Soil Nailed Wall under Bridge Abutment

9th Australian Small Bridges Conference 2019

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Introduction

- **Case study of soil nailed system under bridge abutment implemented on the M1M3 project**
- Soil nailed walls beneath bridge abutments have become more common. Only a few design guidelines are available:
  - 2D approach: BS 8006-2 and FHWA GEC007 (2015)
  - 3D approach: Briaud (1997)
- **Agenda:**
  - Presentation of soil nailed wall analysis performed on M1M3: modelling using Plaxis 2D finite element, stability FOS, impact on existing piles
  - Monitoring results
  - Further study using Plaxis 3D finite element

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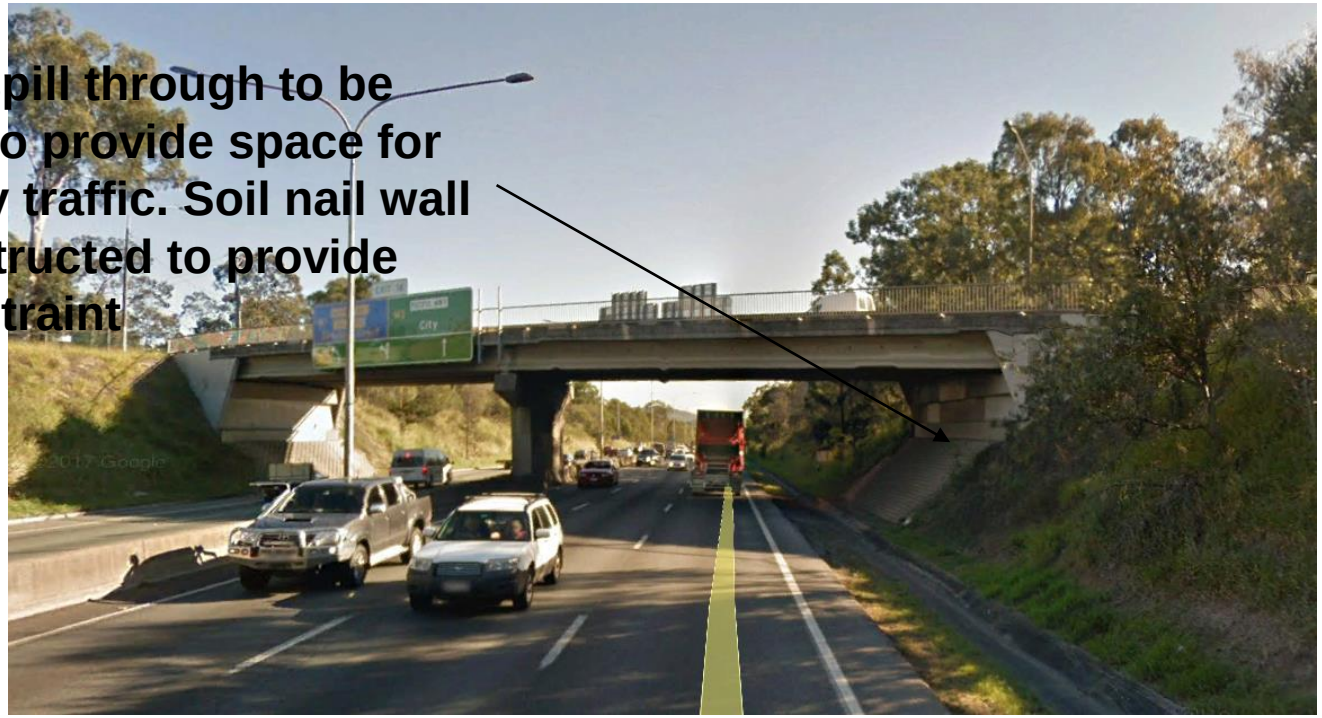
Soil Nail System at M1M3

Existing spill through to be cut back to provide space for temporary traffic. Soil nail wall was constructed to provide lateral restraint



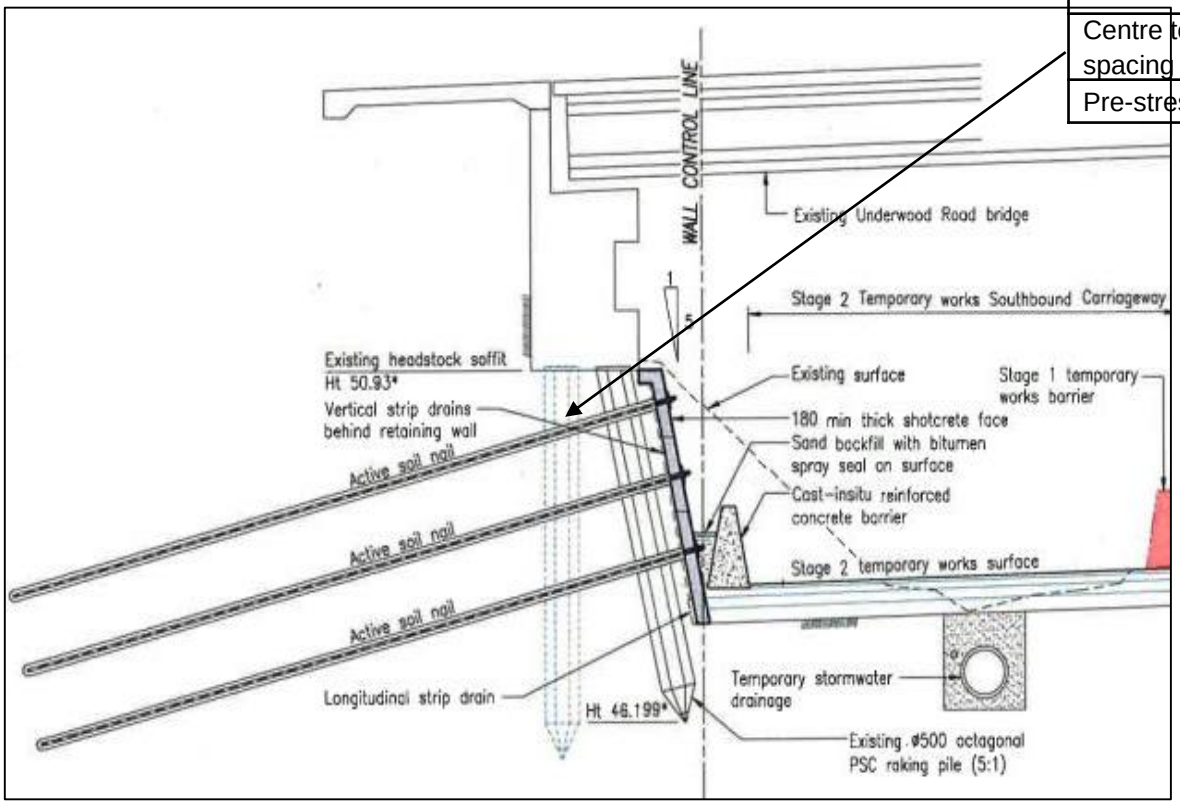
- Existing Underwood Bridge was constructed in 1982. Dimensions:
  - Spans of 26m with cast in-situ deck slab
  - Skewed at approx. 39degrees
  - Existing spillthrough constructed in a 1.2V in 1H batter

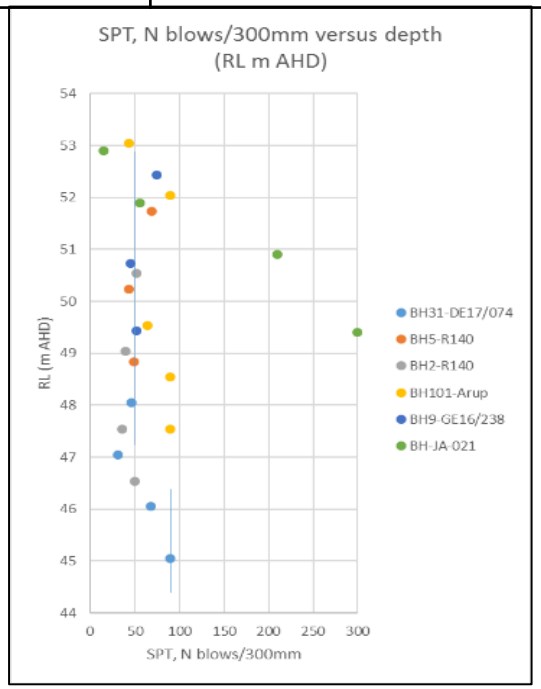
Soil Nail System at M1M3

- Abutment headstock is approx. **17.45m (length) x 1.6m (width) x 2.34m (depth)**
- The headstock is supported on two rows of 500mm octagonal precast prestressed piles. Front piles are raked and back piles are vertical
- 1:25,000 DNRM (2017) Geological Map for Beenleigh indicates Eight Mile Plains Basalt member geological unit
- Geotechnical investigation boreholes indicated **residual soils / extremely weathered material over the excavation depth**

Soil Nail System at M1M3

Soil nail bar	28mm diameter steel bar with steel yield strength of 500MPa
Drilled hole diameter	125mm
Locations and inclination	Top row: typ. 500mm below underside of headstock. Inclination: 15 degrees to horizontal
Centre to centre spacing	Vertical = 1m; Horizontal = 1.2m
Pre-stressed load	25kN for tensioned soil nails





Typical section of soil nail wall (LHS); SPT profile with depth (RHS)

Soil Nail Wall Analysis

- Limit State principles that satisfy both ULS and SLS criteria
- Stability assessment using Slope/W. Verification using Plaxis 2D finite element
- Soil structure interaction to assess impact of the construction of the soil nail using Plaxis 2D finite element
- Plaxis 2D numerical model incorporates the structural actions at the headstock (shrinkage, creep and braking load) and all the structural elements

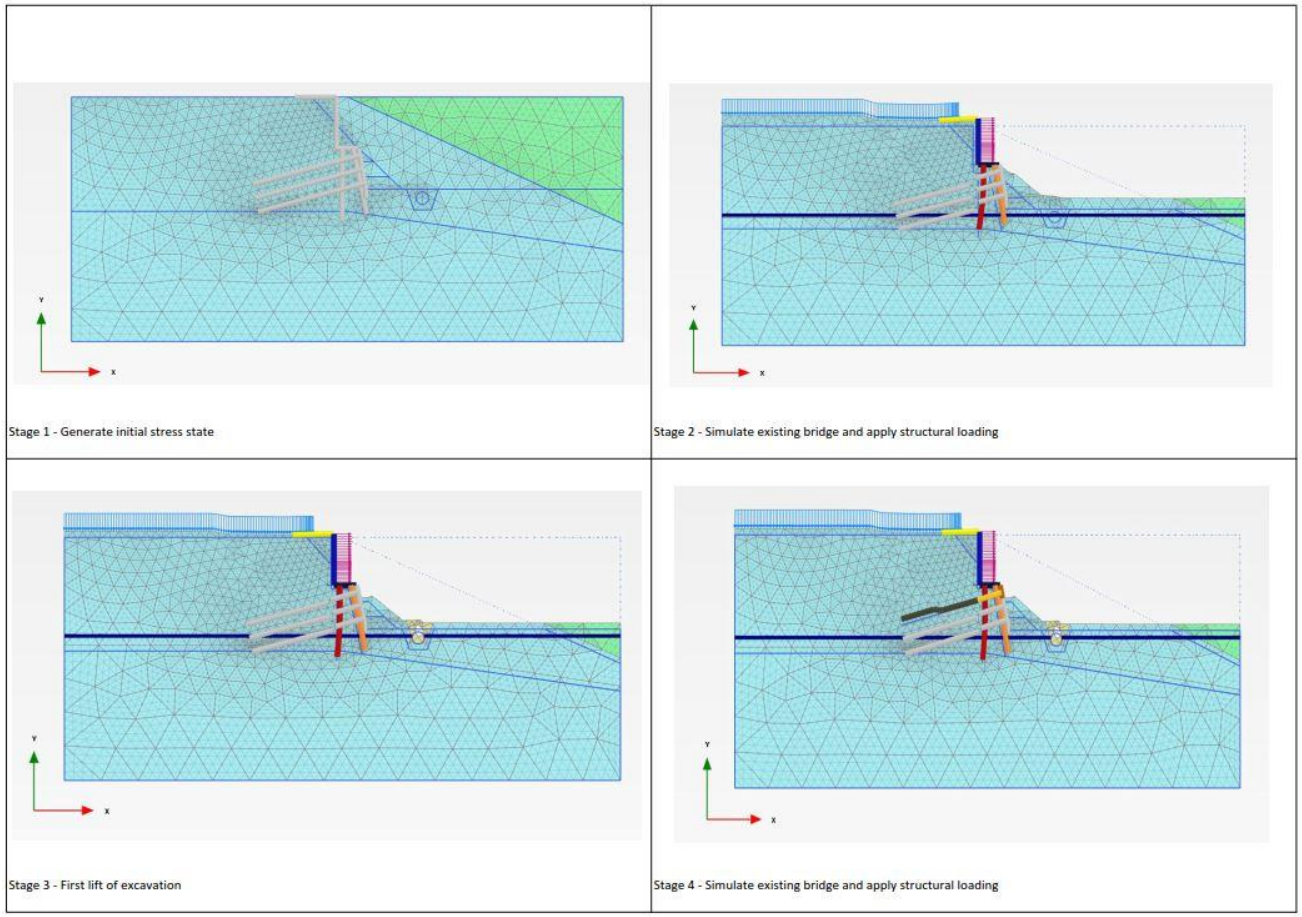
Soil Nail Wall Analysis

- Soils are assigned **Mohr Coulomb model** with drained (long term soil response) conditions

Geological Unit	Material	Unit Weight, γ	Drained Cohesion, c'	Effective Friction Angle, φ'	Young's Modulus, E'
		kN/m^3	kPa	(°)	MPa
Residual soils to Basalt / Extremely weathered material	Silty Clay: Medium to high plasticity, very stiff to hard with fine grained sand	20	3 to 30	25	40
Highly weathered rock	Basalt: Very low strength with spheroidal weathered Basalt clasts contained in a Sandy Clay matrix	22	30 to 50	35	150

- Construction sequence was simulated step by step, consisted of: generation of initial stresses and structural action and three excavation lifts with placement of three rows of nails

Soil Nail Wall Analysis



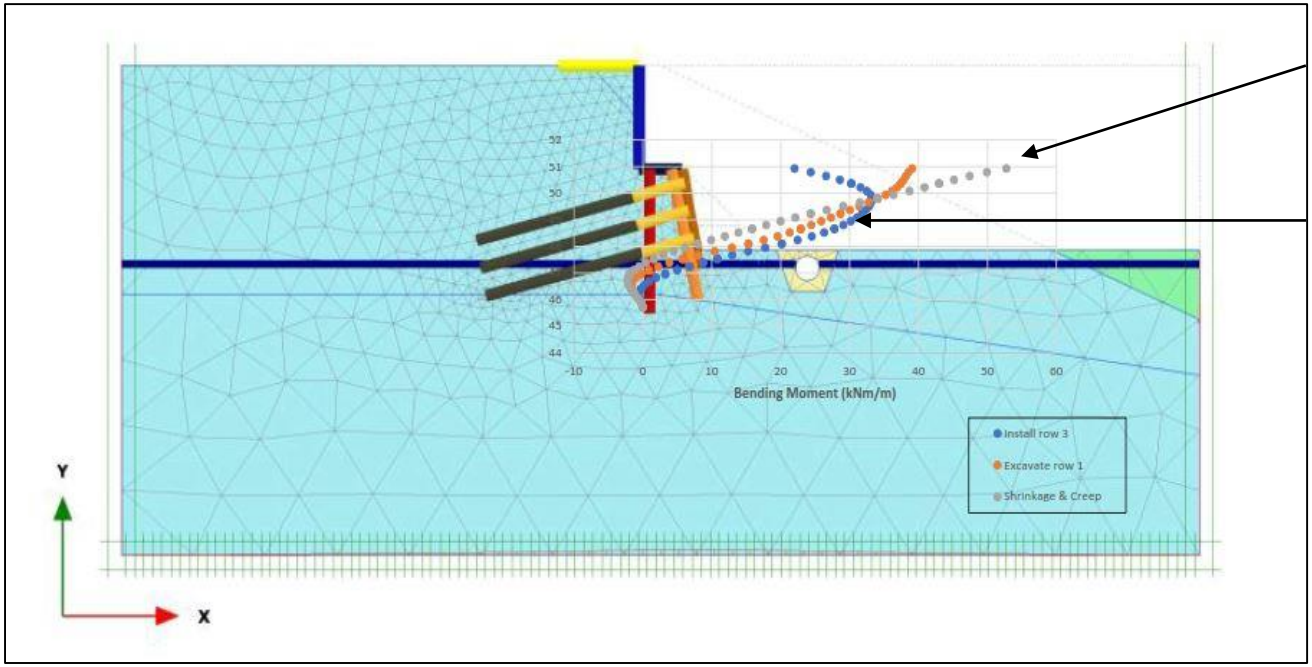
Simulation of Construction Sequence

Soil Nail Wall Analysis (Stability)

- FOS calculated in Slope/W was 1.5
- Slope/W model is considered lower bound, due to:
  - Analysis assumes 2D plane strain
  - **Ignore stiffening effects of the existing piles** and headstock
  - Existing **headstock and bridge deck** is expected to provide **lateral resistance** to the system and distribution of loading
- **FOS calculated in Plaxis is 2.59**

Soil Nail Wall Analysis (Impact to Existing Piles)

- Soil nail wall and the soil behind it will tend to deform outwards during construction
- Most of the movements are expected to occur during or shortly after each excavation lift



1. Shrinkage & Creep: Max. BM at the top of the pile

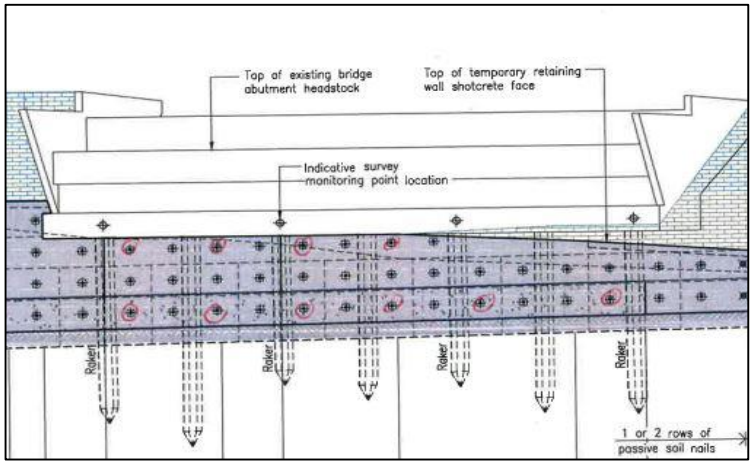
2. Final stage (installation of row 3 nails): Max. BM is shifted lower

3. Overall BM on the pile is reduced as the soil nail system is installed. This is due to impact of pre-loading / prestressed loads in the nails and stiffness of the headstock

Soil Nail Wall Monitoring

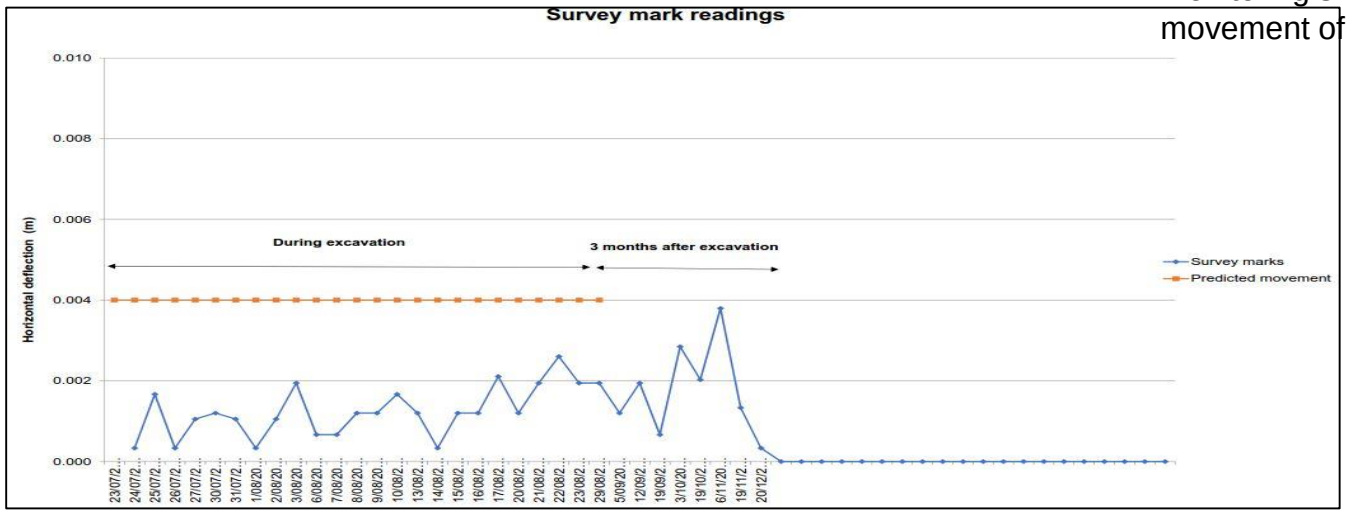
- **Monitoring requirements**:
  - Daily walkover (observational approach)
  - Survey marks affixed on the bridge headstock to monitor vertical and horizontal movements

Soil Nail Wall Monitoring



1. Recorded movement is less than prediction

2. Movement of <3mm during excavation
3. Peak readings were recorded on the first week of November 2018, coinciding with pipe excavation in front of the wall and high rainfall periods during mid of October 2018
4. Further ongoing monitoring shows total movement of <2mm

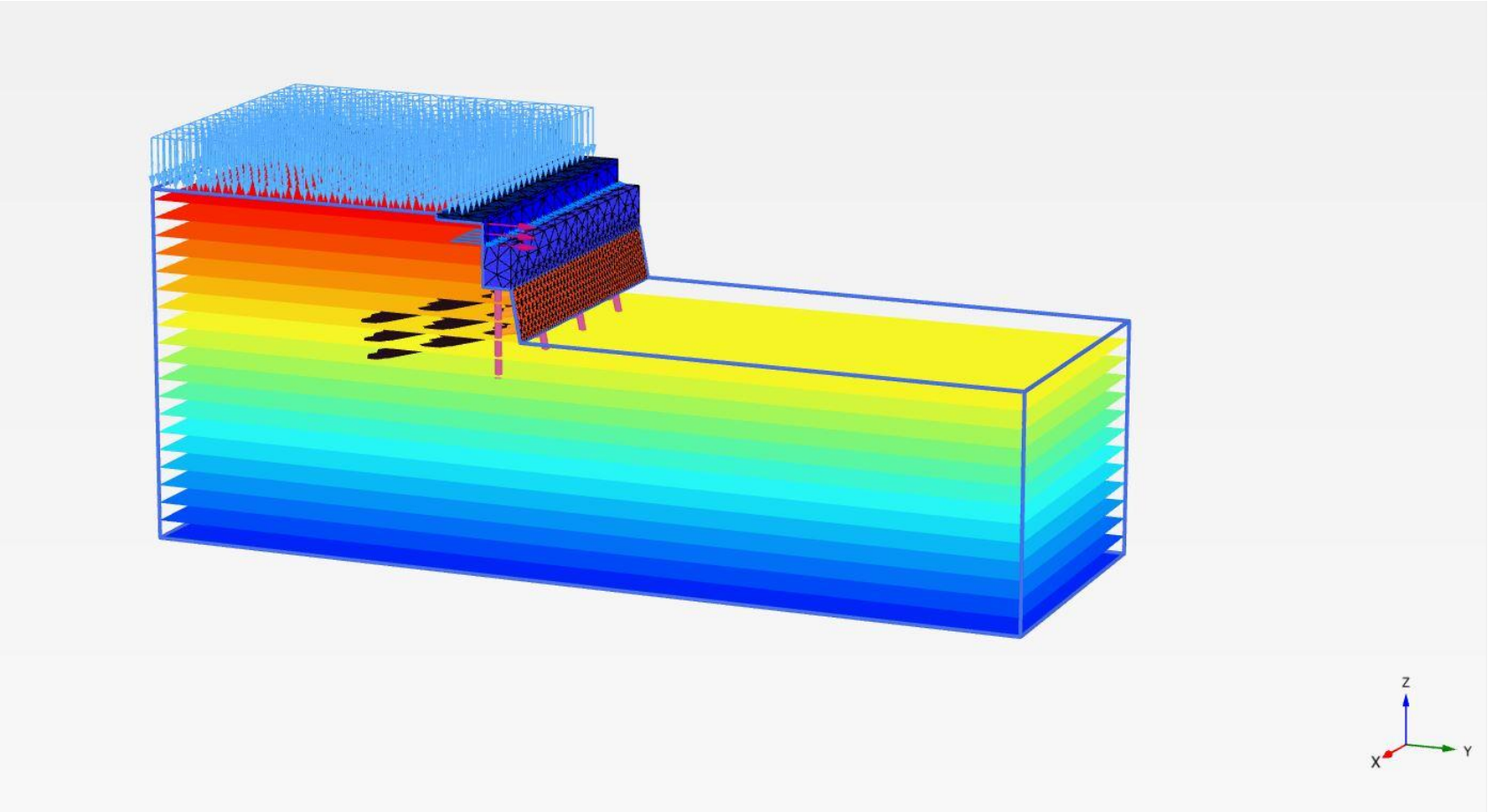


Survey Marks Locations (Top); Survey Marks Readings (Bottom)

Further Study (3D FE Analysis)

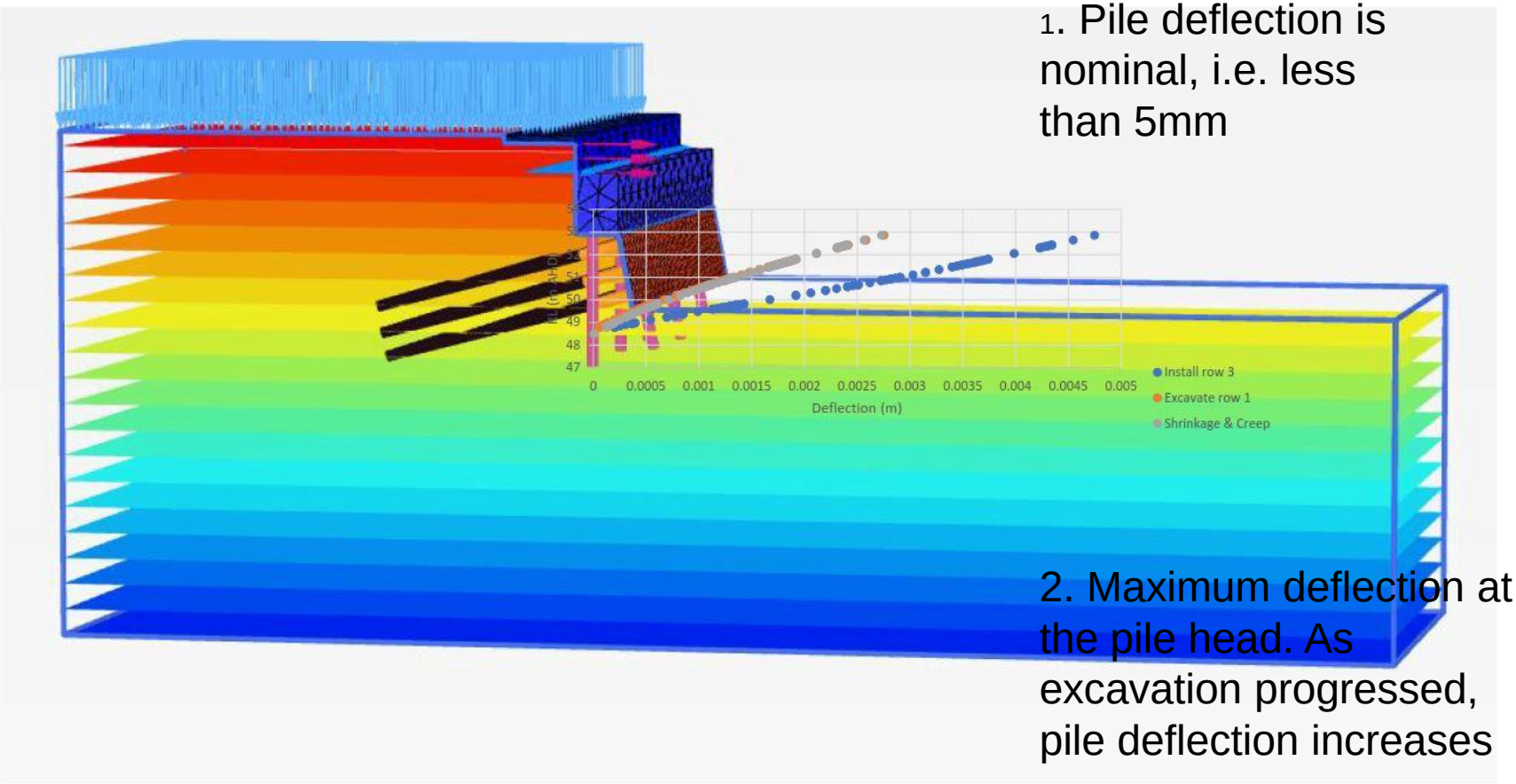
- Further study using Plaxis 3D Finite Element
- Questions to be studied:
  - Assumptions of stiffness parameters of the headstock and piles
  - Interaction between piles
  - Load distribution
  - A true three-dimensional (3D) problem (?)
- 3D numerical model was set-up similar to the 2D model. **It incorporated the structural actions (shrinkage, creep and braking load) and all structural elements.**

Further Study (3D FE Analysis)



Plaxis 3D Numerical Model

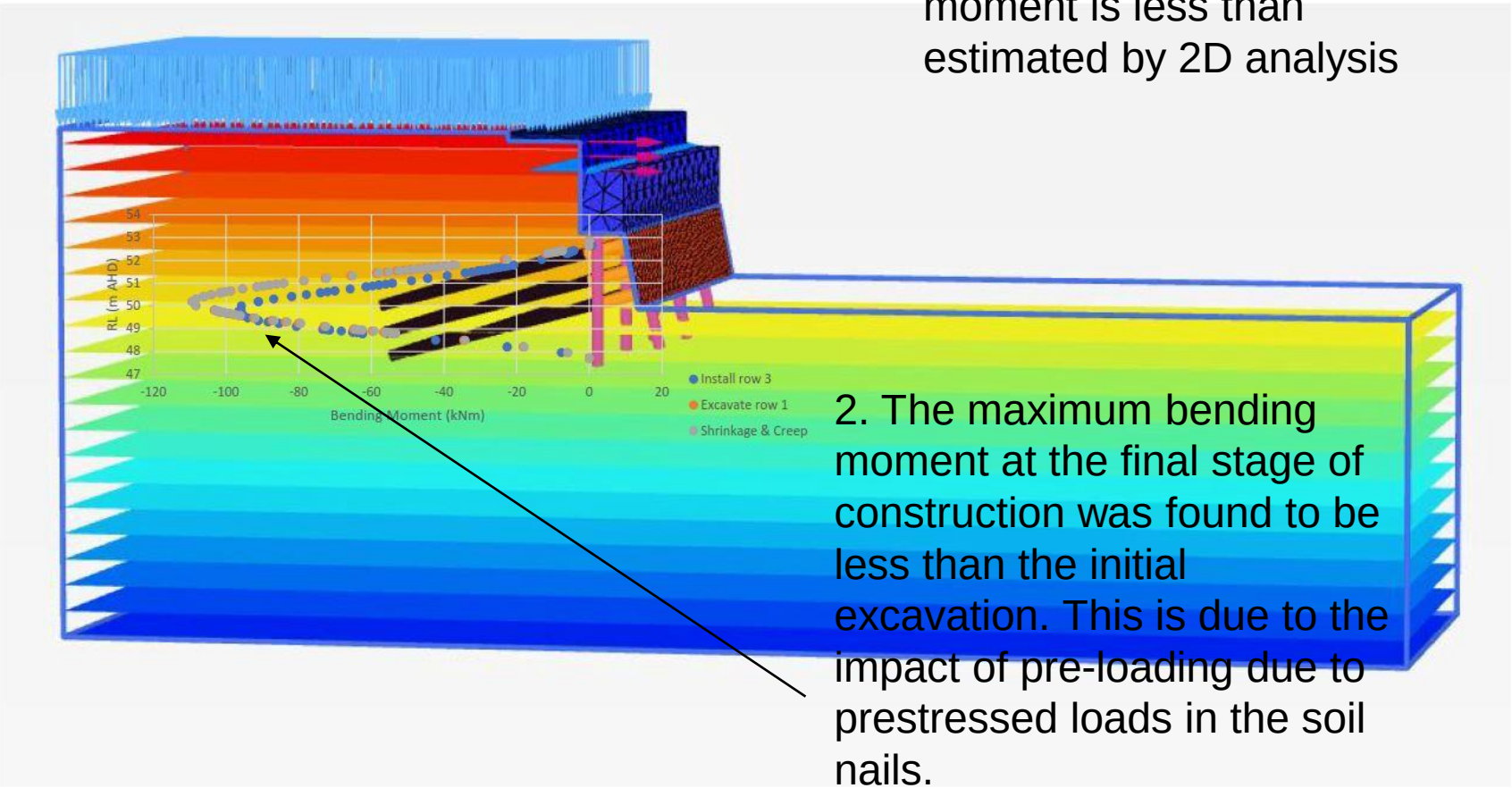
Further Study (3D FE Analysis)



Plaxis 3D – Pile Deflection

Further Study (3D FE Analysis)

1. Overall pile bending moment is less than estimated by 2D analysis



2. The maximum bending moment at the final stage of construction was found to be less than the initial excavation. This is due to the impact of pre-loading due to prestressed loads in the soil nails.

Plaxis 3D – Pile Bending Moment Profile

Discussions

- Important factors in soil nail wall design often ignored in simplified analysis:
  - Lateral restraint at the headstock level due to stiffness of the headstock and bridge deck. This will contribute to the stability FOS and resulting stresses acting on the piles. Assumptions of free head piles would over-estimate deflections and bending moment
  - Stiffening effects of the piles
  - Preloading due to prestressed loads in the soil nails
- Limitations of simplified model can be overcome by performing finite element analyses => **robust design**

Discussions

- Results from 2D finite element analysis are conservative (i.e. slightly overestimate deflection and overestimate bending moment), however appear reasonable. In this case study, the 3D analysis has benefits in modelling better pile group interaction

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