Condition assessment of corrugated steel underpasses including three-dimensional terrestrial laser scanning

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Introduction

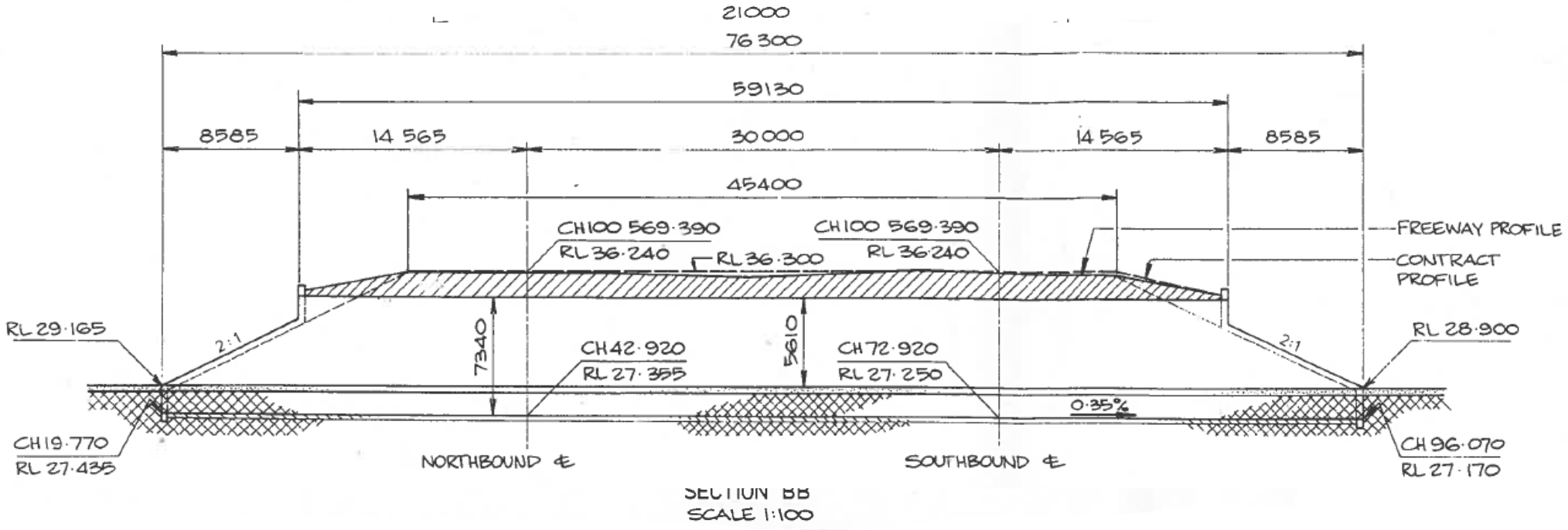
- Background
- Overview of structures
- Methodology
- Site inspection results and observations
- Assessment
  - Durability
  - Capacity
  - Geometry
- Rehabilitation options and costing
- Conclusion

Project background

- Detailed inspection, testing and assessment of six BCMS assets
- The structures are all multi-plate construction
- Accommodate local road, fauna, and pedestrian movements
- Constructed between 1977 and 1997
- Spans range from 3.2 m to 11.5 m
- Structures categorised as either horizontal ellipse or arch
- Three-dimensional laser scanning undertaken for all

Horizontal ellipses

- Provided for local roads
- Full ellipse with bottom filled to form pavement and paths
- Reinforced concrete end collar and thrust beams
- 10m+ wide, up to 90m long, 1.6m to 4.4m cover
- Corrugations with 150mm pitch and 50mm depth. Typically approx. 6mm plate

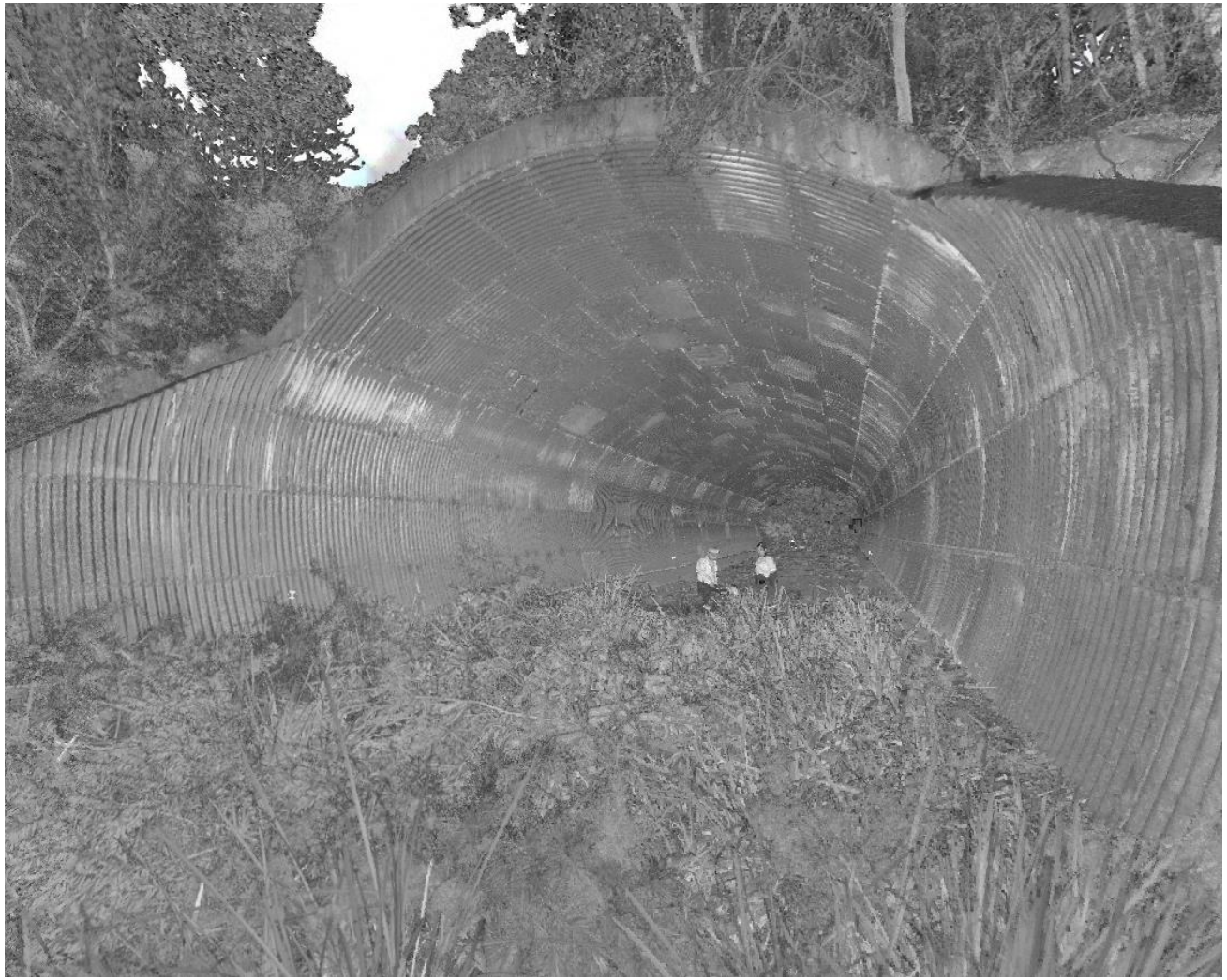


Arches

- Fauna and pedestrian underpasses
- Elliptical or semi-circular geometry
- Supported on reinforced concrete strip footings with channel connection detail
- Calga 11.6m span, similar to ellipse structures, 7mm plate thickness, 85m long, up to 7.3m cover.
- Other structures 3.2m and 8m span, 200mm pitch by 55mm deep corrugations, 3mm and 5mm plate thickness, 2.4m cover

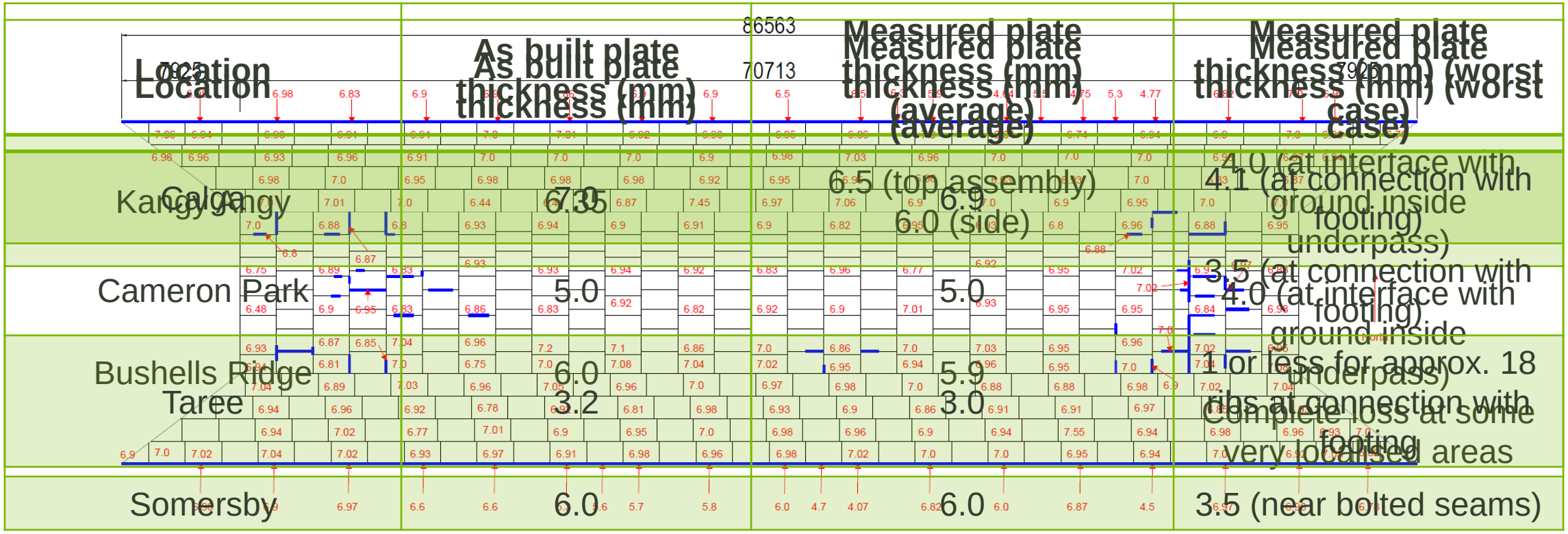
Methodology

- Site inspection, testing and survey
- Durability assessment using established standards, anticipated corrosion losses compared with observed losses
- Laser scan used for geometry assessment
- Structural assessment using PLAXIS for ‘as new’ and ‘as is’ conditions
- Calculation of critical plate thickness at which stress limit exceeded
- Residual life estimated based on observed thickness and corrosion rates
- Remedial options costed and assessed



Site inspections

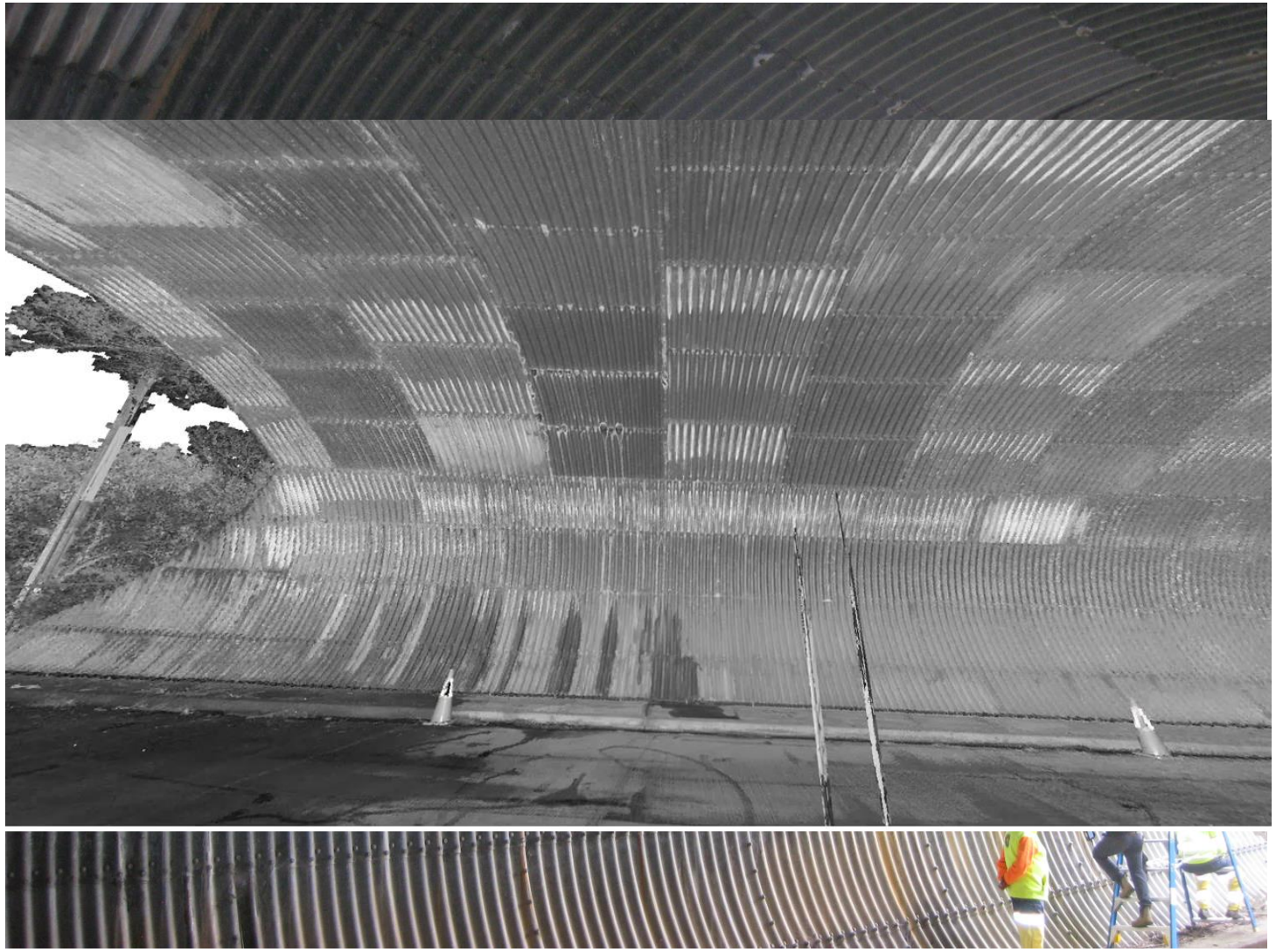
- Visual inspection, photographs, and defect mapping for each structure
- Ultrasonic thickness testing, 50 per cent of visible plates tested
- Galvanising thickness testing
- Terrestrial laser scanning



Location	As built plate thickness (mm)	Measured plate thickness (mm) (average)	Measured plate thickness (mm) (worst case)
Kangy Angy	7.35	6.5 (top assembly) 6.9 6.0 (side)	4.0 (at interface with ground inside footing) 4.1 (at connection with underpass)
Cameron Park	5.0	5.0	3.5 (at connection with footing) 4.0 (at interface with ground inside underpass)
Bushells Ridge	6.0	5.9	1 or less for approx. 18 ribs at connection with footing
Taree	3.2	3.0	Complete loss at some very localised areas
Somersby	6.0	6.0	3.5 (near bolted seams)

Horizontal ellipse observations

- Surface corrosion at bolted joints above horizontal centre line
- Surface corrosion for the bottom 100-200 mm of the plates at interface for unsealed paths
- Poor road drainage through underpass resulting in ponded water repeatedly wetting structure
- Vegetation to be removed
- No visible evidence of overloading



Arch observations

- Increased amount of corrosion at connection to concrete foundation
- Connection detail consistently damp
- Corrosion at footing connection worse on high side
- Surface corrosion at the bolted seams of plates for Calga but not more recent structures
- Vegetation to be removed
- No visible evidence of overloading

Durability assessment

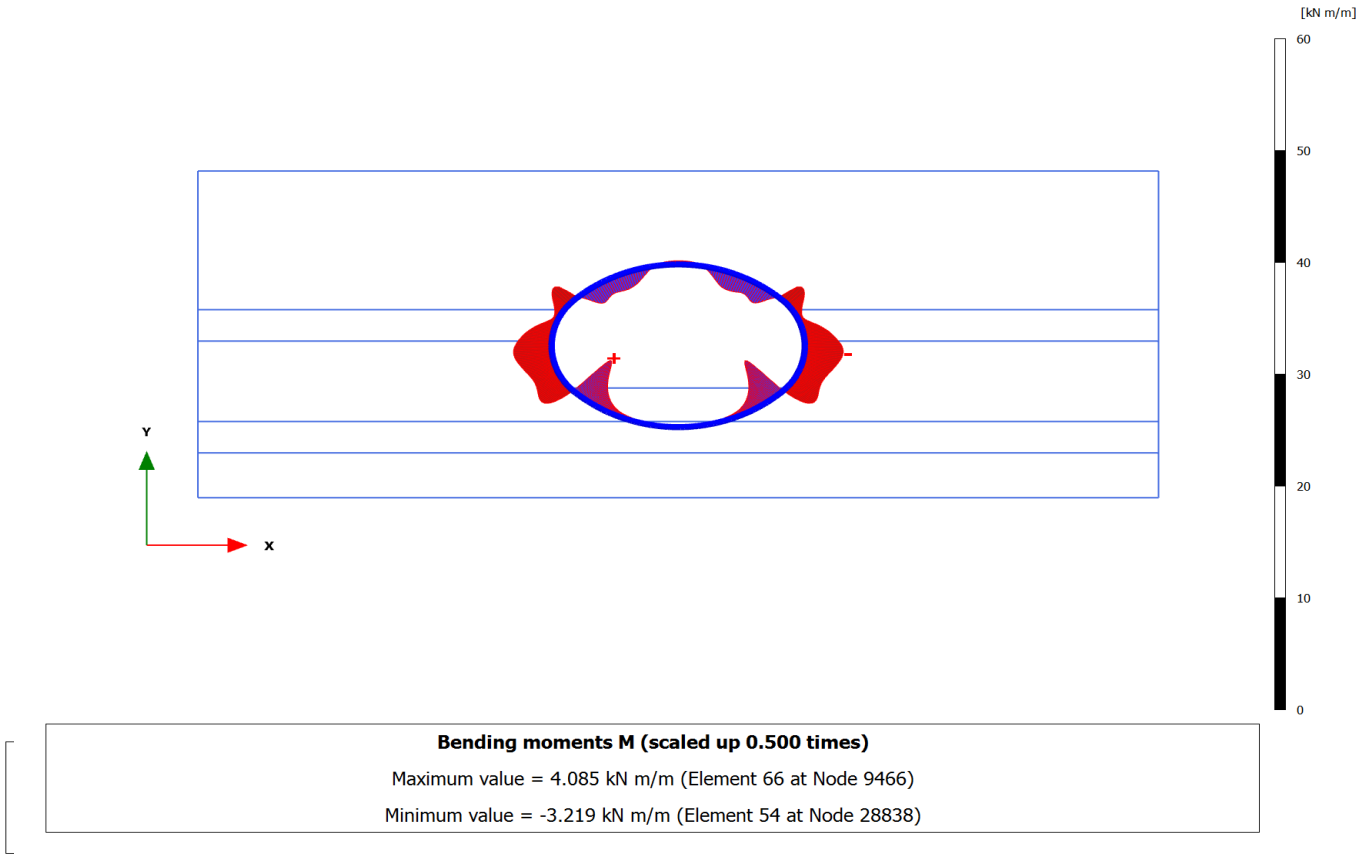
- Soil side corrosion
  - Zinc coating adopted based on standard at construction. Typically 70 microns
  - AS 2041 adopted for corrosion rates for zinc and steel (30 microns per year for steel after loss of zinc)
- Atmospheric corrosion
  - Corrosivity category C3 adopted based on AS 2312 and ISO 9223
  - Corrosion loss calculated based on ISO 9224
- Microclimatic factors
  - Corrosivity category C4 adopted for high frequency wetting

Durability assessment

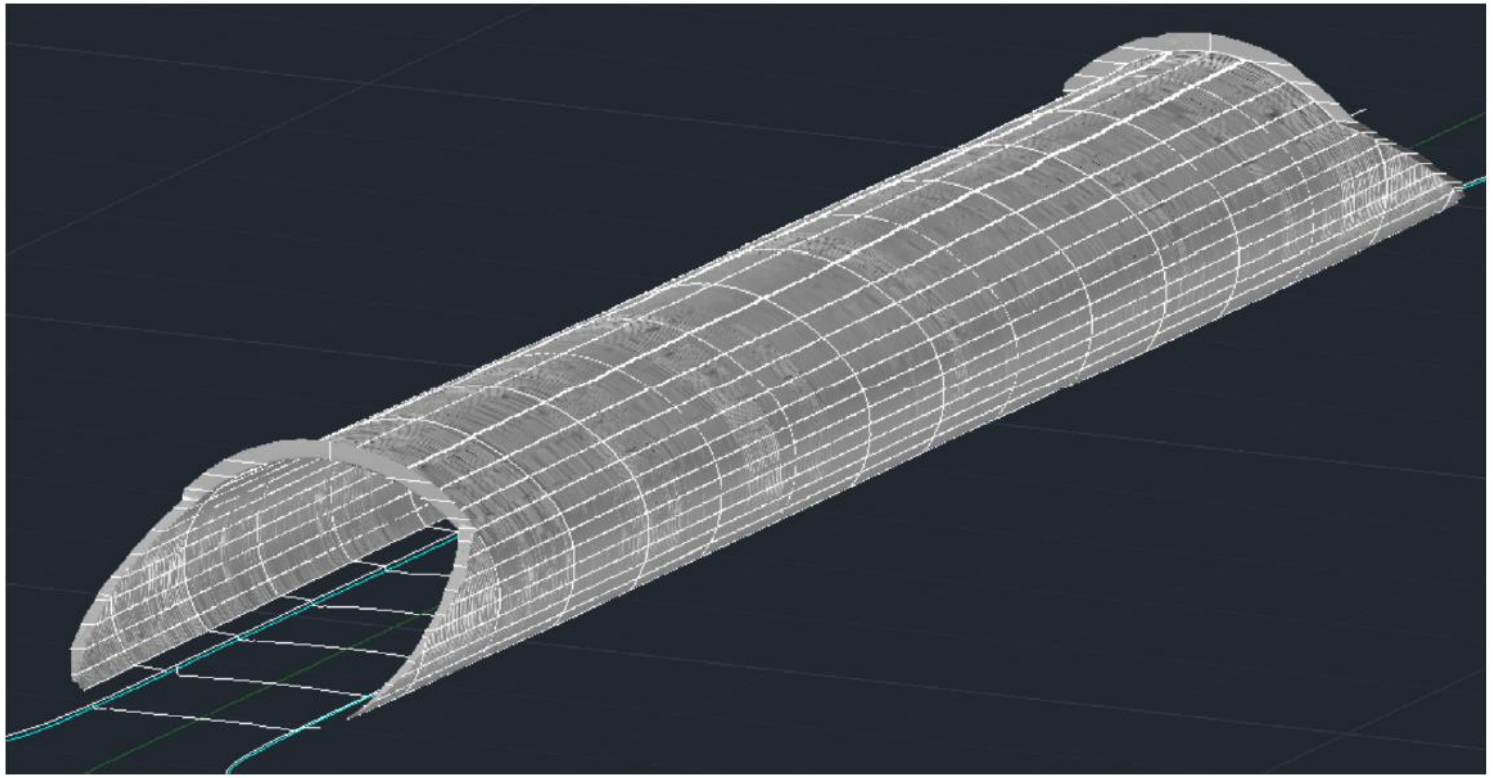
- Soil side – less than initial assessment
  - Better aligned with AS 2159 rate of 10 microns per annum for non aggressive fill
- Atmospheric – less than initial assessment
  - Better aligned with corrosivity category C2
- Microclimatic – more than initial assessment
  - Better aligned with corrosivity category C5

Capacity assessment

- PLAXIS used for eight stage analysis
- Backfill assumed as per current Roads and Maritime specifications
- Yield stress for sheets assumed to be 230 MPa
- Assessed for T44 loading
- ULS and SLS combined axial and bending stresses assessed. Seam strength and global buckling also assessed
- Peak bending stresses for ellipses near thrust beam and pavement / footpath level
- Elliptical arches similar, peak stress for circular arch near footing



Geometry assessment



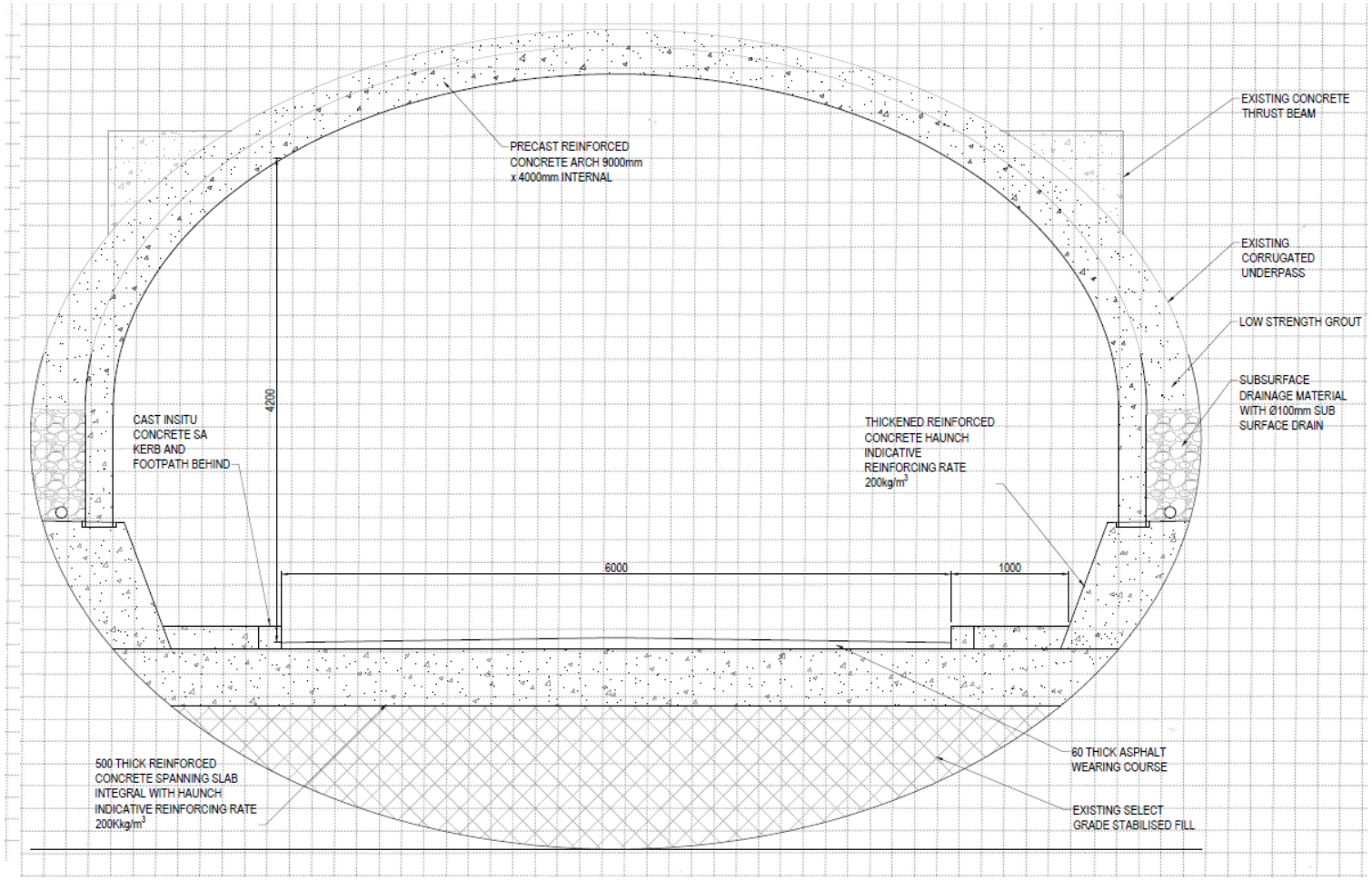
- Point cloud data used to produce millimetre level accuracy 3D model
- Cross sections and longitudinal sections taken at regular increments
- Most structures exhibited reduction in cross section height in comparison with drawings
- Most structures exhibited greater deformation at mid point away from portals. This was compared with PLAXIS with varying degrees of success
- Main intent of survey was to provide benchmark for future inspections
- Future potential for mapping of surface corrosion

Rehabilitation

- Residual life assessed for each structure
- Short term remedial works recommended
  - Sealing of road and footpath (ellipses)
  - Improving road drainage (ellipses)
  - Cleaning foundation connection and improving drainage near foundation (arches)
  - Local propping of arch structures where complete corrosion loss (arches)
  - Cleaning and painting for several structures
  - Removal of trees and vegetation

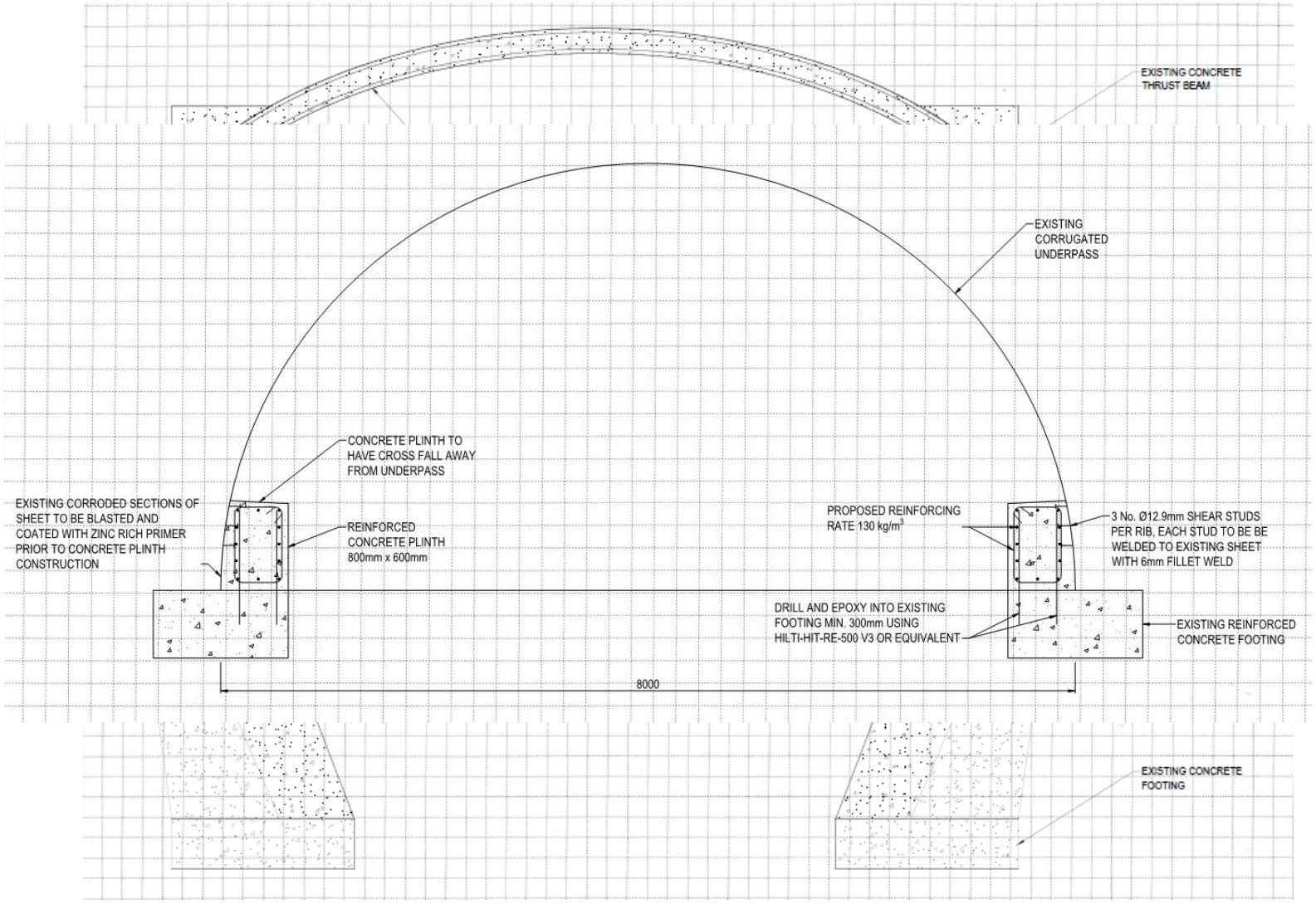
Rehabilitation options – horizontal ellipses

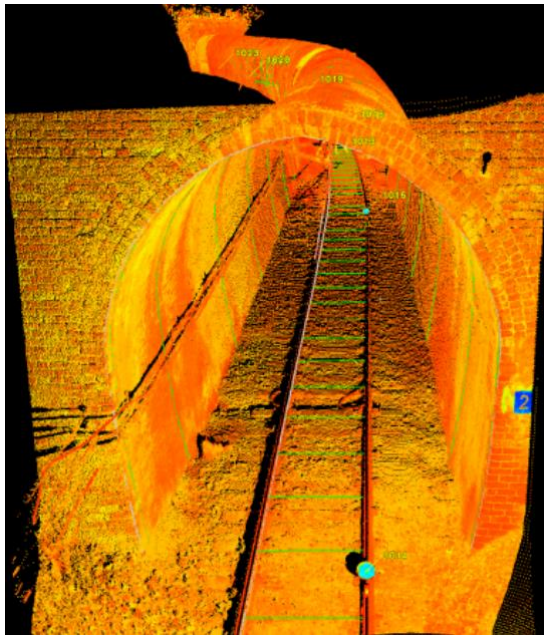
- Proposed long term options
  - Propping using steel sets
  - Shotcrete in-situ concrete arch
  - Replace with precast concrete arch crown units
- FRP lining and CP not considered feasible based on current technology
- All options costed
- Multi-criteria assessment
- Steel sets least expensive, shotcrete lining generally preferred



Rehabilitation options – arches

- Proposed long term arch options
  - Strengthen footing connection
  - Shotcrete lining
  - Precast arches/boxes
- FRP and CP not considered feasible based on current technology
- All options costed
- Multi criteria assessment
- Strengthening of footing connection preferred where possible followed by shotcrete lining



Summary and conclusions

- Corrosion at seams and footpath interface for ellipses
- Corrosion at footing connection for arches
- Laser scanning a safe method to capture an accurate model for ongoing monitoring
- Observed corrosion rates generally lower for soil side and atmospheric corrosion but higher for microclimatic corrosion
- Steel sets most cost effective for ellipses, shotcrete better whole of life cost
- Strengthening footing connection most cost effective for arches
- Assessing similar structures simultaneously provides efficiencies and consistency
- Scanning and reality capture technology finding more applications in asset management