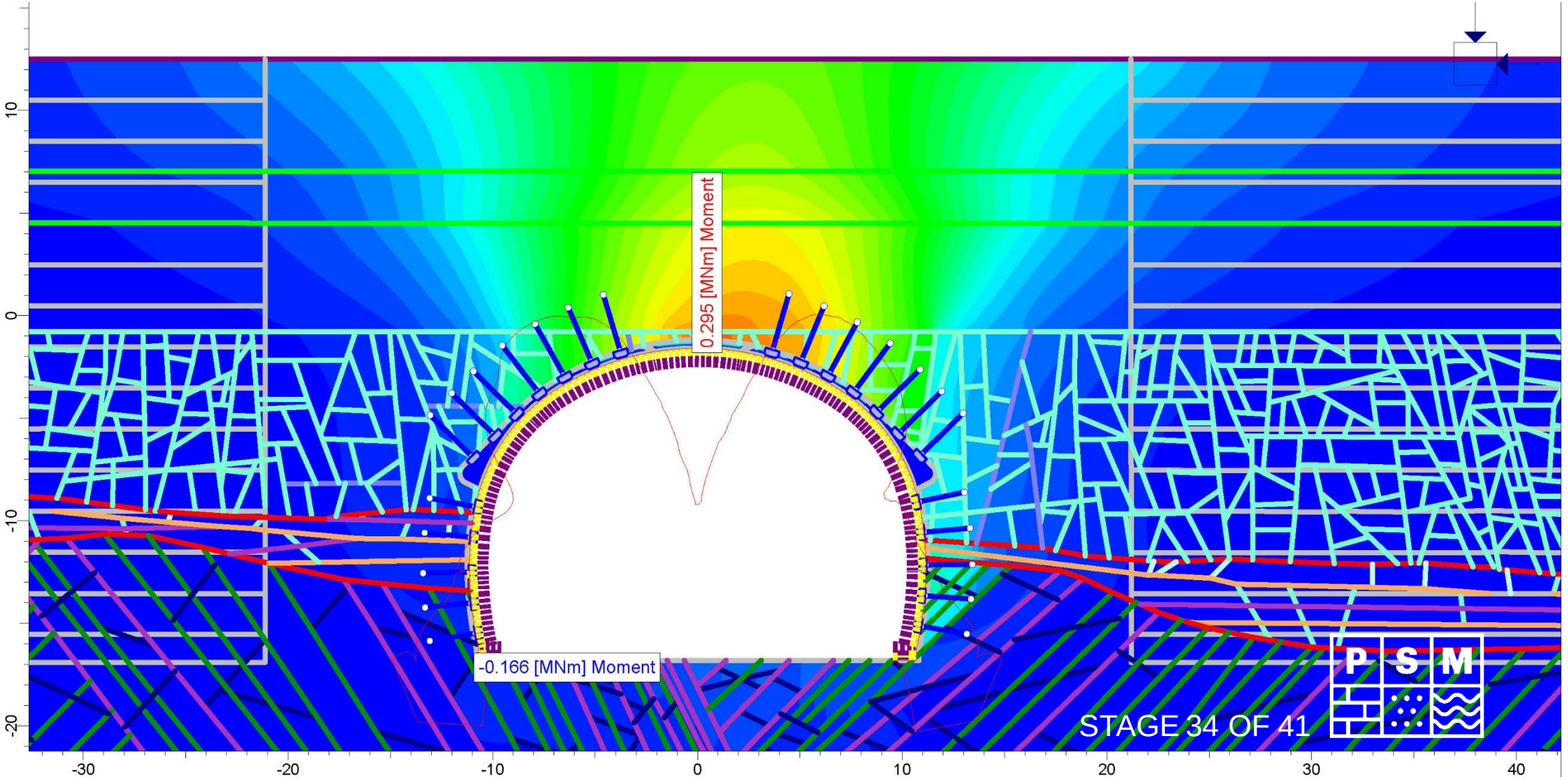
Structural design of tunnel linings

Ground load assessment example



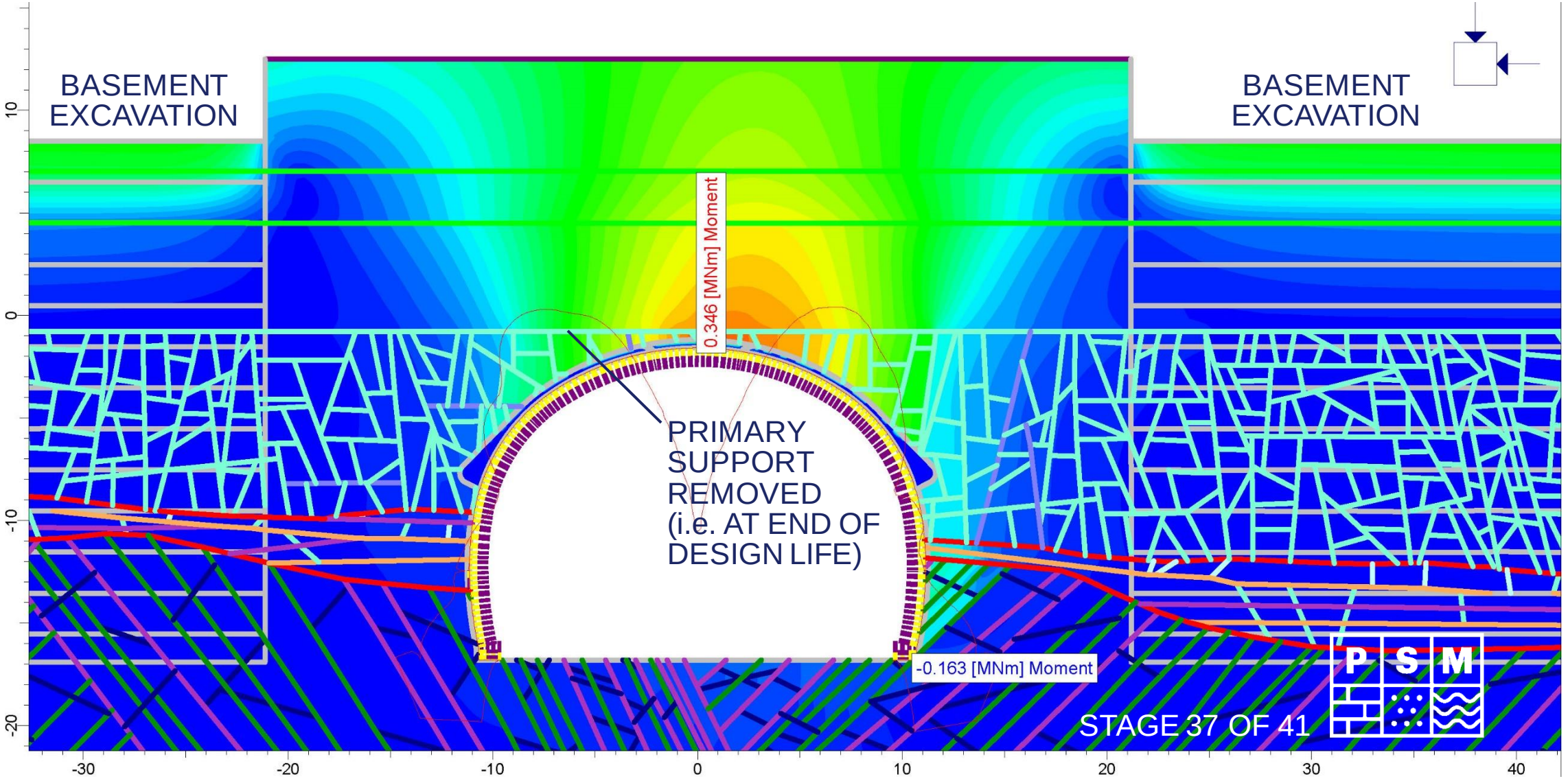
Structural design of tunnel linings

Ground load assessment example



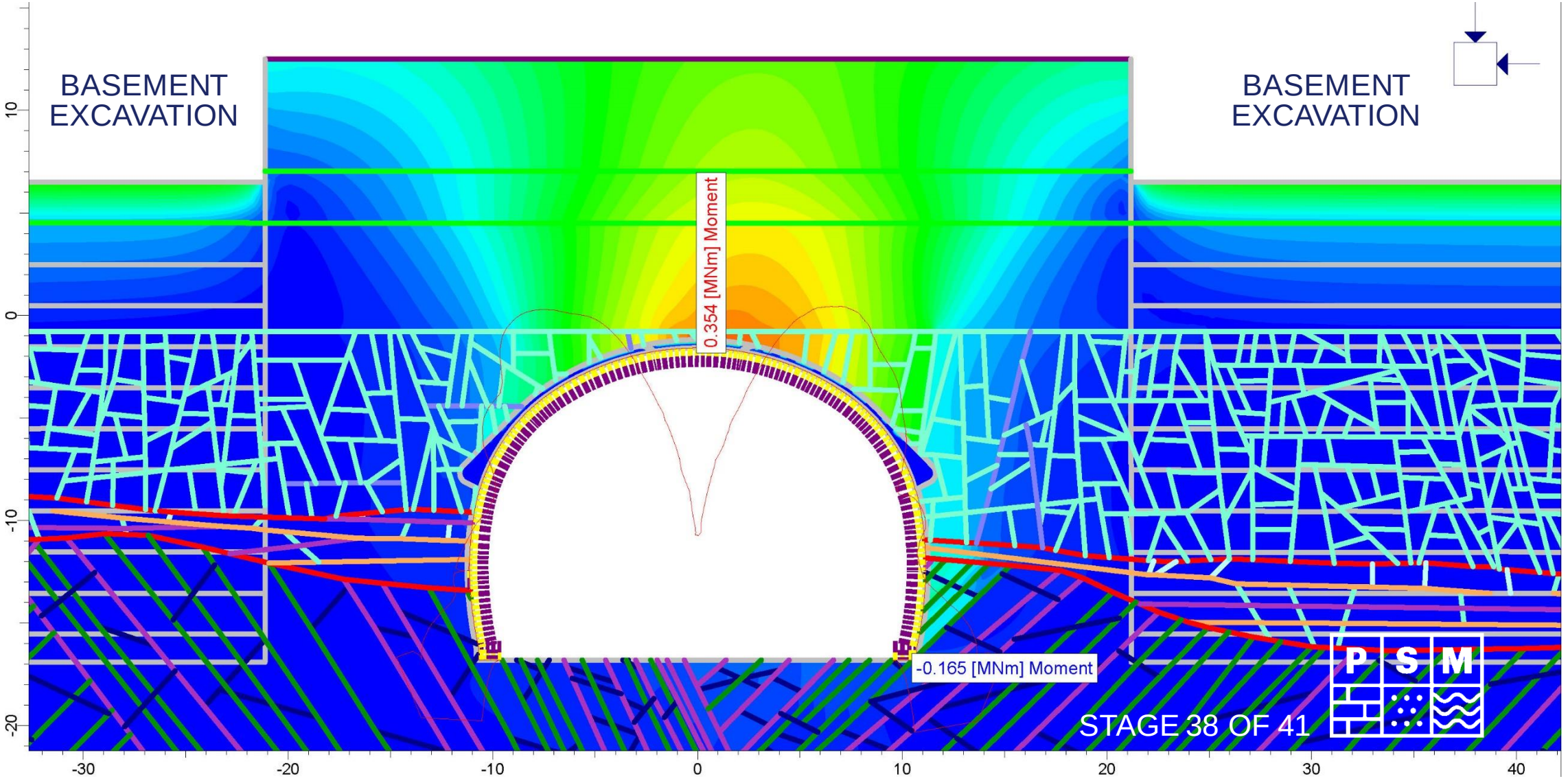
Structural design of tunnel linings

Ground load assessment example



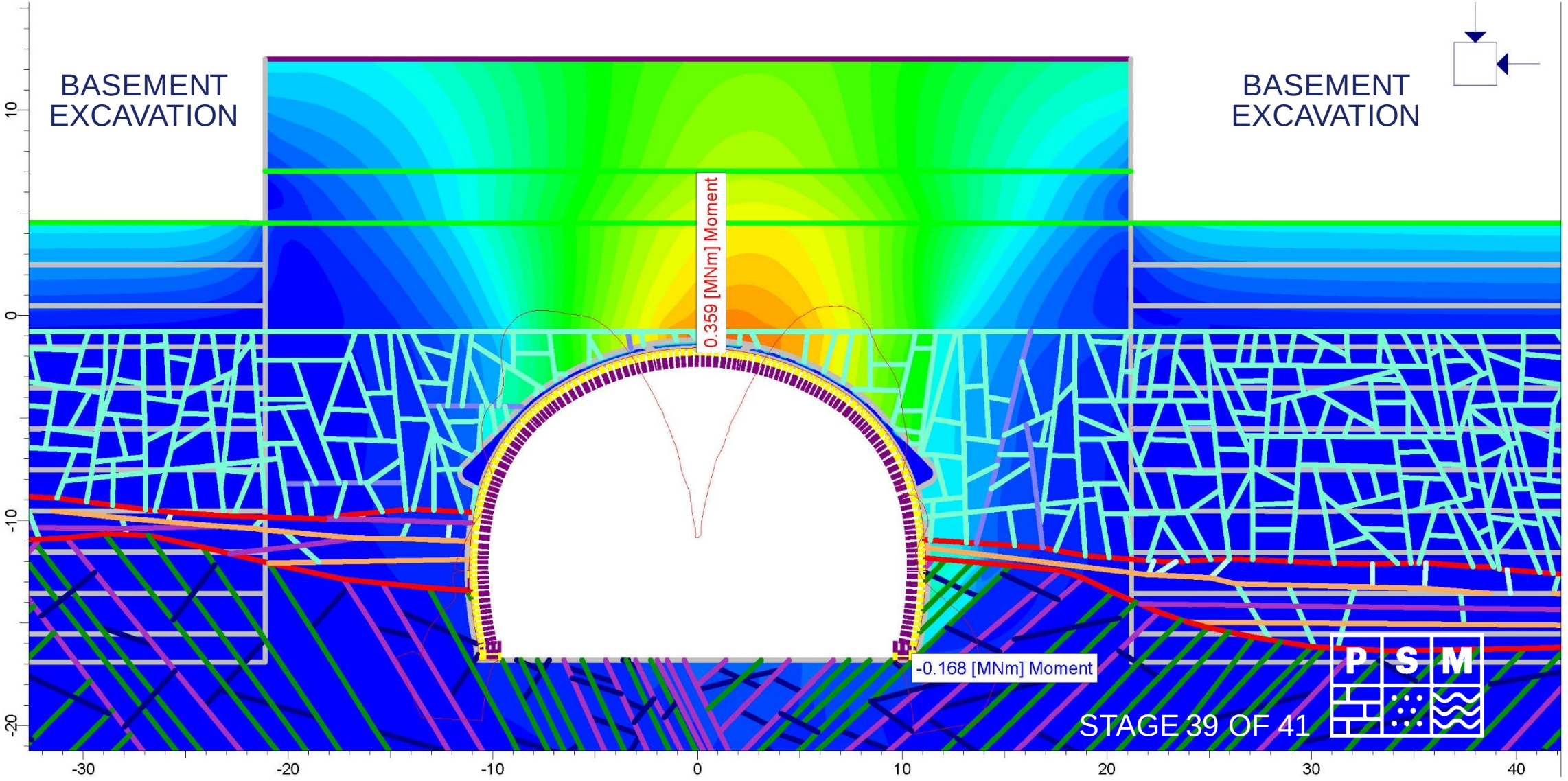
Structural design of tunnel linings

Ground load assessment example



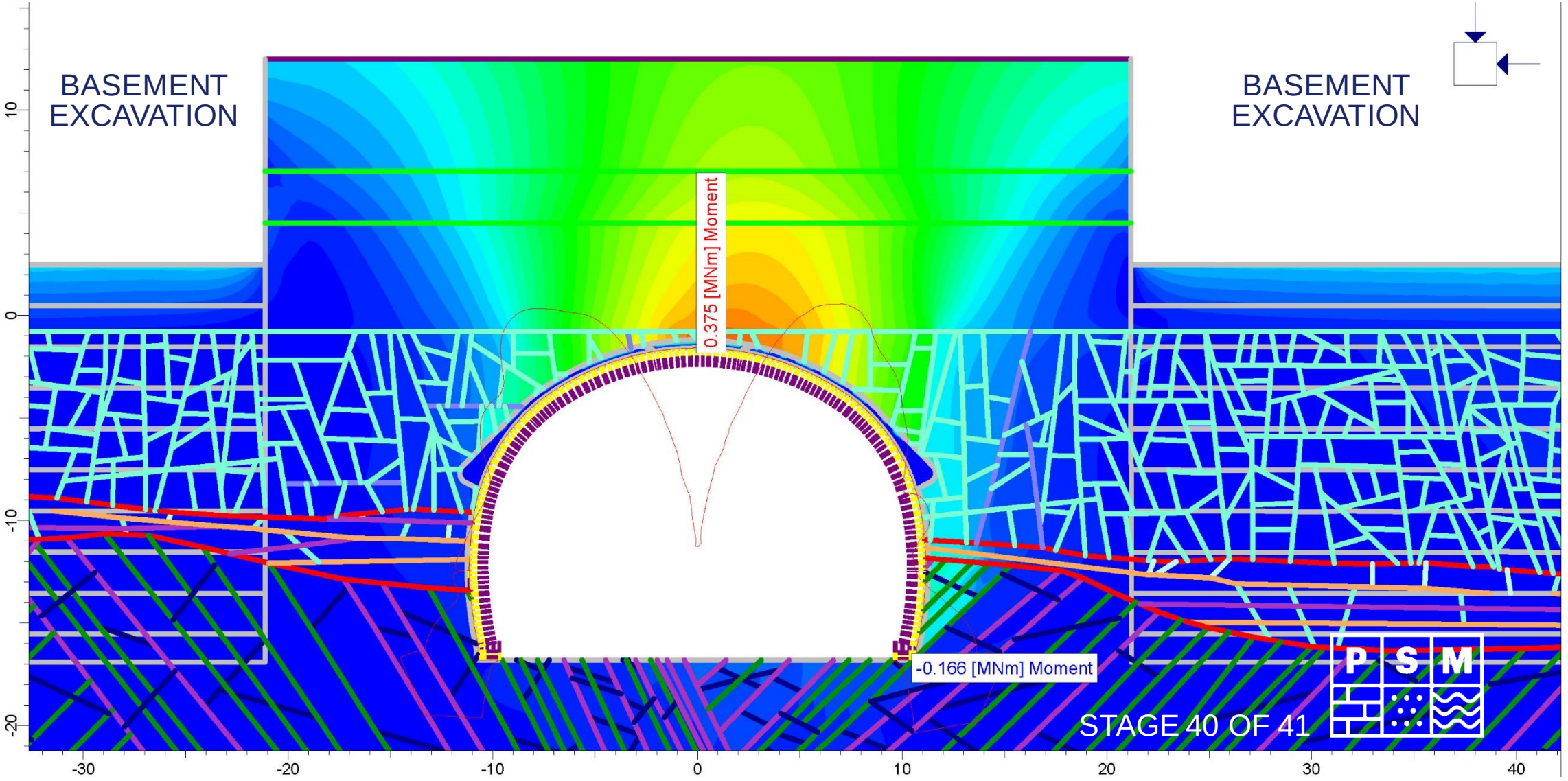
Structural design of tunnel linings

Ground load assessment example



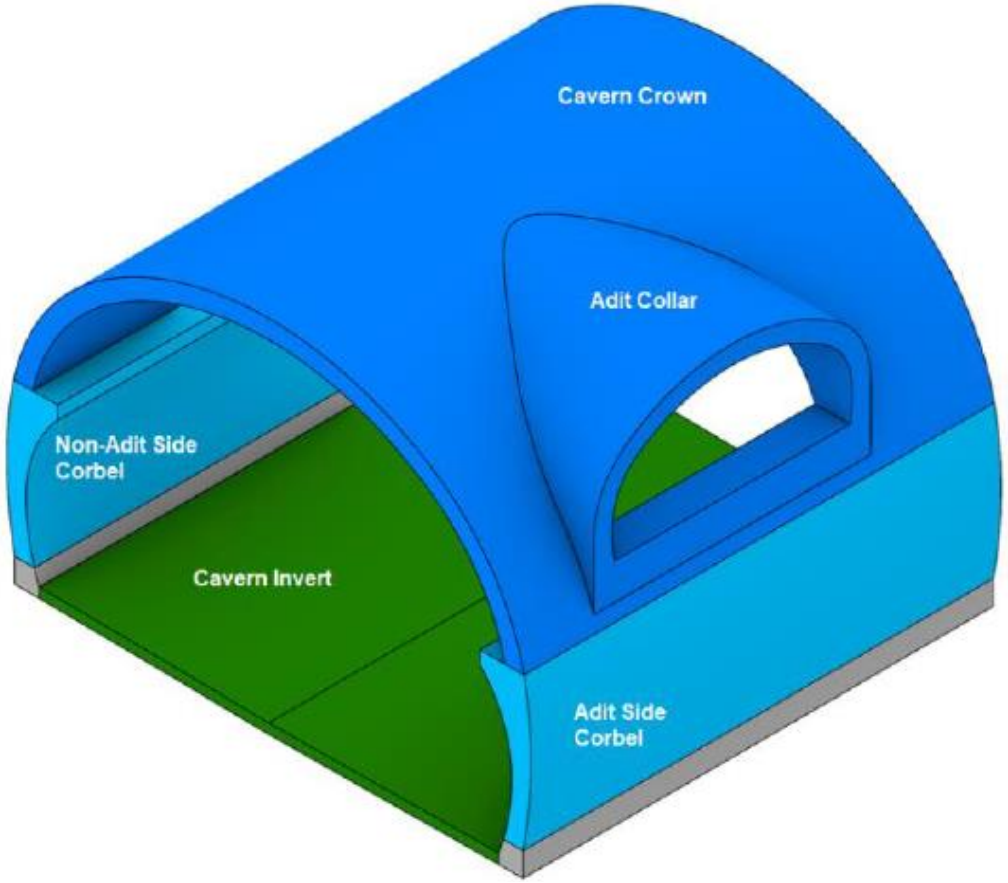
Structural design of tunnel linings

Ground load assessment example

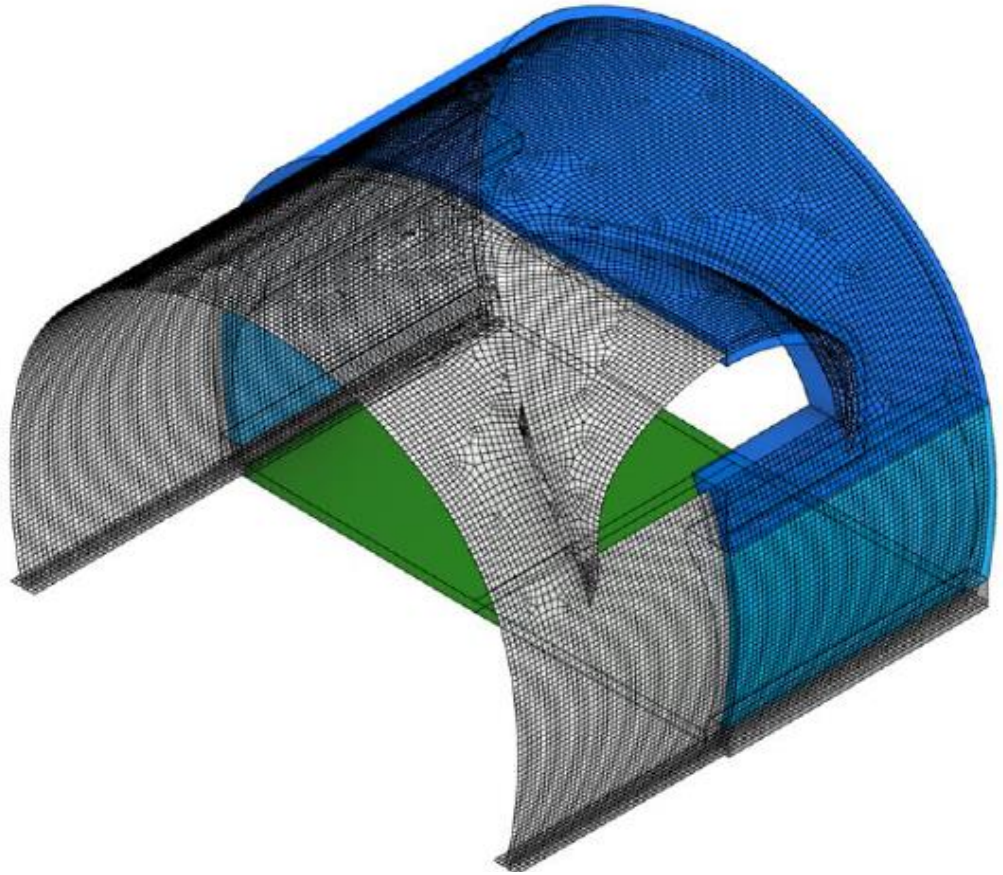


Structural design of tunnel linings

Finite element analysis



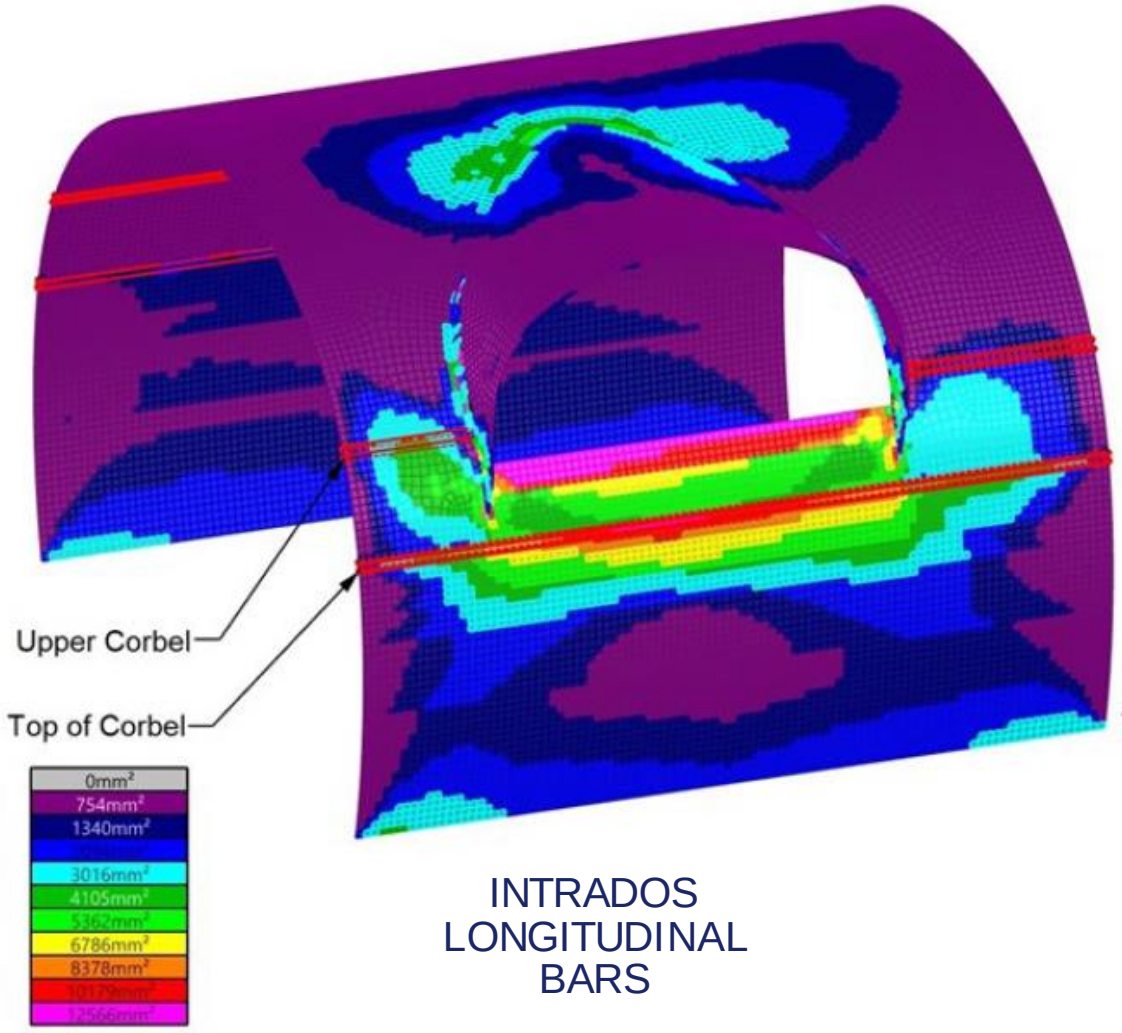
CAVERN
INTERSECTION
GEOMETRY



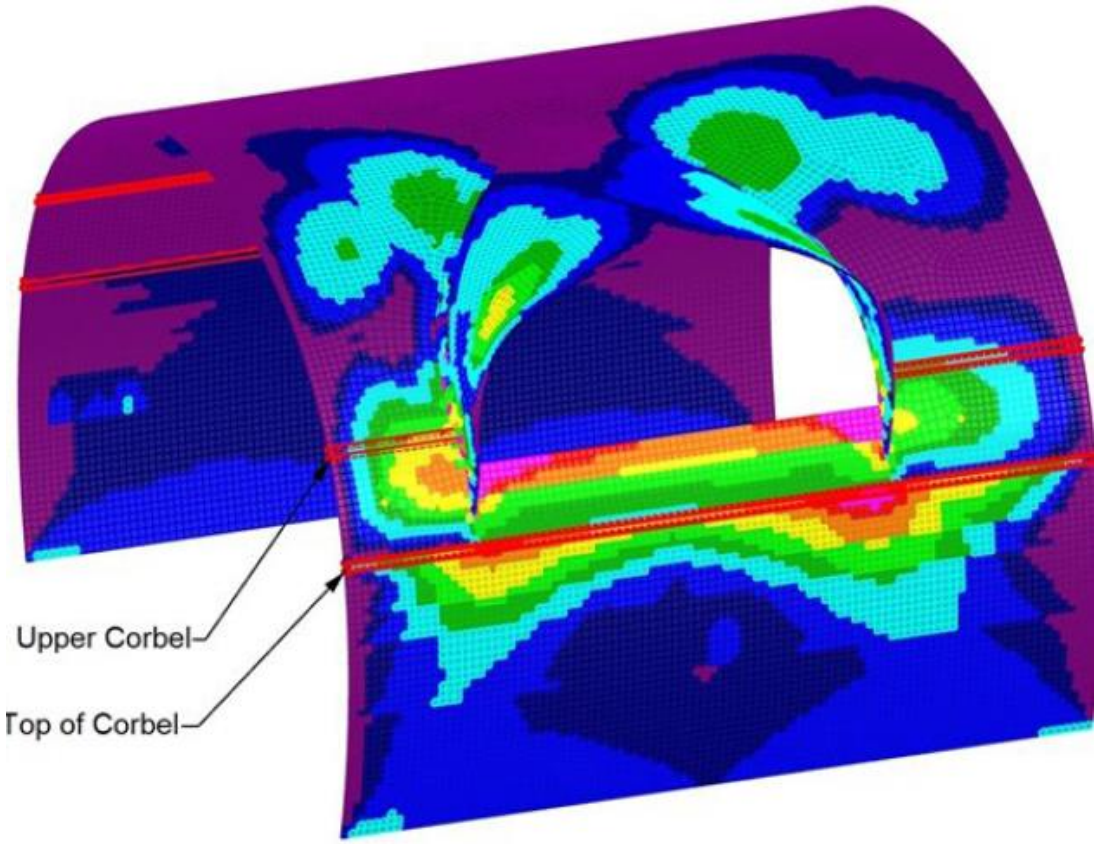
STRAND7
FINITE ELEMENT
MESH

Structural design of tunnel linings

Assessment of reinforcement quantities



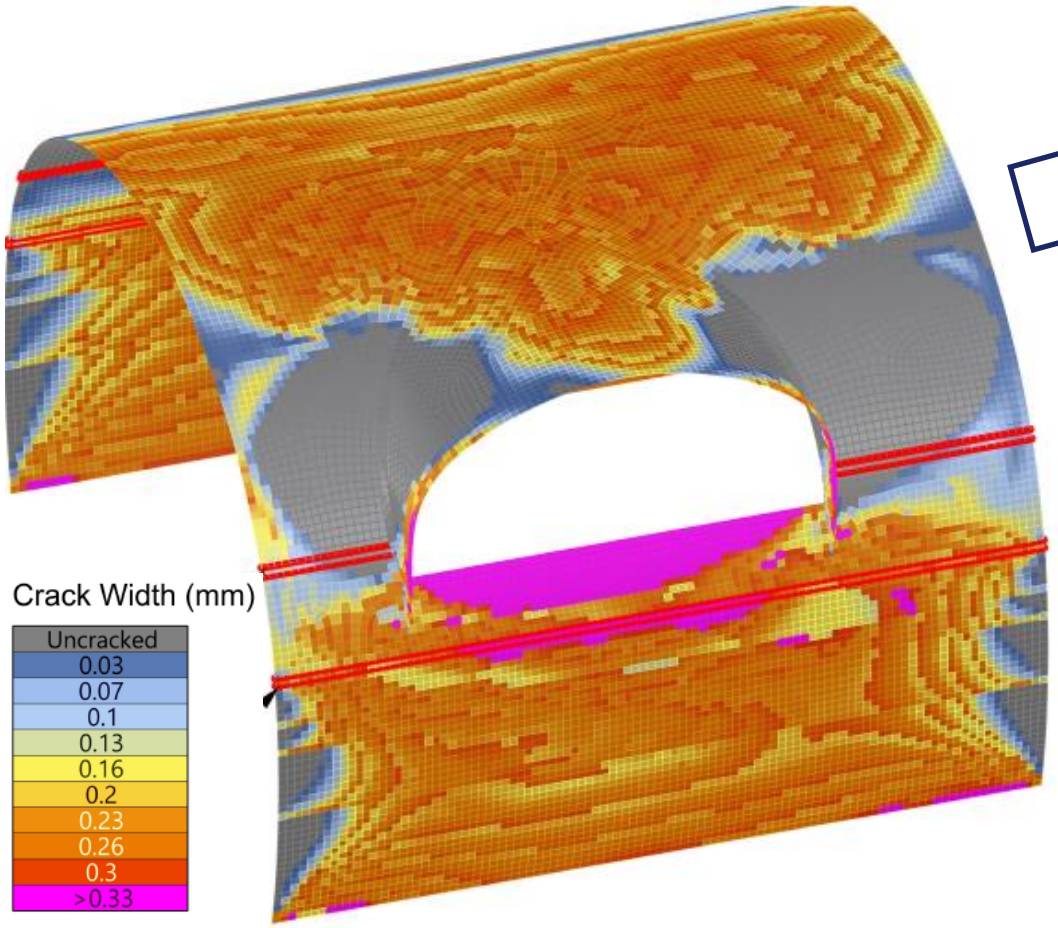
INTRADOS LONGITUDINAL BARS



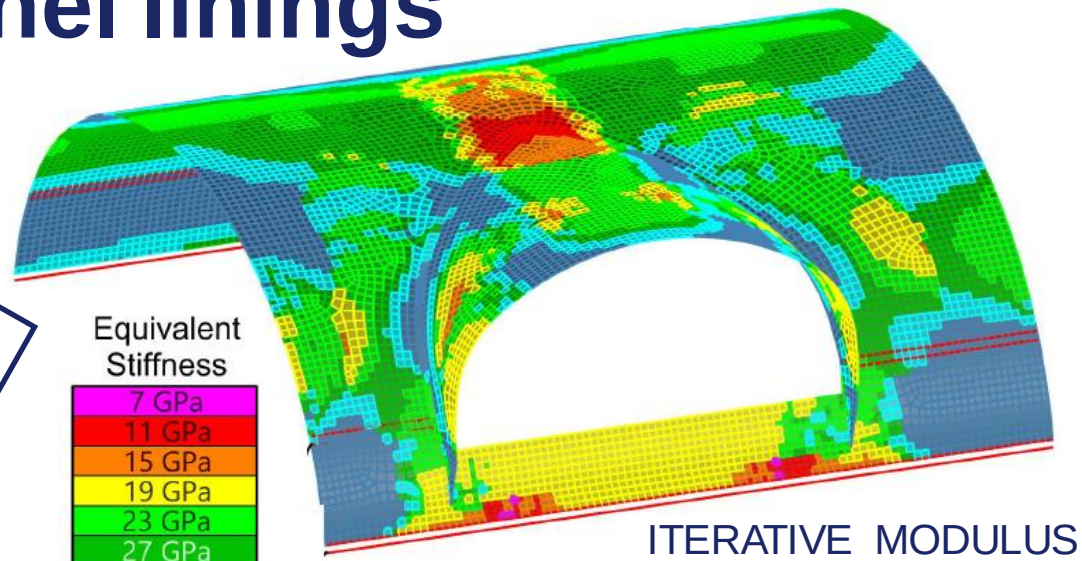
INTRADOS TRANSVERSE BARS

Structural design of tunnel linings

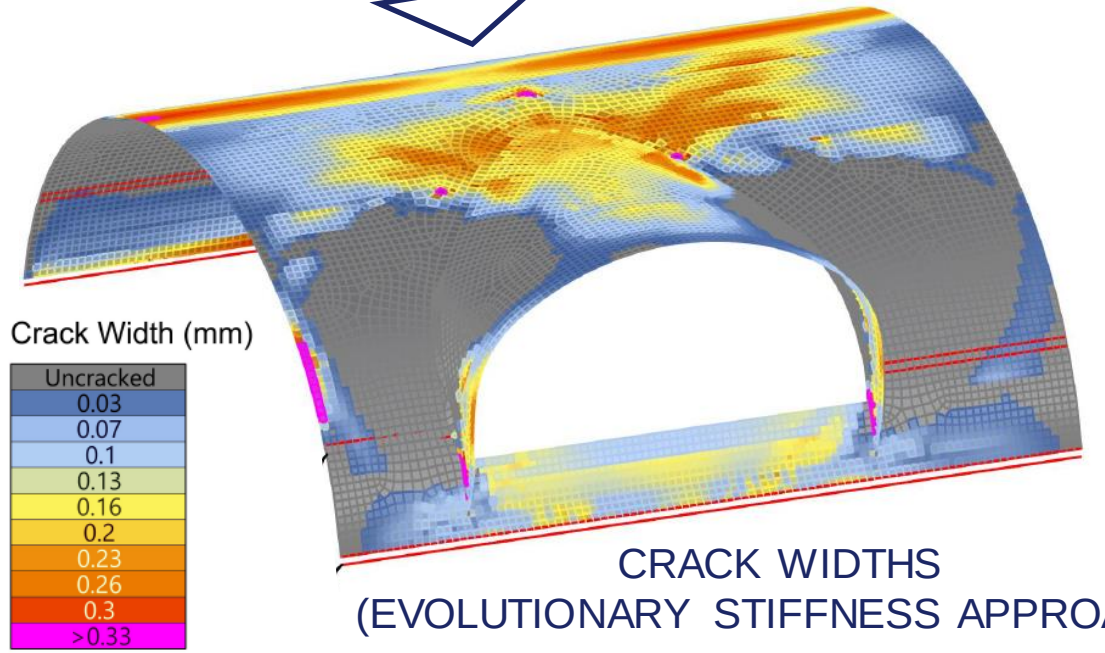
Calculation of crack widths



CRACK WIDTHS
(UNIFORM MODULUS)



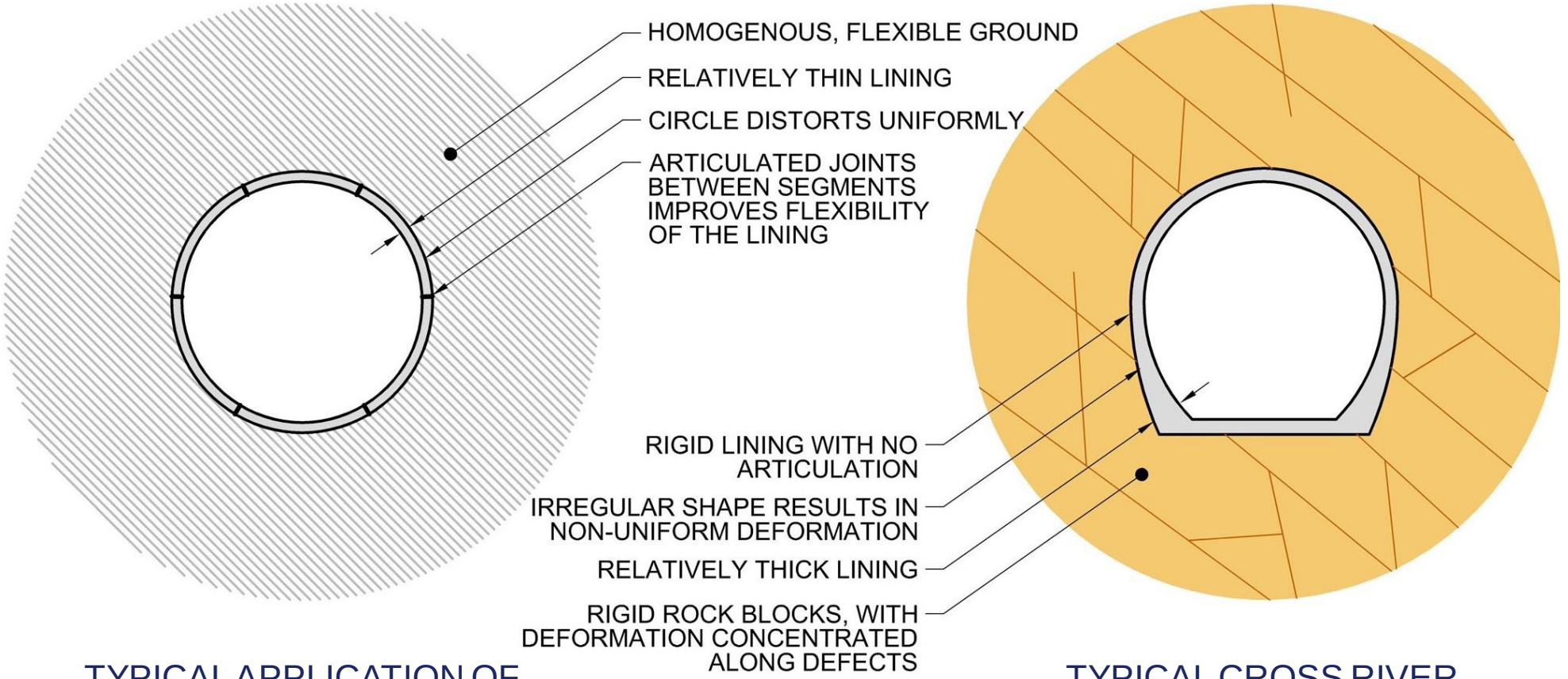
ITERATIVE MODULUS
(VARIES WITH LOAD)



CRACK WIDTHS
(EVOLUTIONARY STIFFNESS APPROACH)

Project Scope & Technical Requirements

Ovalisation criteria - Original application



TYPICAL APPLICATION OF LAND & TRANSPORT AUTHORITY GUIDELINE (SINGAPORE)

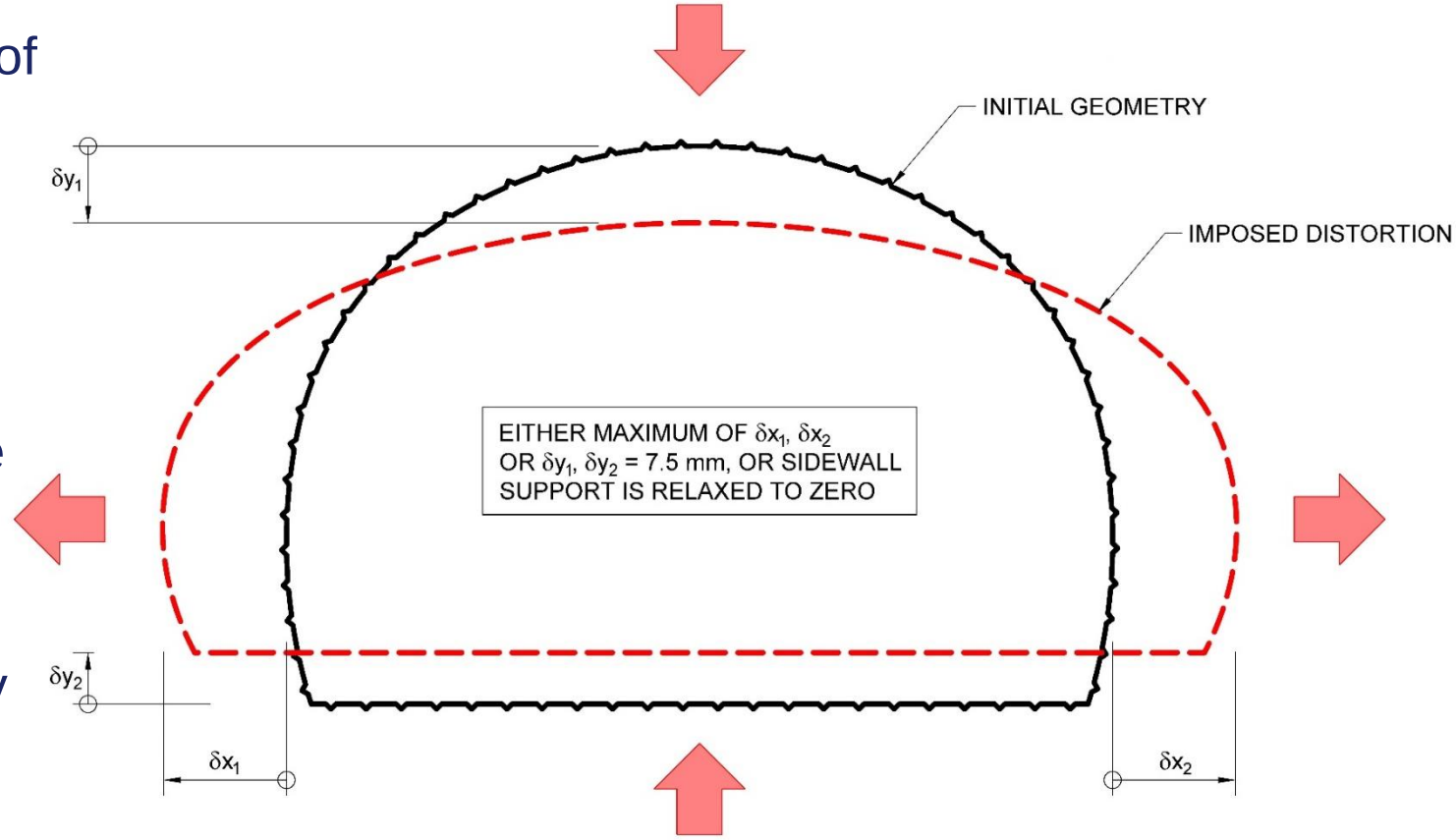
TYPICAL CROSS RIVER RAIL TUNNEL PROFILE (BRISBANE)

Project Scope & Technical Requirements

Application of ovalisation criteria to tunnel lining design

Agreed details in the application of the ovalisation criteria included:

- 7.5 mm radial deformation of sidewalls OR until sidewall support completely removed.
- Use of creep-adjusted concrete modulus (i.e. as per LTA guideline).
- Adoption of load factors of unity (consistent with LTA approach).



Conclusions and recommendations

- Consideration of the impacts of future development at the design stage is a simpler and more efficient means of facilitating development around metro stations compared to assessing redevelopment proposals as they arise.
- For the generic development requirements in the PSTR a sensible balance was achieved that:
  - Avoided placing excessively onerous requirements on tunnel design.
  - Facilitates extensive development over and adjacent to tunnels.
- When considering potential future over tunnel development this should be limited to realistic scenarios, with impacts assessed based on appropriate ground structure interaction methods.
- The ovalisation clause in the PSTR is based on overseas practice for circular, segmentally lined tunnels constructed in soft soils which are not relevant to the CRR mined tunnels. The imposed deformation approach should be constrained to the tunnelling conditions for which they were developed.

Thank you