# 16TH AUSTRALASIAN TUNNELLING CONFERENCE 2017

30 OCT – 1 NOV 2017
THE STAR SYDNEY

**CHALLENGING UNDERGROUND SPACE: BIGGER, BETTER, MORE**

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# Use of the Convergence-Confinement Method (CCM) in Hawkesbury Sandstone

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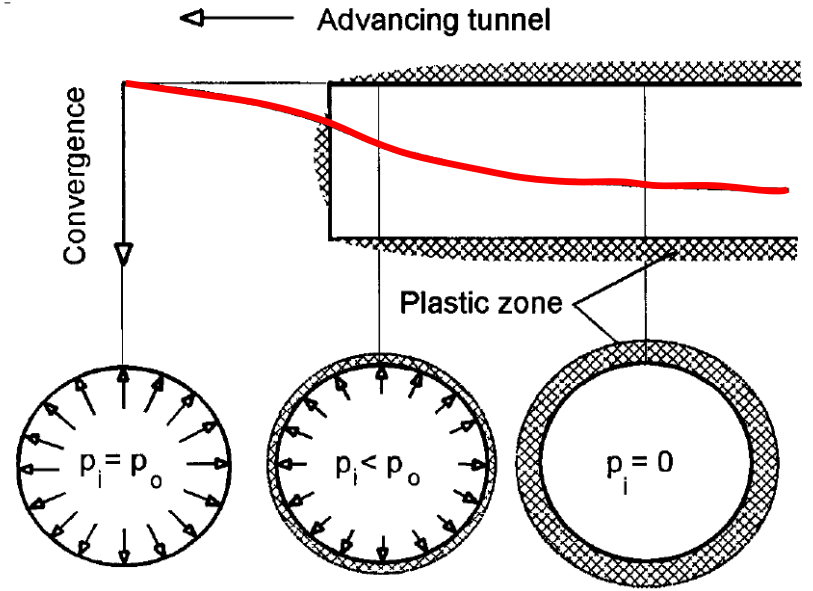
# OUTLINE

- Introduction
  - Tunnel convergence and Convergence Confinement Method (CCM)
- Objective
- Problem analysed
- Results
  - Numerical vs. Analytical
- Conclusions

# What is Tunnel Convergence?

- Produced by stress changes around the excavated area.
- A four-dimensional problem
  - Three- dimensional redistribution of stress around the excavation
  - Time-dependent weakening of rock.



# Why Tunnel Convergence Estimation Required?

- Designing of ground support
- Deciding the excavation sequence (max. length of unsupported advance)

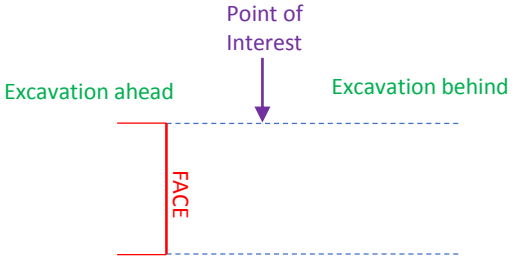
# How Tunnel Convergence estimated?

- Analytical methods:
  - Convergence-Confinement Method (CCM)
- Numerical Methods:
  - Finite element and Discrete element methods

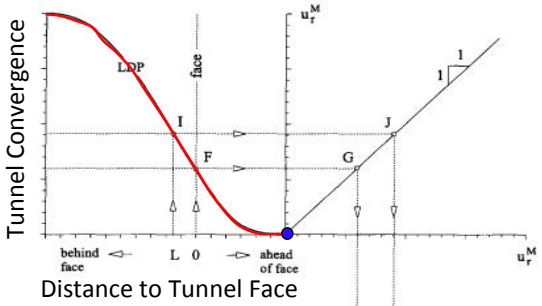
# Convergence-Confinement Method (CCM)

- Relationship between tunnel excavation advance and the ground support in terms of displacements and stress redistribution.
- Basic components of the CCM are:
  - Longitudinal Deformation Profile (LDP)
  - Ground Reaction Curve (GRC)
  - Support Characteristic Curve (SCC).

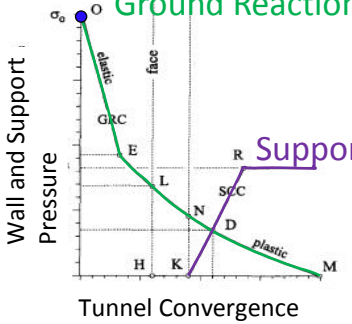
# LDP, GRC and SCC




Longitudinal Deformation Profile (LDP):




Ground Reaction Curve (GRC)




Support Characteristic Curve (SCC):

# Assumptions of CCM

- Circular excavation
- Hydrostatic in-situ stress field
- Isotropic and homogeneous rock mass
- Elastic-perfectly plastic support

# Objectives

- Analytical method (CCM) for use in the tunnel support design in Hawkesbury Sandstone.

# Problem Analysed

- Three typical stable geological conditions
  - Sandstone I
  - Sandstone II
  - Sandstone III
- Two main characteristics of the Hawkesbury Sandstone
  - Strongly bedded
  - High horizontal stresses.
- Tunnel size (span = 12.5 m, height = 7.5 m and depth = 50 m).

# Rock Parameters

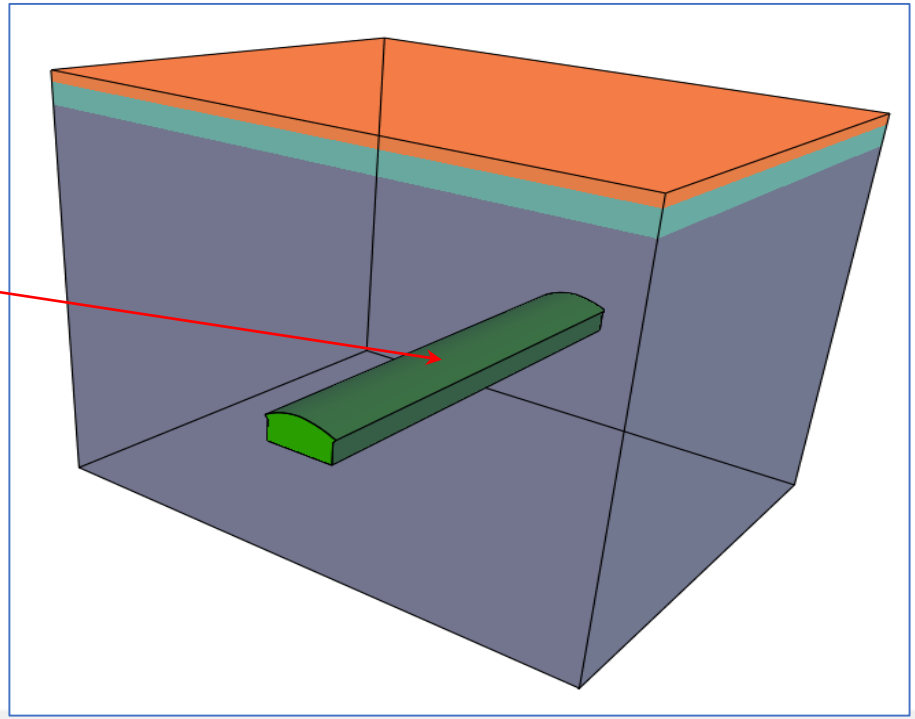
- Typical Sandstone parameters used in the design of tunnels.
  - Discontinuum parameters (block scale).
  - Continuum parameters (tunnel scale).
- In-situ stress relationships as a function of vertical stress.

# Analytical CCM solution

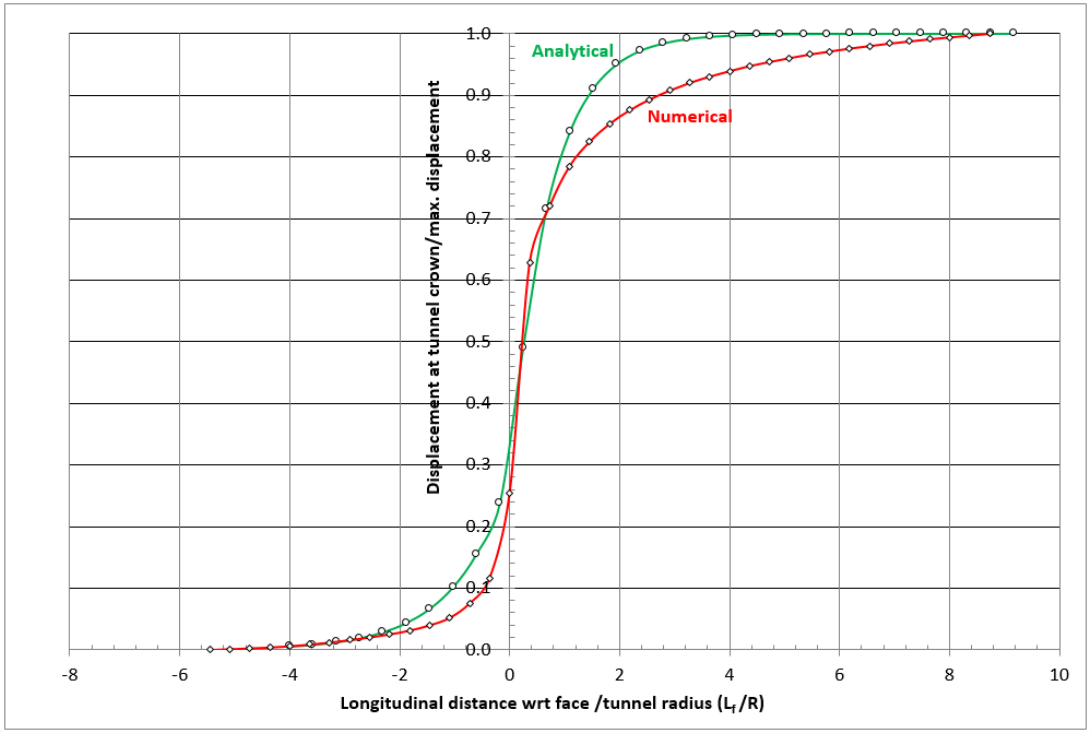
- Initial stress was averaged from the major horizontal stress and vertical stress.
- Young's modulus was used as provided in continuum approach.
- LDP was derived as proposed by Vlachopoulos and Diederichs (2009).

# Numerical LDP

Location where the LDP developed



# Numerical LDP vs. Analytical LDP

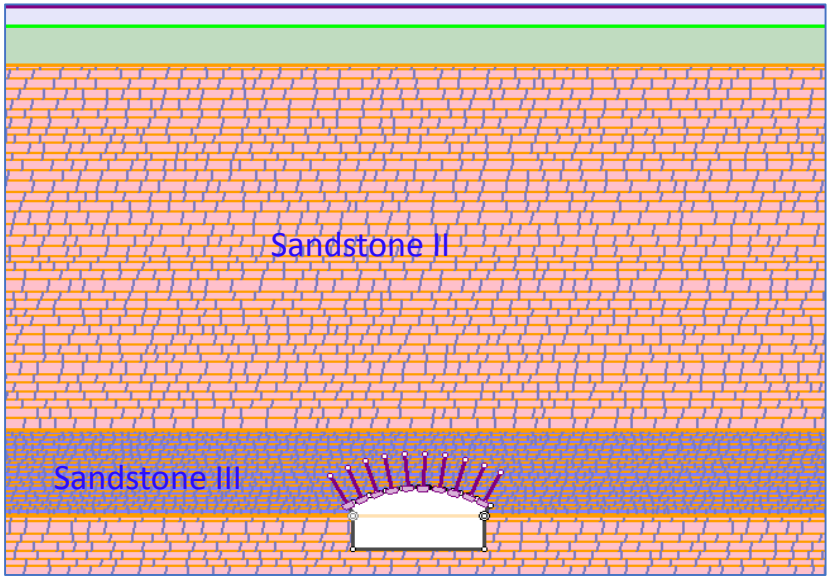


# Analytical GRC

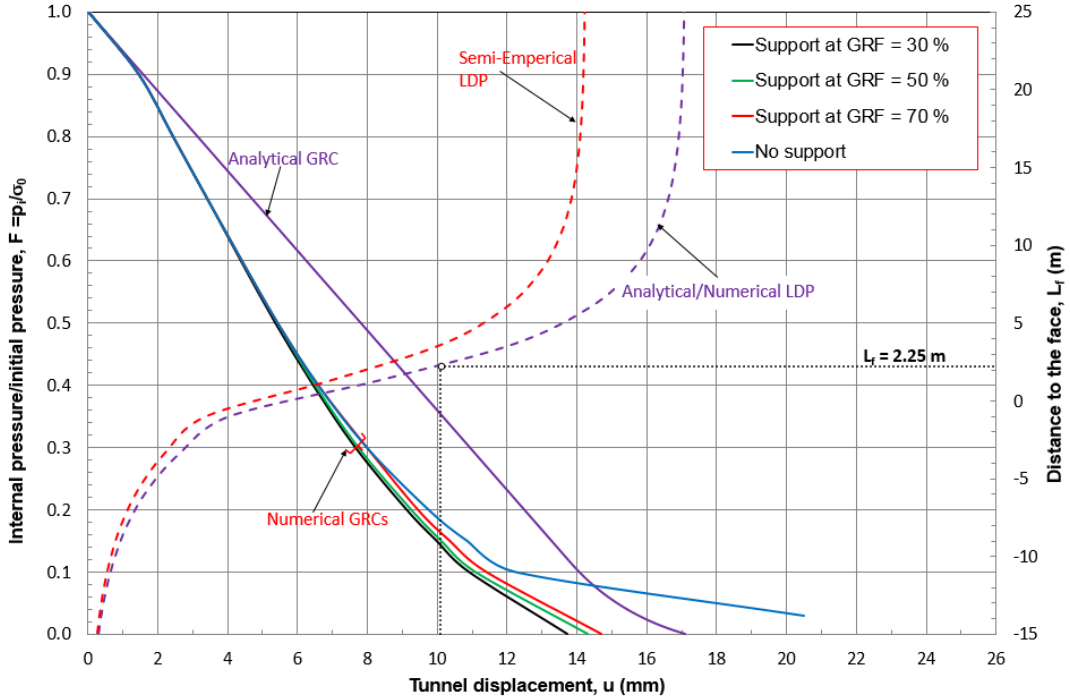
- The analytical GRC solution as proposed by Carranza-Torres and Fairhurst (2000).

# Numerical GRC

- The numerical GRC was established using RS2.



# Numerical GRC vs Analytical GRC



# Design Applicability (at $L_f$ = 2.25 m)

| Tunnel Geology | Analytical | | Numerical | |
|---|---|---|---|---|
| | Tunnel Convergence (mm) | Ground Relaxation Factor (GRF), % | Tunnel Convergence (mm | Ground Relaxation Factor (GRF), % |
| SS-I | 5.0 | 60 | 3.5 | 75 |
| SS-II | 6.0 | 60 | 5.5 | 70 |
| SS-III | 10.0 | 65 | 8.5 | 70 |

# CONCLUSIONS

- Analytical method provides satisfactory results compared to numerical solutions.
- The Analytical CCM can be used adopting
  - Anisotropic in-situ stress field to an equivalent isotropic stress.
  - An equivalent continuum deformation modulus (Hoek-Brown failure criterion).
- Solutions were compared to stable tunnel excavation in Hawkesbury Sandstone (SS-I to SS-III).

?

# Thank You