Three-Dimensional Modelling of an Excavation Adjacent to a Major Structure

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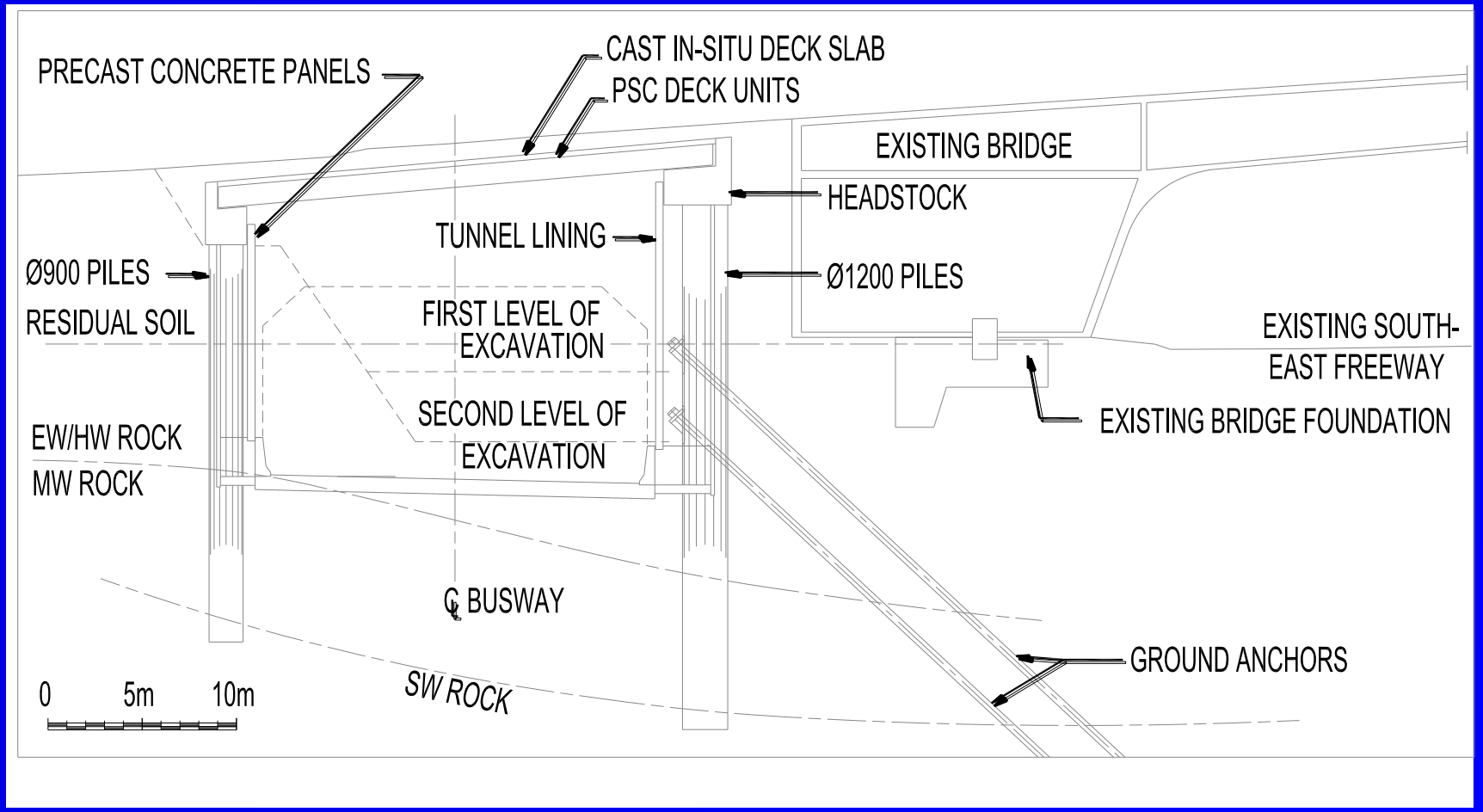
Background

- South-East Transit Project 2 - traffic corridor through inner Brisbane, Australia
- Tunnels, bridges, retaining walls used to minimise impact on other roads, infrastructure
- Hawthorne Street Tunnel: cut-and-cover, adjacent to shallow foundation of major bridge
- *FLAC*^{3D} model to guide support design

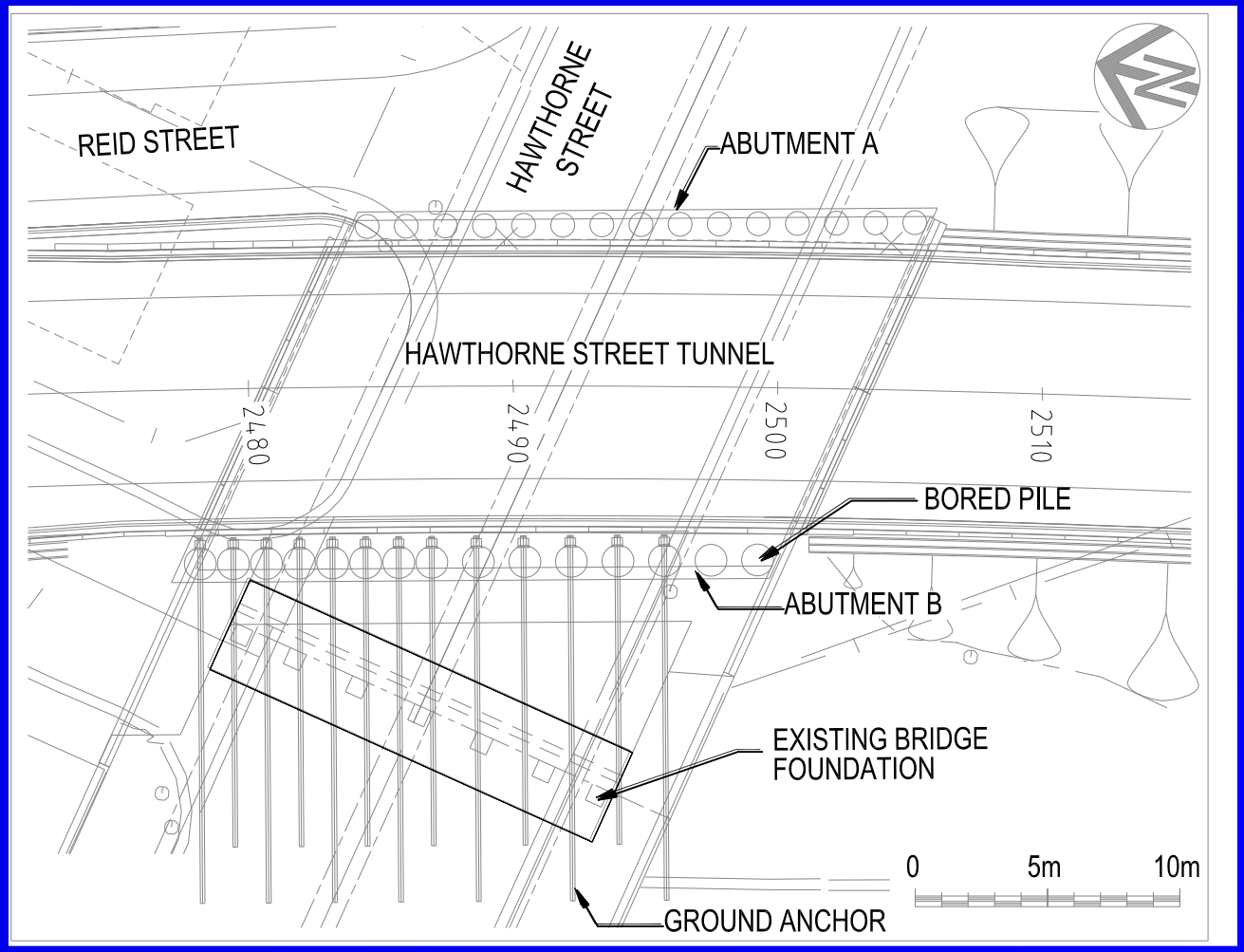
Site Geology

- Residual soils near surface
- Underlying fine-grained phyllite, with degree of weathering varying from extreme to slight with increasing depth
- Groundwater table measured about 1 m below busway design level

Site Elevation



Site Plan


REID STREET
HAWTHORNE STREET
ABUTMENT A
HAWTHORNE STREET TUNNEL
2480
2490
2500
2510
BORED PILE
ABUTMENT B
EXISTING BRIDGE FOUNDATION
0
5m
10m
GROUND ANCHOR

Hawthorne Street Bridge

- 4-lane single span arch, strip footings at abutments
- Structural analysis: hinged mid-span, held up by horizontal support at foundations
- Damage to bridge likely if horizontal movement at footings exceeds 10 mm
- Therefore design support to limit lateral movement to 5 mm

Structural System

- Cut and cover tunnel, running obliquely to bridge
- Bored pile walls:

  western side - 1.2 m diam. at 1.77 m c/c spacing, 1.25 m c/c within 3 m of foundation, permanent ground anchors;
  eastern side - 0.9 m diameter, 1.5 m c/c;
  piles socketed 0.5 m into SW phyllite, anchors 10 m;
  fibrecrete between piles;
  anchors prestressed to 1000 kN

- Roof: pre-stressed concrete plank and reinforced concrete deck slab

Construction Sequence

- Construct bored pile walls
- Excavate N half to level of upper row of anchors, fibrecrete, install and stress anchors; then likewise for S half
- Similarly to level of lower row of anchors
- Excavate to tunnel floor level
- Install concrete planks and slab
- Monitor Hawthorne Street Bridge throughout; ground anchors to be further stressed if > 5 mm laterally

Numerical Modelling - 1

- *FLAC*^{3D} chosen because of need for 3D analysis with nonlinear rock response and range of structural elements
- *FISH* programming used extensively for grid generation, excavation staging and managing structural elements
- Analyses performed in 1999, using version 2.0

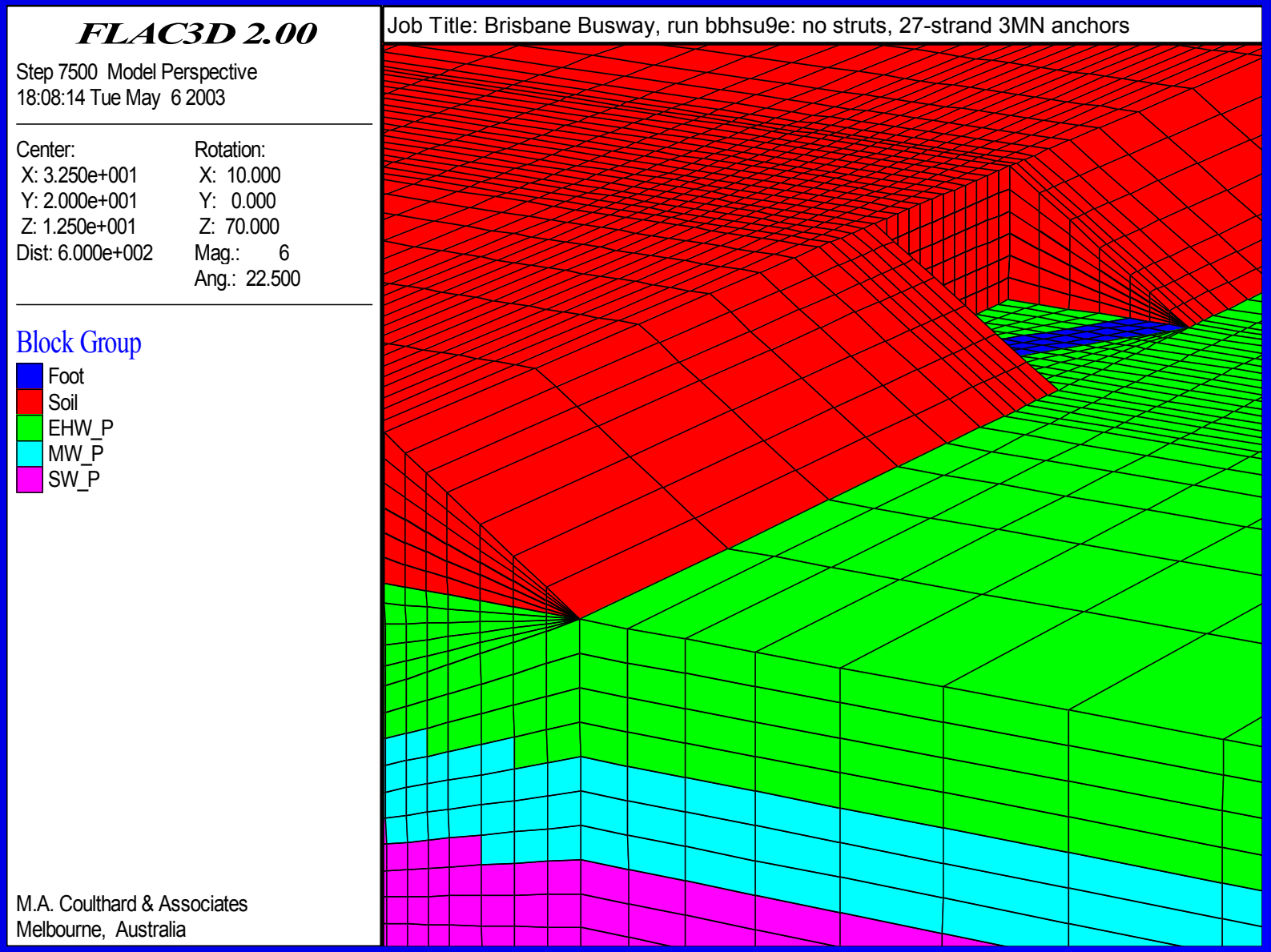
Numerical Modelling - 2

- Uniform layering, Mohr-Coulomb model
- In situ stress: horizontal = vertical in rock
- Bridge: represented via loads applied to footing; two cases considered
- Piles and anchors modelled using pile and cable elements; fibrecrete not included in model

Finite Difference Grid

- Soil slope around foundation, reverse slope after excavation
- Grid generated in sections, some joined via ‘attach’
- Final grid transformed to make tunnel oblique to bridge
- Horizontal rock layering approximate in parts

Excavation adjacent to bridge foundation



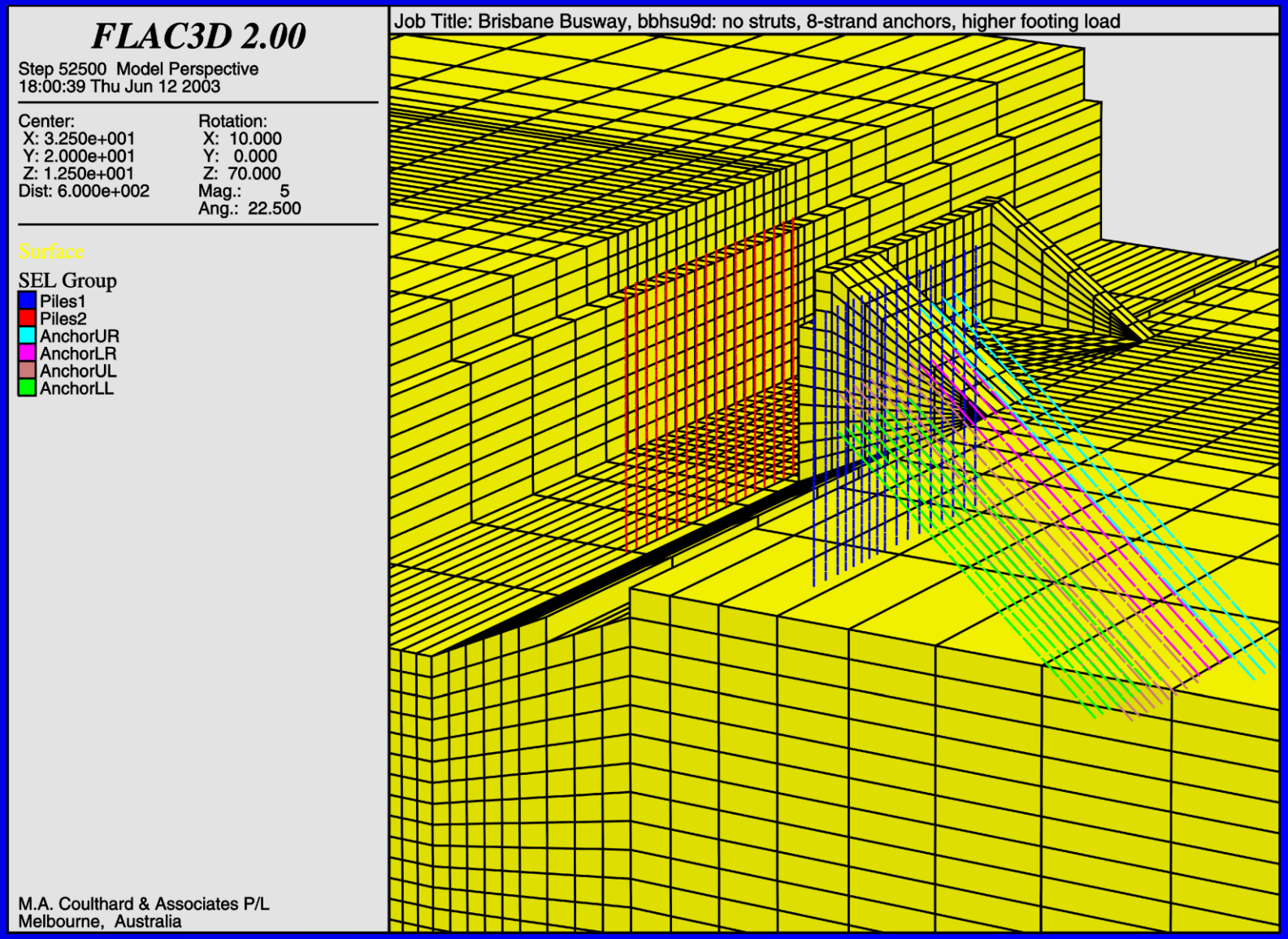
Modelling Strategy

- Equilibrate pre-excavation state
- Follow construction sequence of excavation and installation of support (8 stages)
- Install crossbeams along lines of piles and struts across tunnel in some cases

Modelling Structural Elements

- Difficulty: each structural node can be source of only one link - node-to-zone or node-to-node
- Require multiple coincident nodes to, e.g., link cable to pile below ground surface
- Create links thus: cable-node to pile-node to zone
- Explicitly delete links from deleted nodes
- Manage via *FISH*

Excavation adjacent to bridge foundation



Cases Modelled

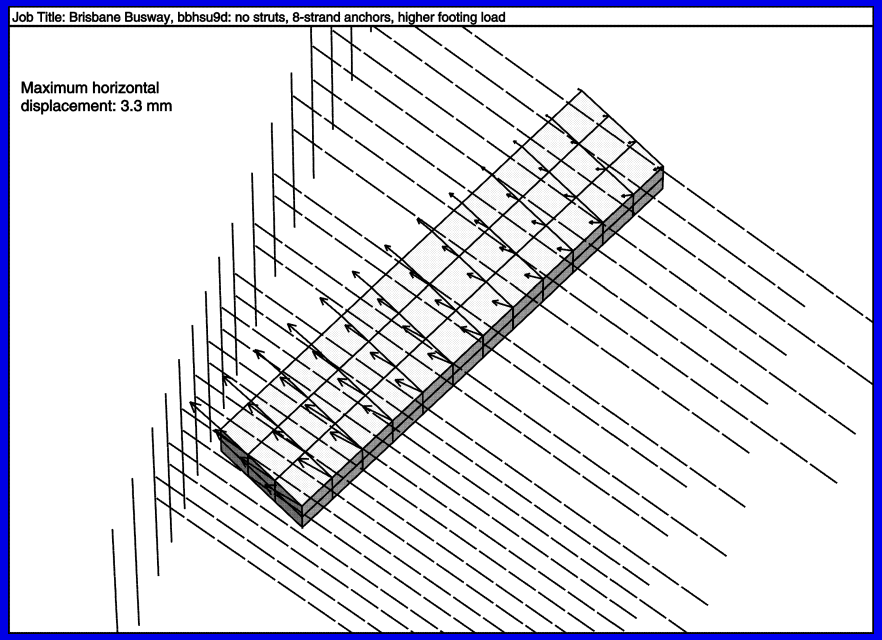
Final analyses included piles and ground anchors but not temporary struts:

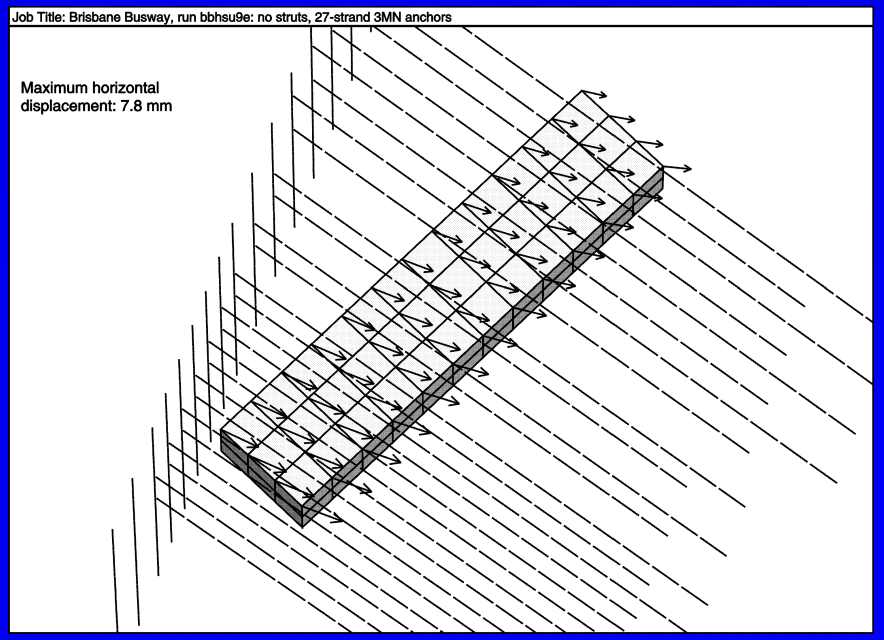
bbhsu9c: 8-strand cables, 1 MN pre-tension

bbhsu9d: as for 9c but higher footing load

bbhsu9e: as for 9d but 27-strand cables, 3 MN pre-tension

Induced Footing Displacements

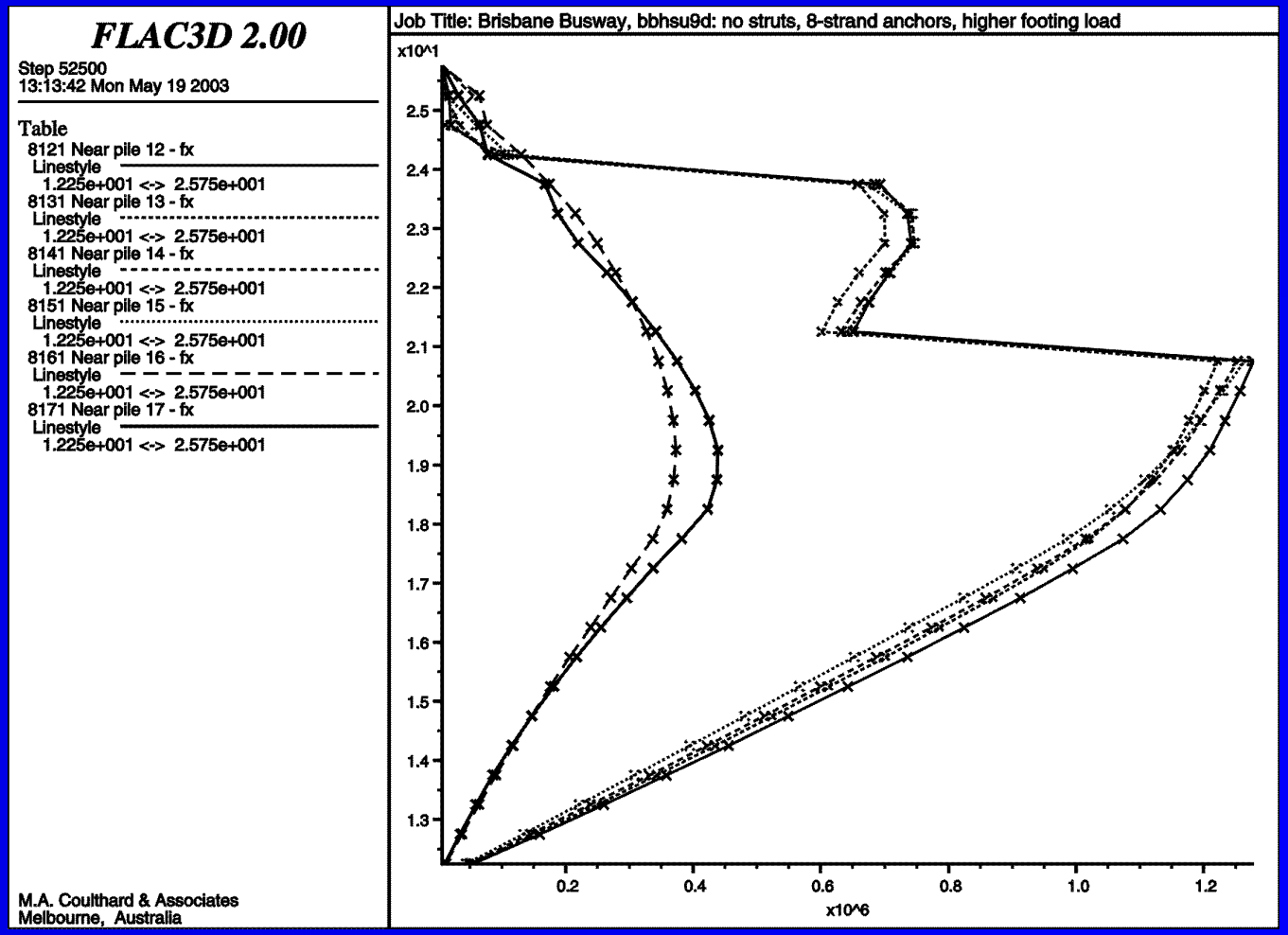




9d: 8-strand cables, 1 MN
max. horiz. disp. = 3.3 mm
support satisfactory

9e: 27-strand cables, 3 MN
max. horiz. disp. = 7.8 mm
support excessive

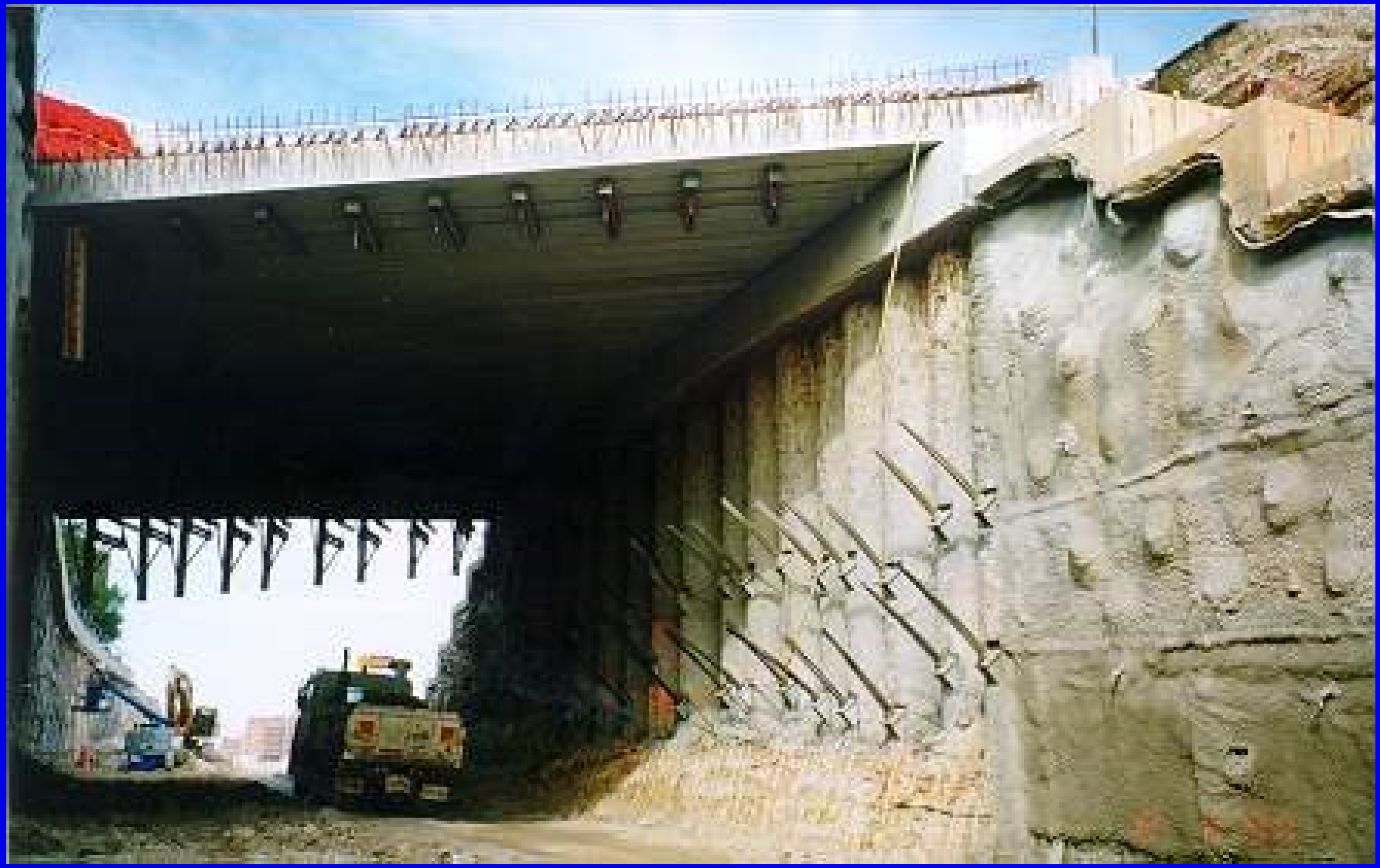
Axial Forces in Piles



Field Performance

- Anchors used: 8-strand cables, 1 MN pre-tension
- Monitoring during construction: lateral deflection of abutment of Hawthorne Street Bridge < 5 mm, as required
- No distress of bridge during or after construction
- Response of system consistent with *FLAC*^{3D} predictions

Excavation adjacent to bridge foundation



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