

Building around existing tunnels

Seminar



Preliminary Impact Assessment for New Building Applications over existing Tunnels

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ENGINEERS
AUSTRALIA

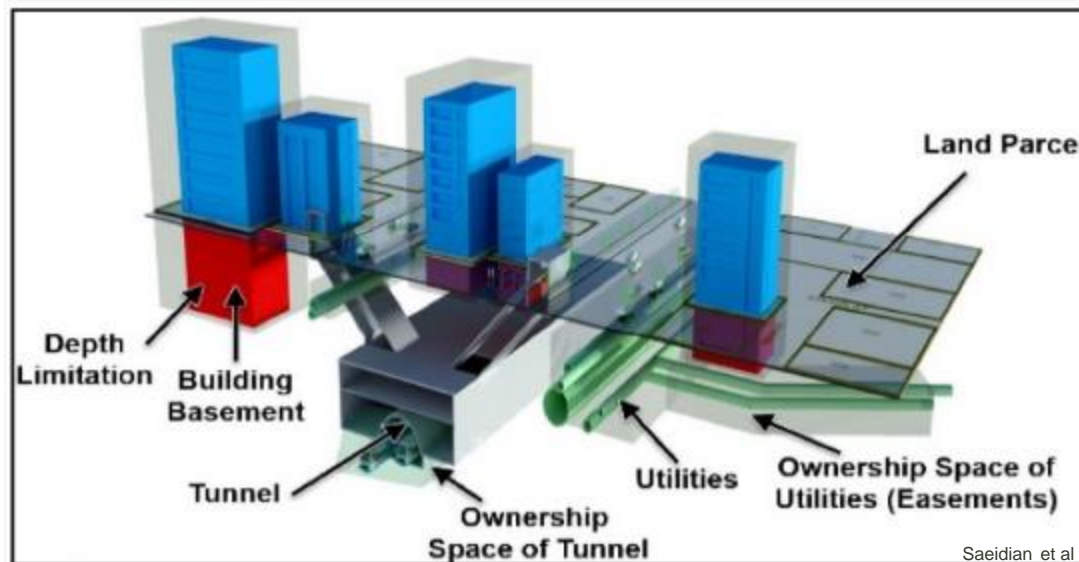


AUSTRALIAN GEOMECHANICS SOCIETY

Disclaimer: The speakers are presenting their own personal views and are not expressing the view of ATS or AGS.

Introduction

- New developments require development application approvals
- New developments in vicinity of existing tunnels require approval from tunnel asset owner
- Provide guidance to developers, engineers and tunnel asset owners for undertaking and assessing impact assessments for development applications



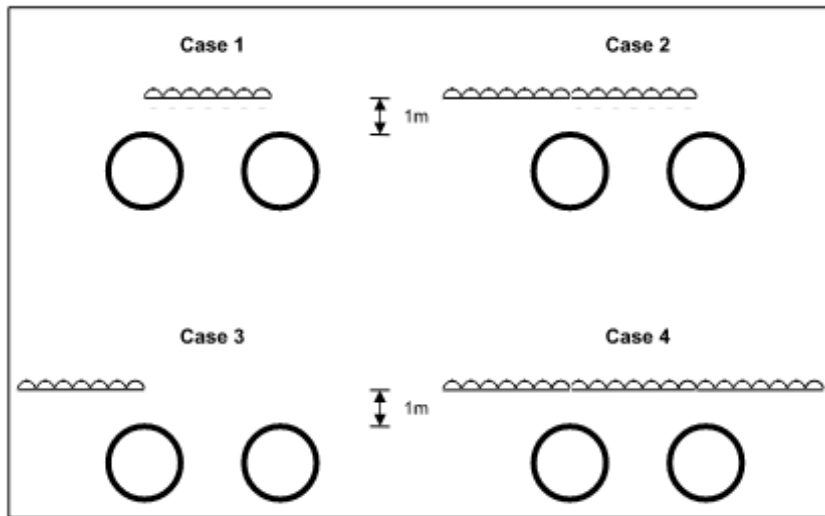
Allowable Conditions

- Future development conditions imposed upon the tunnel may be defined during the design and construction of the tunnel:
 - Loading from building onto tunnel
 - Unloading on tunnel due to bulk excavation (basement)
 - Allowable movements of tunnel structure, limit cracking of tunnel and waterproofing impacts

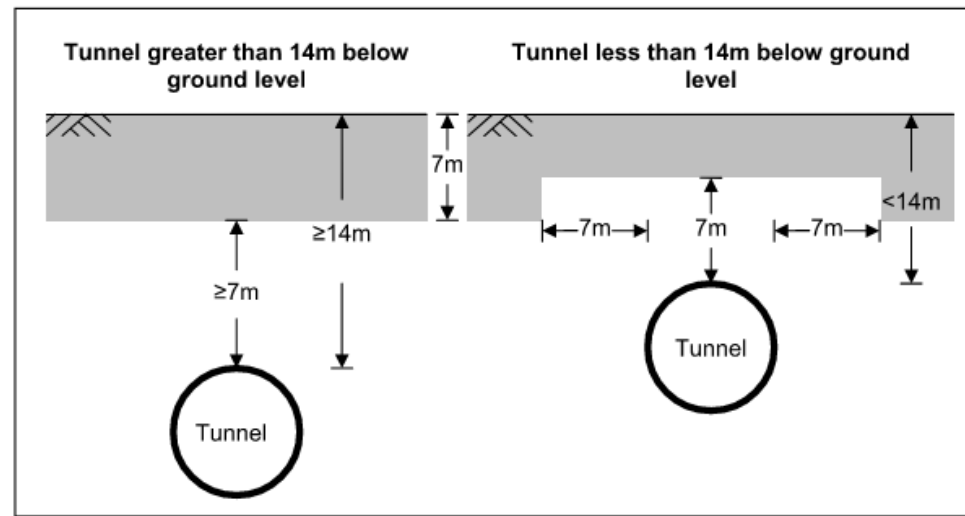


Allowable Conditions

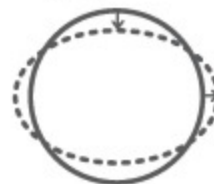
Loading



Unloading



Distortion



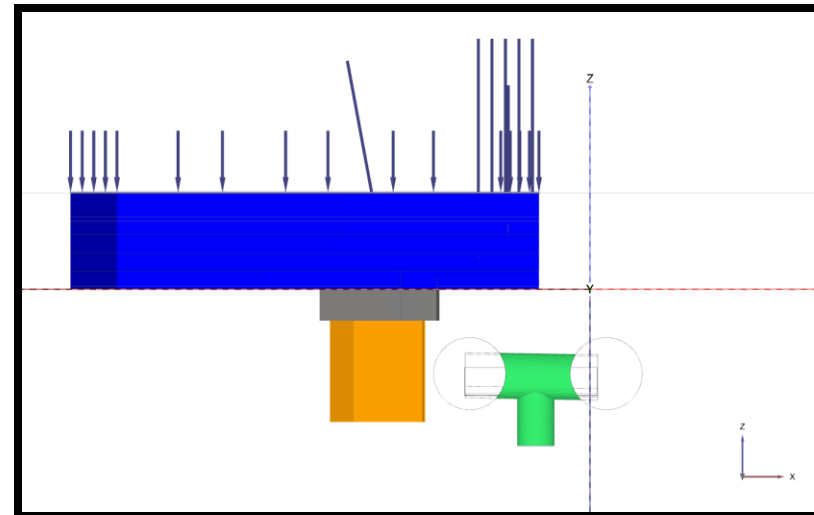
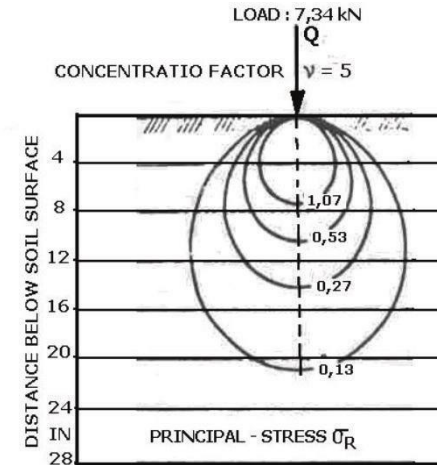
Development Applications

- Allowable conditions provide certainty to developers on what can or cannot be undertaken
 - Building height/form (additional loading)
 - Basement excavation (unloading)
 - Allowable movement (distortion) to protect existing tunnel integrity

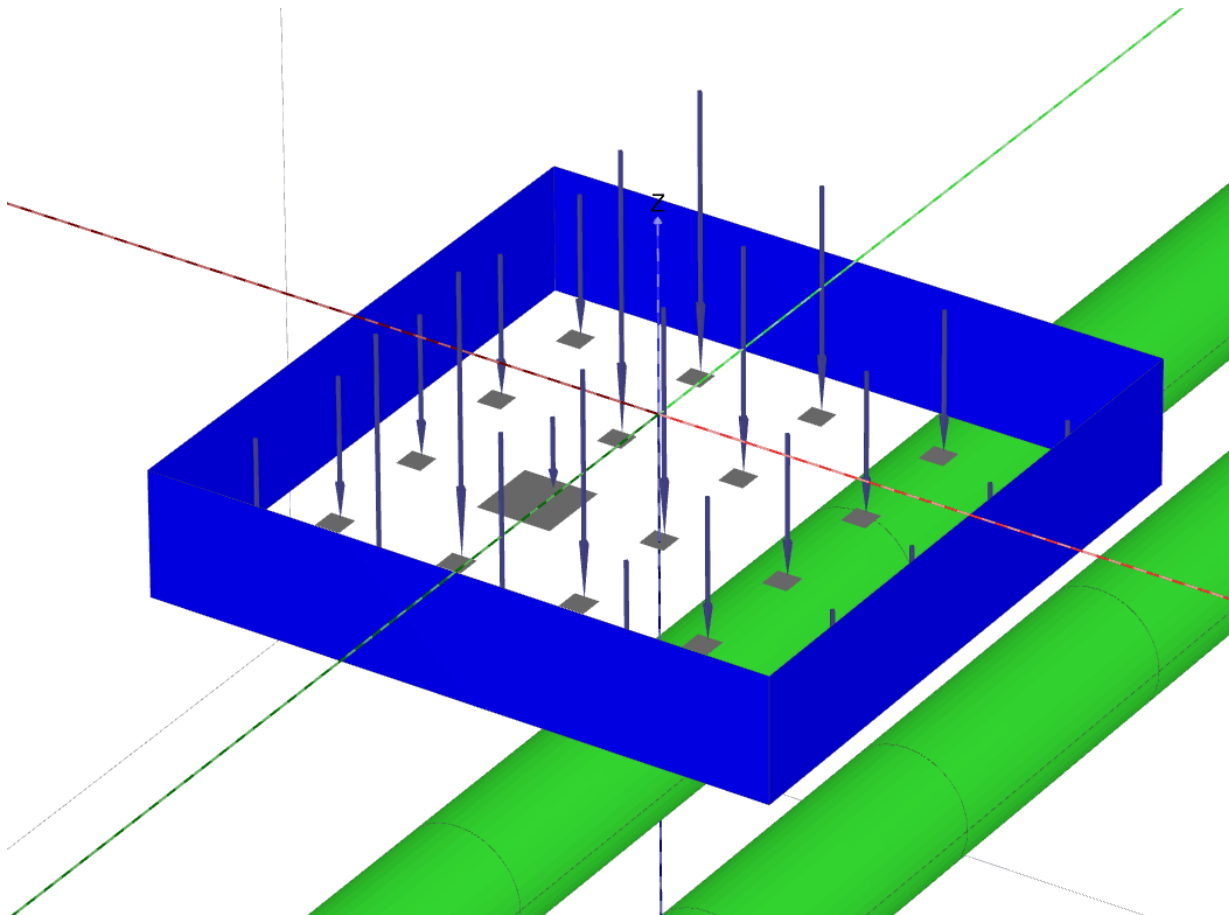
**Planning
Application**
APPROVED

Development Applications

- Simple cost effective methods of engineering assessments to support the development application
 - Loading via simple footing theory (Boussinesq)
 - Unloading via simple 2D continuum FEM
 - Distortion via simple 2D continuum FEM
- Rigorous and detailed engineering assessments undertaken where developers step outside of the Future Development Allowable Conditions
 - Loading and unloading impacts on structural actions of tunnel lining
 - Movement and integrity of existing tunnel waterproofing systems
 - Groundwater drawdown assessments



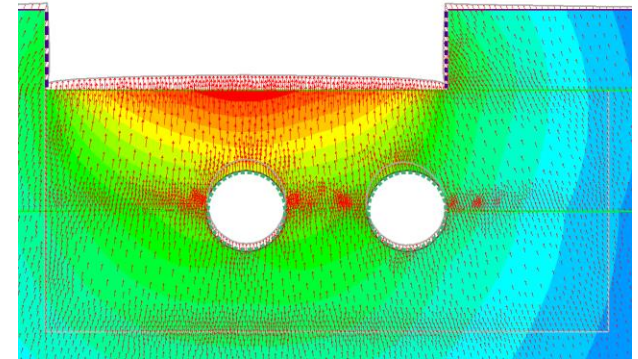
Assessment Methods



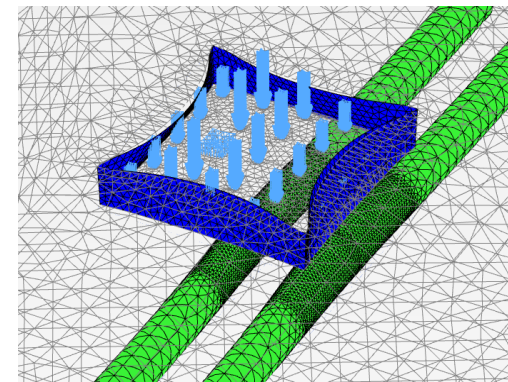
Assessment Methods

- Example modelling comparison
- 2D FEM using RS2
- Loading theory using Boussinesq
- 3D FEM using Plaxis 3D

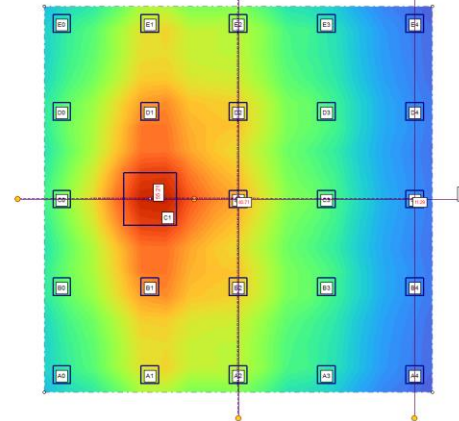
2D FEM –
RS2



3D FEM –
Plaxis3D



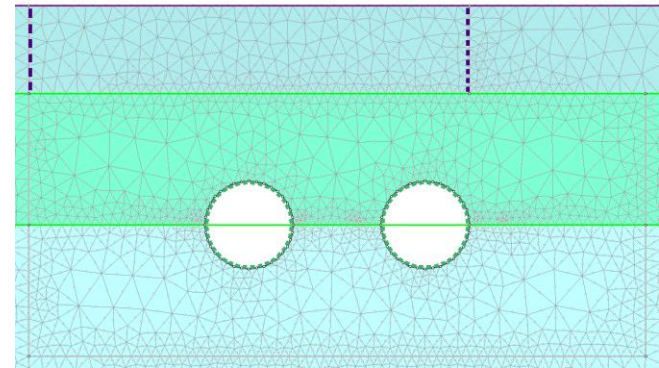
Boussinesq
– Settle3



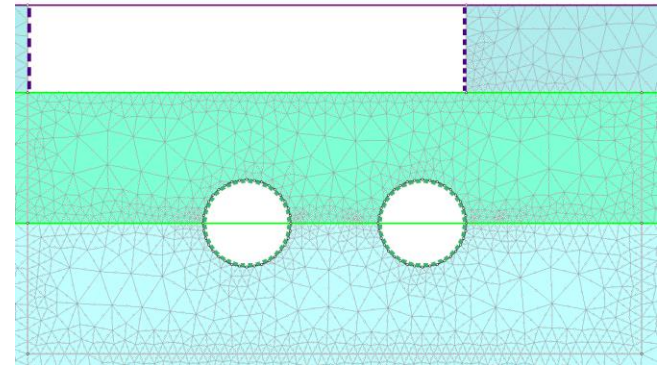
Modelling methodology

- How to best capture the tunnel behaviour in your model due to building development
 - 1. Excavation and support of existing tunnel – establish initial conditions
 - 2. Basement excavation – unloading effect on the tunnel
 - 3. Building construction – loading effect on the tunnel

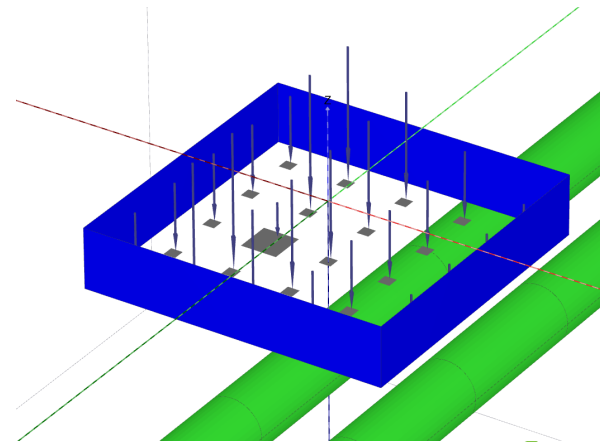
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2

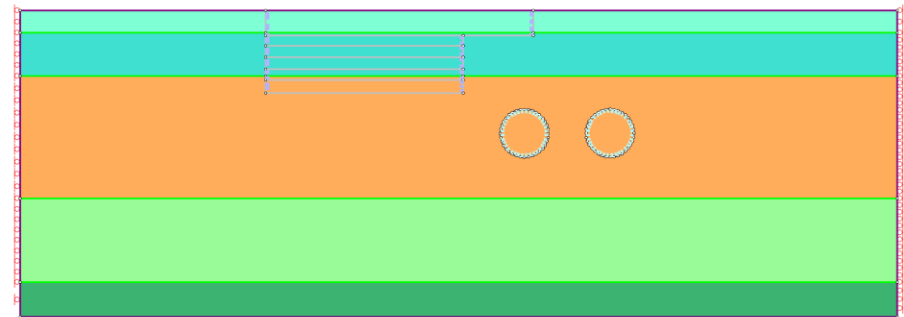
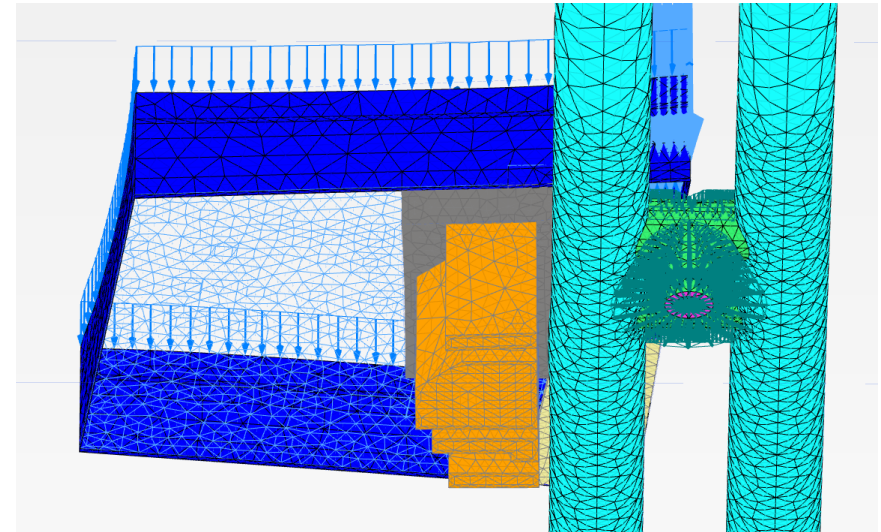


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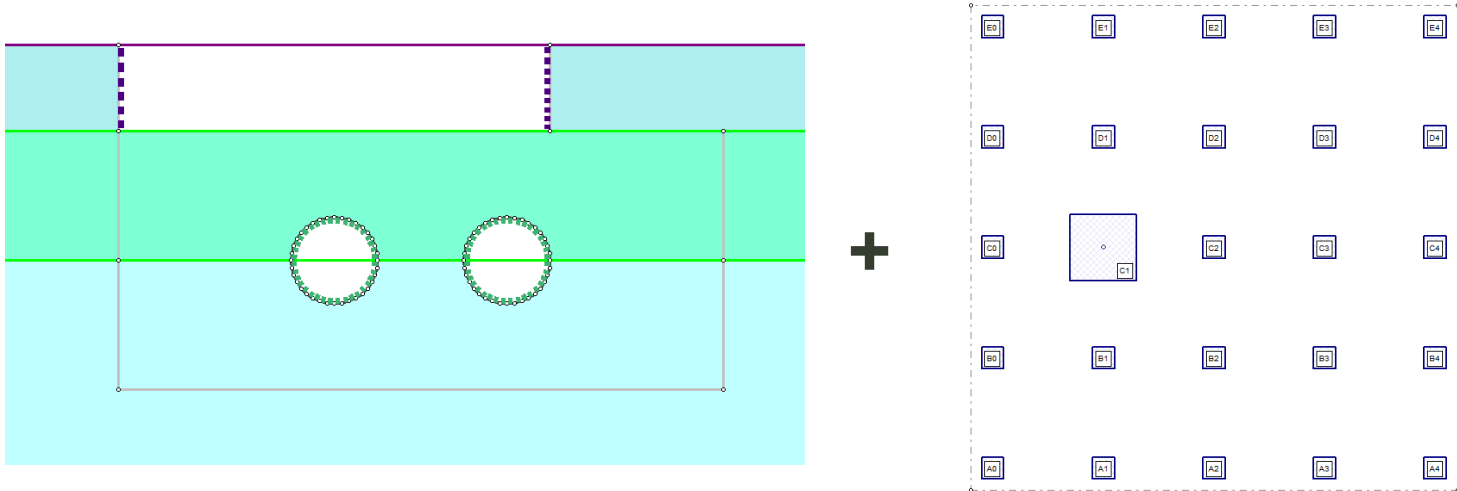
2D vs 3D modelling

- When determining the best way to analyse with modelling, consider the problem, time and accuracy required, and stage of the project.
- 2D – simple geometry, quick run time, quicker to update and change, less prone to errors, conservative
- 3D – time-consuming, expensive, harder to troubleshoot, minimal value for increased effort (for DA scope of work)
- DA stage – the level of detail does not need to be of detailed design – 2D and simpler theories are sufficient

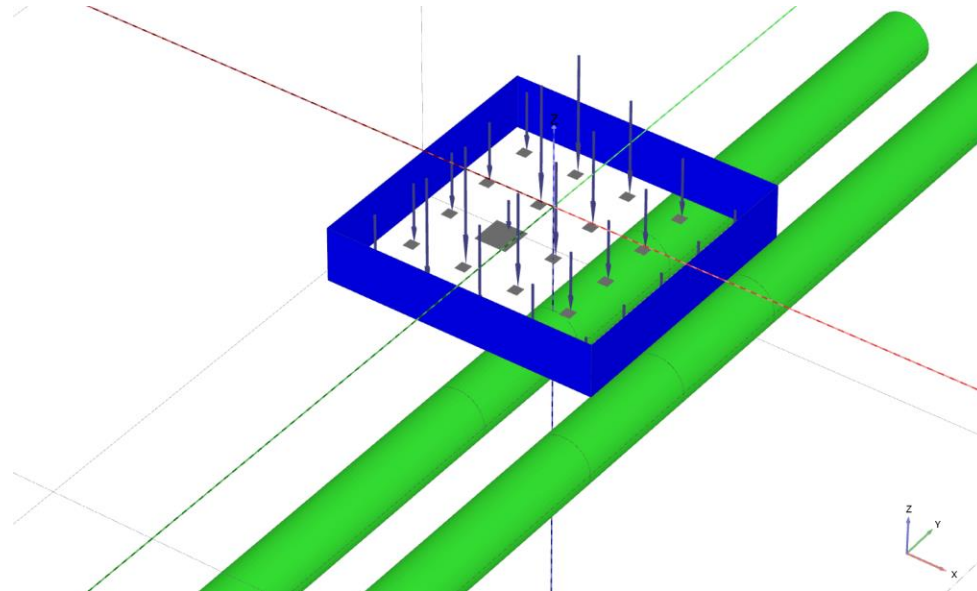


2D vs 3D modelling

2D



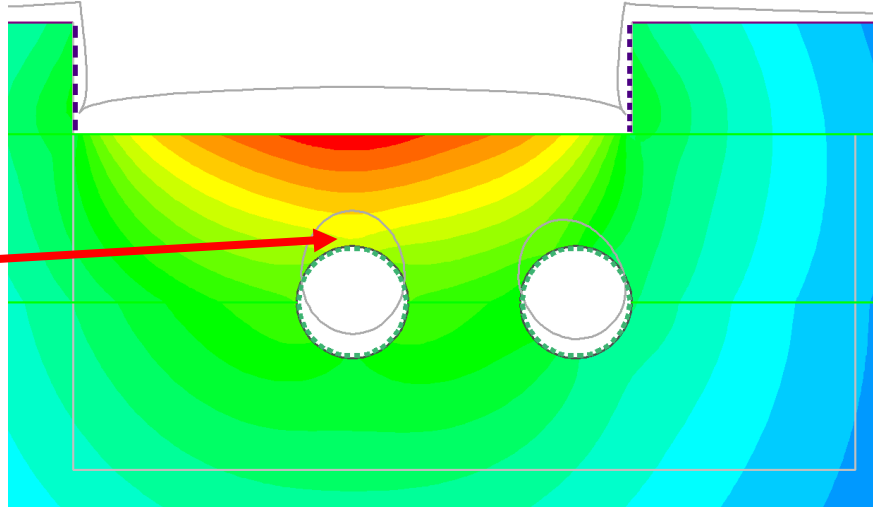
3D FEM



Unloading modelling (Basement Excavation)

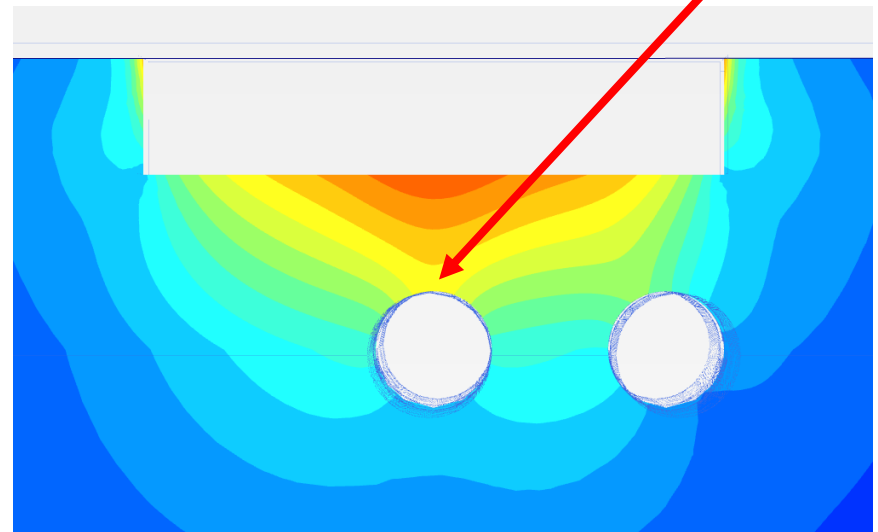
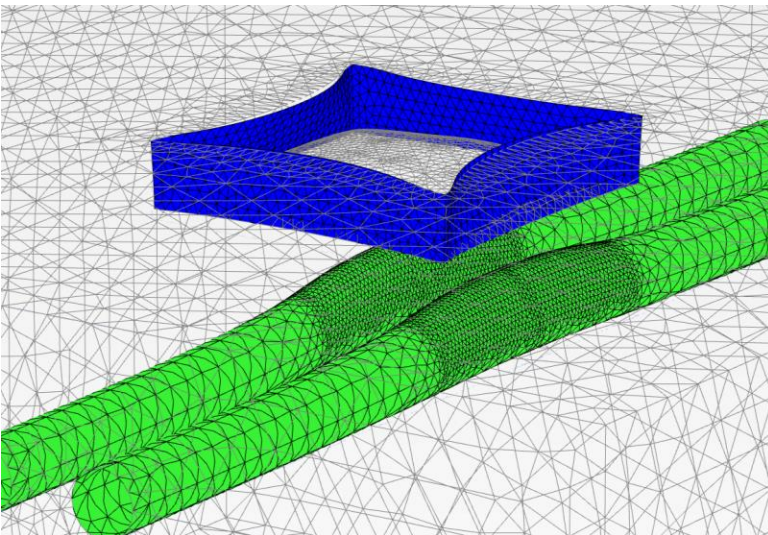
■ 2D FEM

Max total displacement
above Tunnel 1 crown:
5.9mm

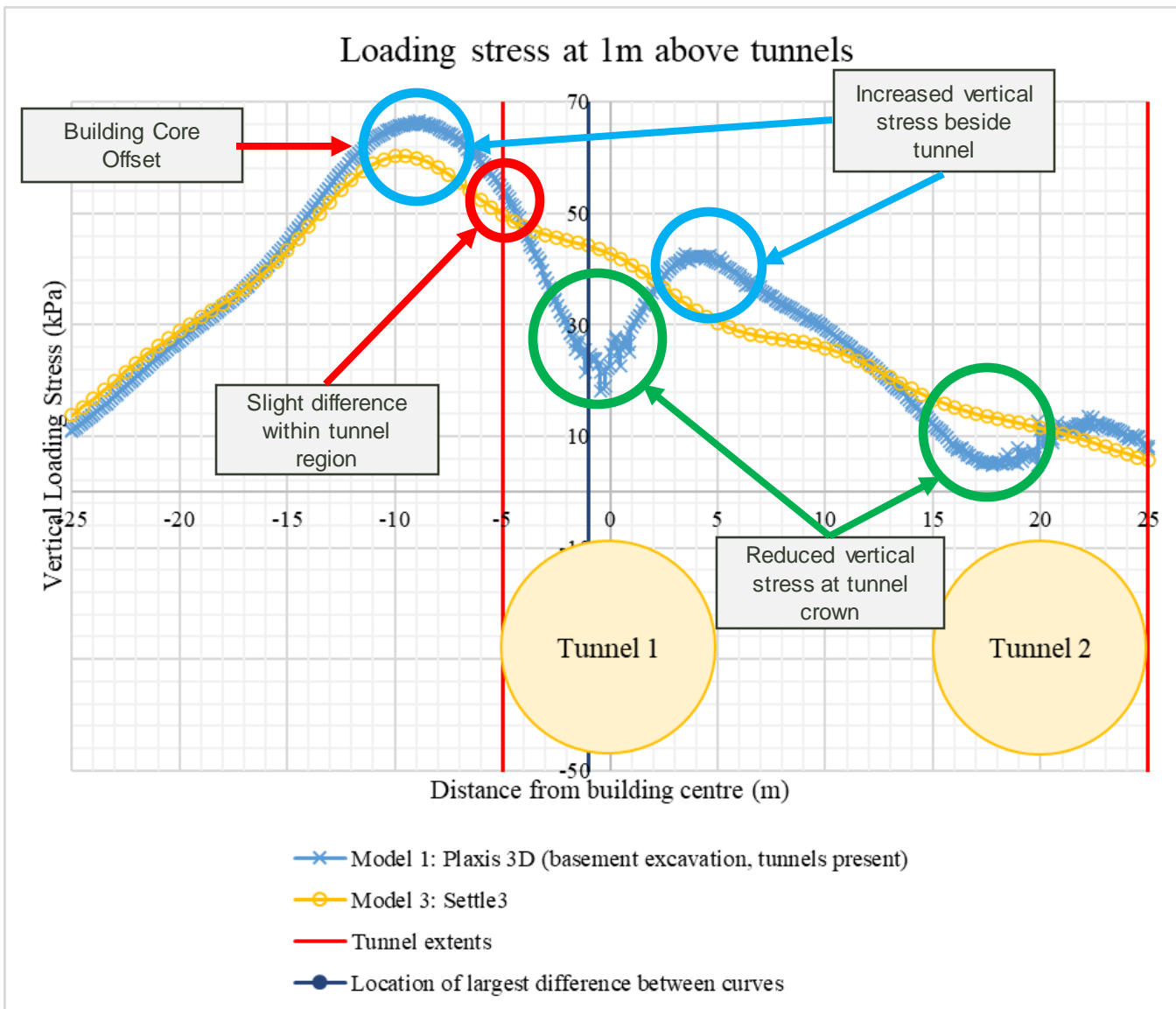


Max total displacement
above Tunnel 1 crown:
5.2mm

■ 3D FEM

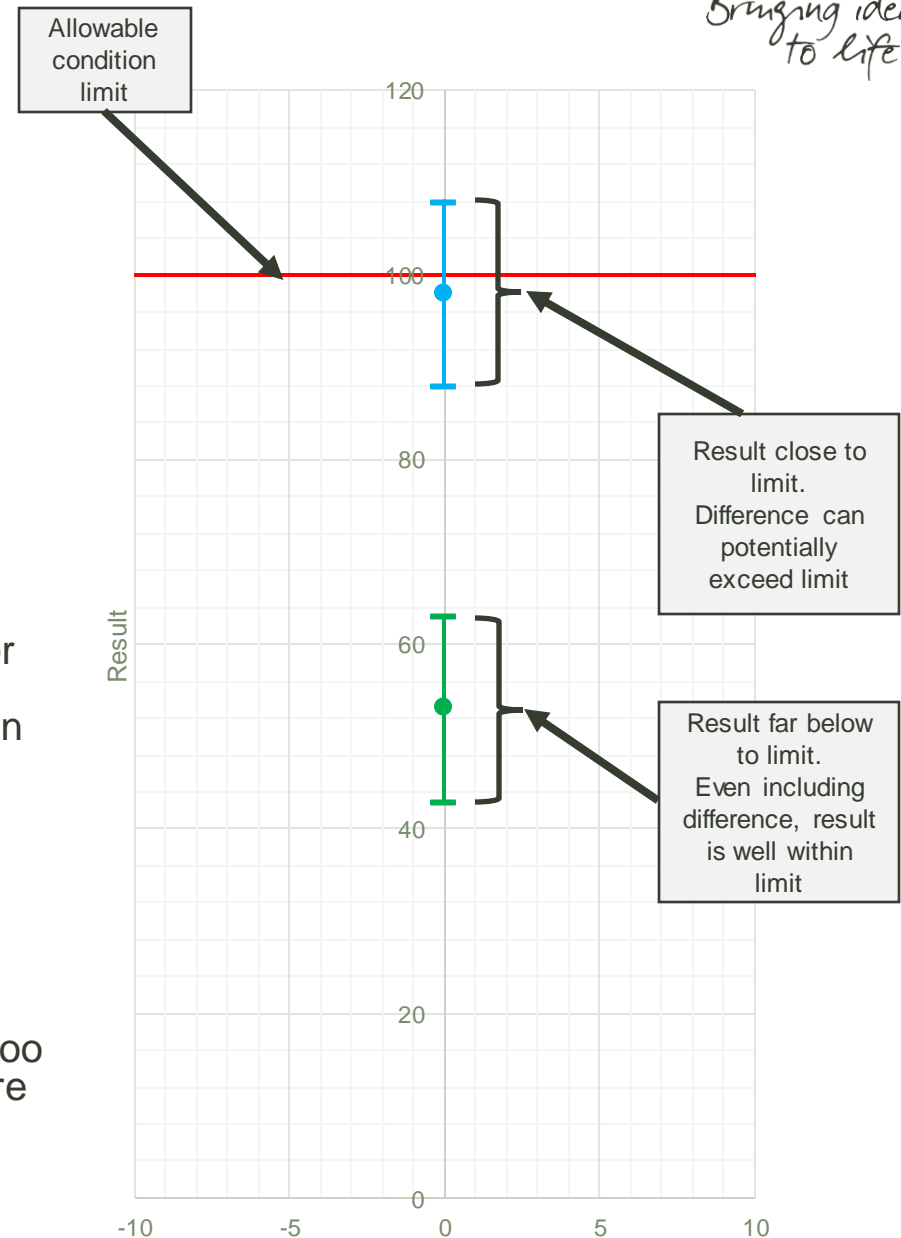


Loading modelling (Building Construction)



Assessment limitations

- Not every method is perfect, know the limitations of your assessment method so that your method is appropriate
- 2D is conservative for total movement estimation however differential movements (distortion) can be underestimated
- Boussinesq using Settle3 does not account for stress redistribution around the tunnel, which can underestimate the vertical loading stress in the vicinity of the tunnel
- Consider the difference between the limit and the result. If an assessment method shows results far below the allowable condition limit then the assessment method can be used for development applications
- If the assessment method result approaches too close to the allowable condition limit, then more complex modelling methods should be considered for development applications



Conclusions

- Future Development loading (additional loading) assessed via simple footing loading theory, such as that originally proposed by Boussinesq
 - Plaxis 3D and Settle3 loading results differences were small (10% difference)
 - Initial assessment Boussinesq theory appropriate for loading assessment. If results approach the allowable loading conditions limit, more detailed modelling should be undertaken
- Future Development unloading (continuous excavations) assessed via simple 2D continuum FEM
 - 2D typically provides conservative (larger) unloading displacements
- Tunnel distortion from development's loading and unloading via simple 2D continuum FEM
 - 2D model provides conservative (larger) movements at both the crown and invert
 - Conducting the initial assessment in 2D to provide an initial estimate of the range in which the diameter displacement. If results approach the allowable distortion limit, more detailed modelling should be undertaken
- Future Development construction vibration assessed via simple vibration theory, using known site constants if available as well as documenting the proposed construction method/equipment

Thank you

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2023. Civil + Structural Engineer