Weathering Steel in Bridge Replacement of Rail Overbridges

27 November 2017

JACOBS

Outline

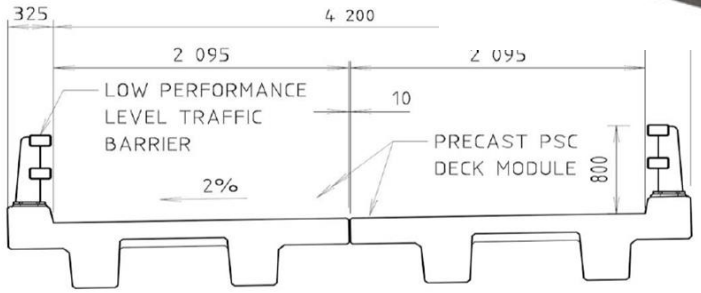
- Introduction
- What is Weathering Steel
- Benefits
- Design Considerations
- Recent Experience with Weathering Steel
  - Nooroo Overbridge
  - Michelago Overbridge
  - Cooma Overbridge
- Conclusion

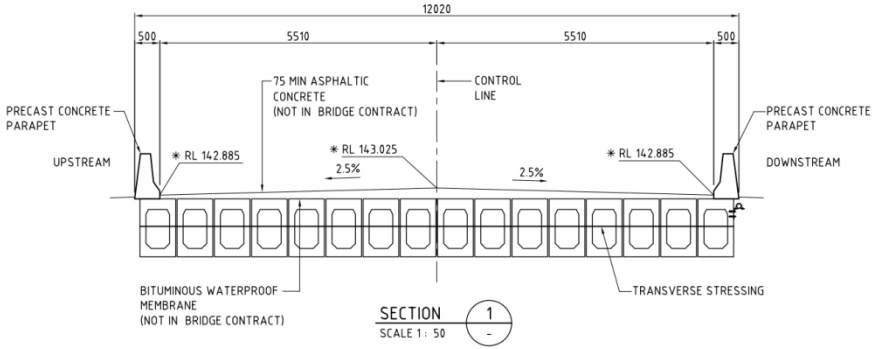
Introduction – NSW Timber Bridges

- 1,894 Council owned bridges (2014 IPWEA)
  - 950 in fair condition
  - 504 in poor condition
- 83 Country Rail owned bridges
- Program of Bridge Replacements
  - Improve safety
  - Eliminate load capacity restrictions
  - Reduce maintenance commitment
  - New low maintenance structures

Bridge Replacement Options

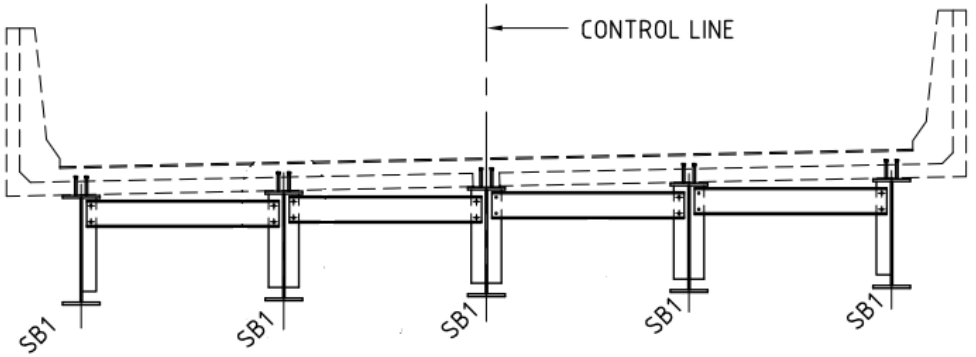
- Proprietary Precast Concrete Modular Bridge Deck Systems
  - M-Lock® bridge system Rocla Span 7m to 15m
  - HumeDeck® bridge system Span 6m to 12m
- RMS Country Bridge Solution (CBS)
  - Prestressed Concrete Double T-Deck Modules – Span 8m to 12m
- PSC Planks
  - RMS Planks – Span 6m to 18m
  - QLD PSC Deck Units with Transverse Stressing – Span 12m to 25m
- PSC Super-T Girders (T-Roff) – Span 18m to 37m





Bridge Replacement Options

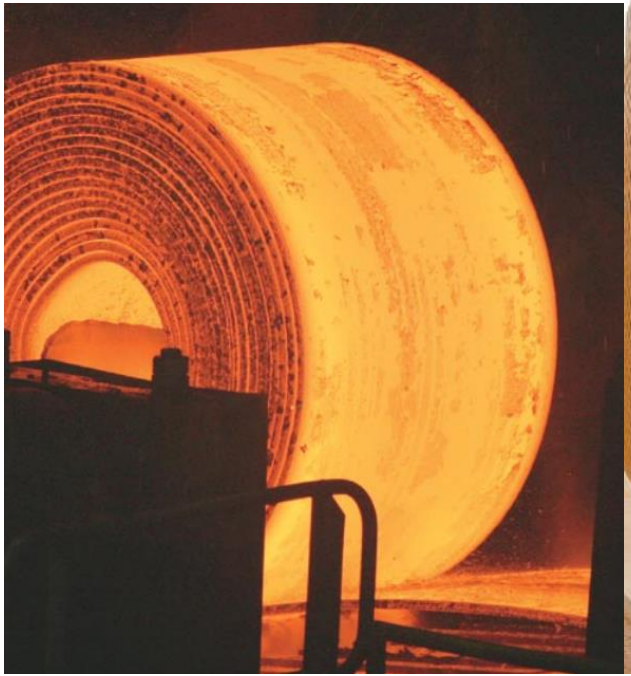
- Steel Bridges
  - Traditionally Not the first choice!
  - Typically second consideration where weight and/or structural depth prevent the use of concrete
  - As low as 5% of bridge designs in recent years
- Issues
  - Ongoing maintenance of the protective coating
  - Whole of life cycle costs



- INTRODUCTION OF WEATHERING STEEL WILL CHANGE THIS

What is Weathering Steel

- Structural steel alloy with enhanced atmospheric corrosion resistance
- Uncoated it develops a stable protective oxide coating, ‘Patina” which prevents the steel’s tendency to continually rust
- Alloying elements include copper, chrome, silicon, nickel and phosphorus
- Commonly referred to as COR-TEN® (United States Steel Corporation) and typically used for architectural panels, screens and cladding applications
- BlueScope Steel now manufacture structural plate from 10 to 80mm thickness complying with AS/NZS 3678 Structural steel – Hot-rolled plates, floor plates and slabs



Weathering Steel

- BlueScope's REDCOR™ Weathering Steel AS/NZS 3678-WR350 (B) (L0, L20)
  - 10mm-80mm
- Chemical composition refined and engineered to provide
  - High steel toughness
  - Good weldability

- Comparable alloy levels of standards for weathering steels, ASTM A588 and A709 and EN 10025 Part 5
- AS/NZS 3678-WR350 is a genuine high strength structural plate grade
- Approx. 15% premium on material cost

Tensile Properties (Transverse)		Thickness (mm)				
		9.95 < t ≤ 16	16 < t ≤ 22	22 < t ≤ 32	32 < t ≤ 50	50 < t ≤ 80
Yield Strength (MPa)	Guaranteed Min	340				
	Typical	400 – 480	400 – 450	380 – 450	360 – 460	360 – 450
Tensile Strength (MPa)	Guaranteed Min	450				
	Typical	500 – 580	480 – 530	490 – 580	460 – 550	500 – 580
Elong. On $5.65\sqrt{S_0}$ (%)	Guaranteed Min	20				
	Typical	28 – 39	28 – 39	28 – 39	28 – 39	28 – 39

Weathering Steel Bridges

- No Road/Rail public weathering steel bridges in Australia
  - Forestry Tasmania in 1990's built weathering steel plate girder bridges
- First used worldwide:
  - 1964 – USA, New Jersey Turnpike
  - 1969 – Rail bridge in UK
  - 2012 – KiwiRail replaced 4 underbridges
- Over 50 years of data on performance

Forestry Tasmania, 2013

Benefits of Steel

- Structural Benefits
  - High strength to weight ratio
    - Minimise structural depth
    - Longer spans
  - Variable structural depth
  - Splice connections for continuous spans
  - Less demand on substructure design
- Construction Benefits
  - Lighter girders
  - Rapid construction
  - Fabrication off site in controlled workshop, automated
- All steel is visible for inspection

Steel Innovations Conference 2013, Christchurch NZ

Weathering Steel vs Conventional Steel

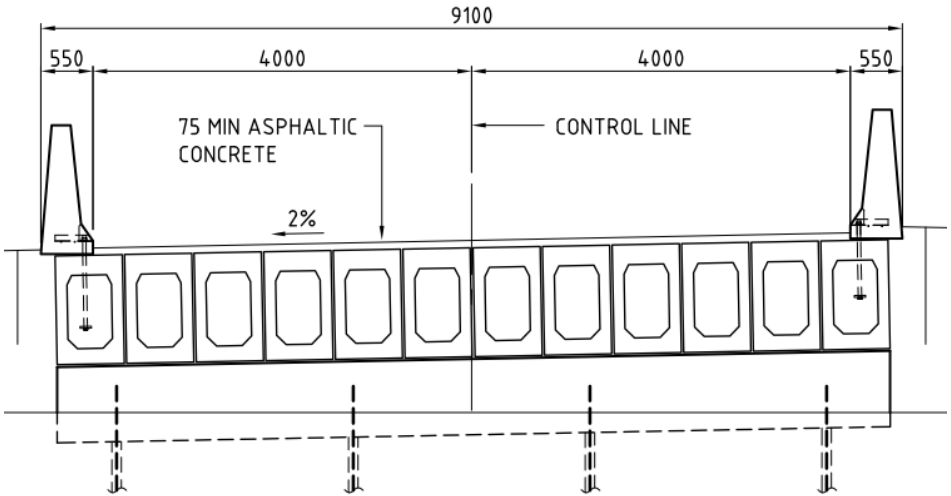
- No protective coating
  - Additional cost premium offset
  - Quicker fabrication
- No coating maintenance
  - Reduced whole of life cost
  - No temporary scaffold
  - No temporary lane closures
- Environmental benefits
  - No VOC from oil based coatings
  - No coating removal or containment of particles

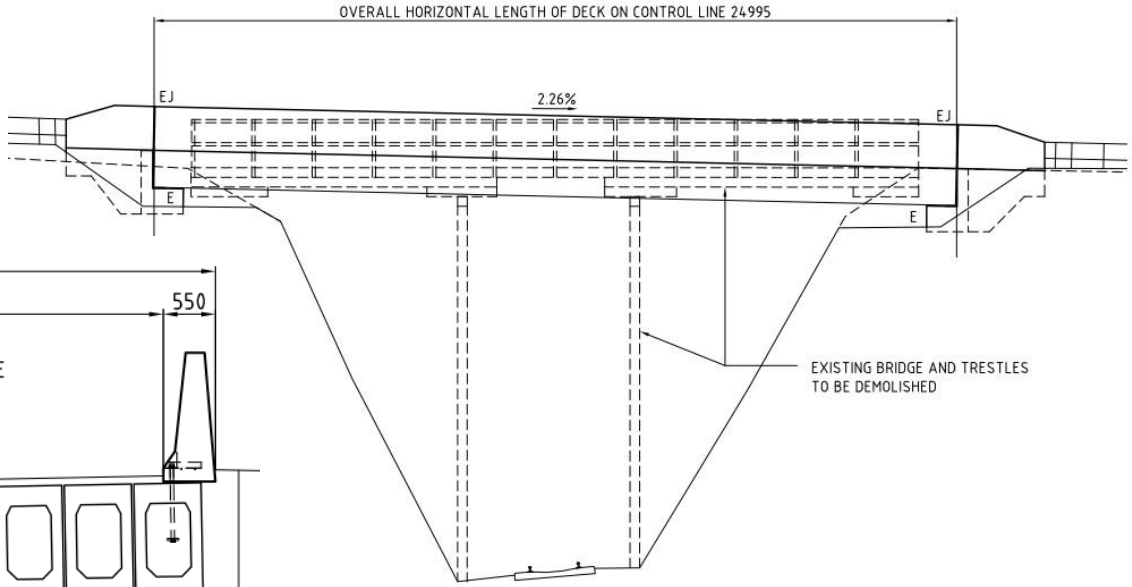
Benefit of Steel Bridge Replacement - Example

- Rail Overbridge replacement over the North Coast Line near Stroud, NSW

Benefit of Steel Bridge Replacement - Example

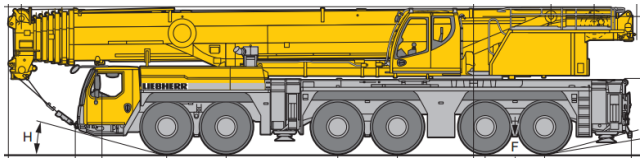
- Concrete PSC Plank deck units with transverse stressing adopted and designed





Benefit of Steel Bridge Replacement - Example

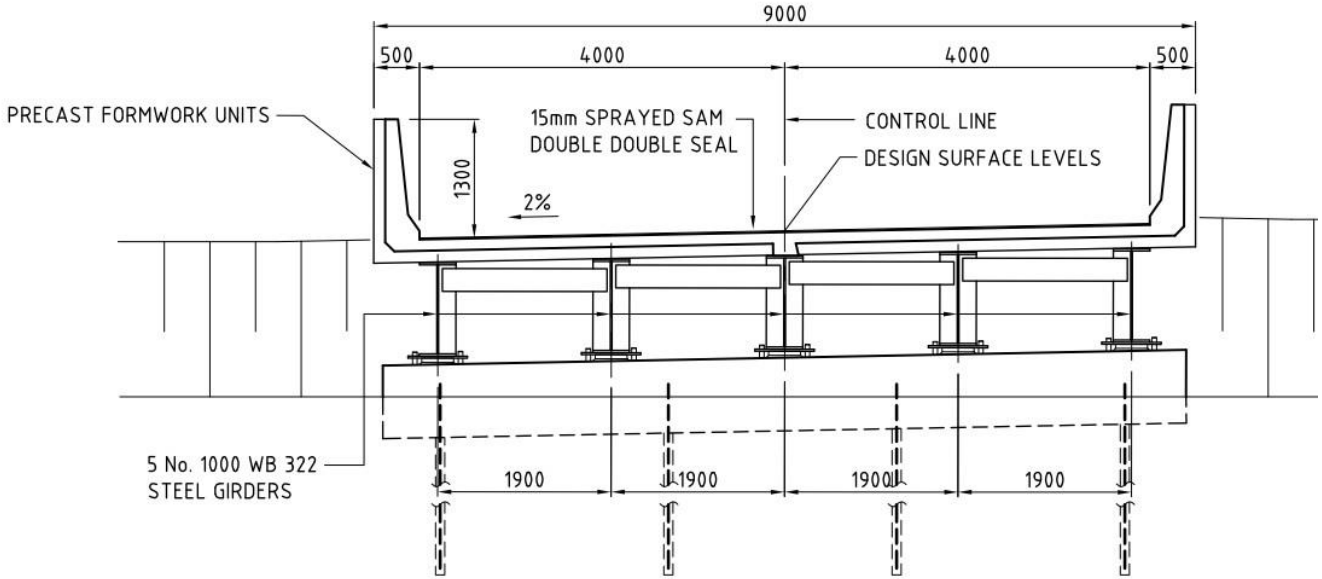
- Mass of plank 38 tonnes
- Required 300 tonne crane with a gross mass of 72 tonnes
- Existing approach creek crossings
- Timber bridges structurally inadequate
- Temporary propping required
- Environmental issues



- Re-design bridge with steel I-girders = less weight = smaller crane = no temporary propping

Benefit of Steel Bridge Replacement - Example

- Redesign with steel I-girders and composite concrete deck including precast deck panels



Benefit of Steel Bridge Replacement - Example

- 1000WB322 Girders 8.5 tonnes

Benefit of Steel Bridge Replacement - Example

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- Precast concrete formwork key in achieving fast, simple and safe deck construction
- Simplicity of design in steel, precast concrete formwork and composite cast in-situ deck was such that overall $200,000 savings compared to concrete PSC bridge

Benefit of Steel Bridge Replacement - Example

- 1000WB322 Girders 8.5 tonnes
- Precast concrete formwork key in achieving fast, simple and safe deck construction
- Simplicity of design in steel, precast concrete formwork and composite cast in-situ deck was such that overall $200,000 savings compared to concrete PSC bridge
- ADDITIONAL BENEFITS IF WEATHERING STEEL USED
  - Whole of life cost less than concrete bridge

Weathering Steel Design Considerations

- AS5100.6 (2017) weathering steel requirements include;
  - Corrosion allowance (Cl 3.7.2)
  - Fatigue category (Cl 13)
  - Welding consumables (Appendix H4.2)
- Strength and serviceability requirements no different

- Two key considerations for durable weathering steel design;
  1. Suitable Site Condition
  2. Bridge Detailing

Weathering Steel Design Considerations

- Design References
  - New Zealand Weathering Steel Guide for Bridges: HERA Report R4-97:2005
  - UK Design Manual for Roads and Bridges Volume 2 Section 3 Part 8 – BD 7/01 Weathering Steel for Highway Structures
  - FHWA Technical Advisory “Uncoated Weathering Steel in Structures”

- BlueScope Information
  - REDCOR™ weathering steel Product Brochure
  - Weathering steel Design Guide for Bridges in Australia (HERA Guide)
  - Technical Bulletin 26
  - Technical Note – Guidance on the welding of weathering steels
  - Datasheet – AS/NZS 3678-WR350 (B) (L0, L20)

Suitable Site Condition

- Atmospheric environment major factor in formation and long term performance of the patina
- NOT suitable environments include;
  - Constant dampness, buried
  - High chloride concentrations, coastal environment
  - High pollutant concentrations, industrial area, corrosive fumes
  - Directly over water bodies within 2.5m (UK BD 7/01)
- Require constant wetting, drying cycles to form adherent, stable patina
  - Moisture day/night cycle
- Corrosion allowance related to atmospheric environment and classification

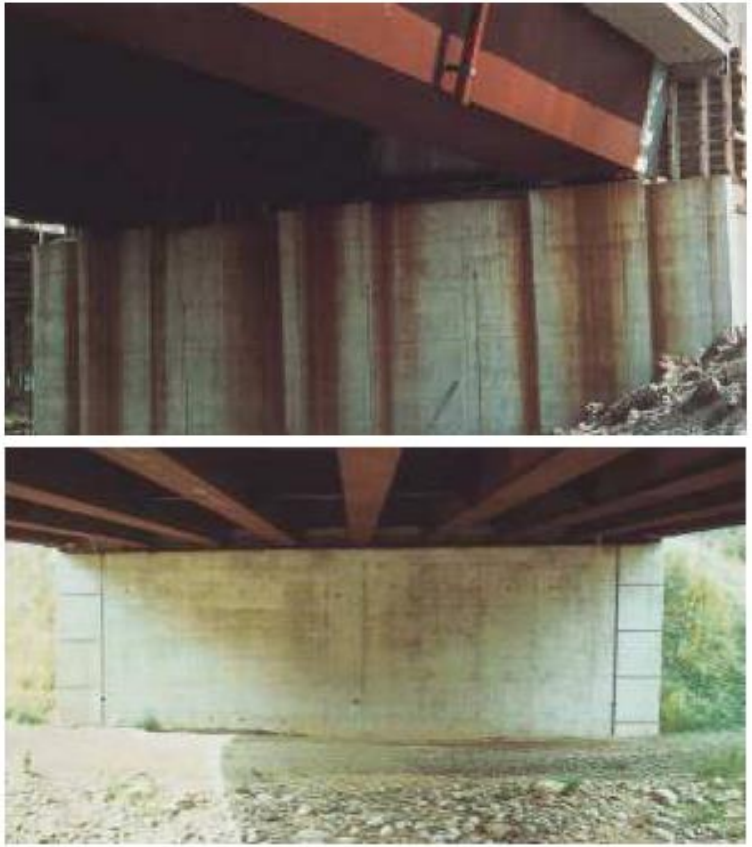
Atmospheric Classification

- AS4312 – Atmospheric corrosivity zones in Australia
- Category C5 and C4 not suitable
- Category C3 Site specific studies recommended
- Category C2 and C1 suitable
- Corrosion allowance as per AS5100.6 (2017)

Category	Corrosivity	Environment	Corrosion Allowance
C1	Very Low	Dry indoors	1mm
C2	Low	Arid / Urban Inland	1mm
C3	Medium	Near Coast	1.5mm
C4	High	Coastal	N/A
C5	Very High	Sea-Shore	N/A

Bridge Detailing

- Drainage
  - Steelwork can dry out, eliminate moisture and debris retention, drip plates on bottom flange
  - Grind flush welds, terminate web stiffeners above the bottom flange,
  - Avoid expansion joints where possible
  - Control run-off from steelwork, staining, slope abutment headstocks, bearing plinths and drip pans



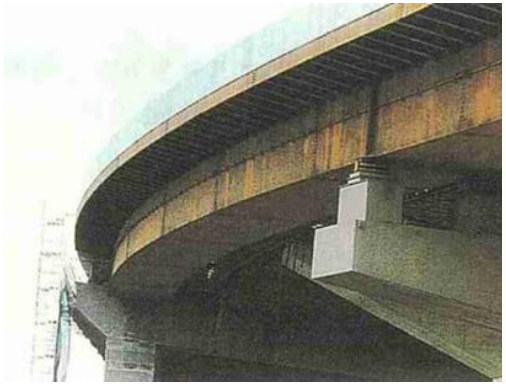
NZ Guide HERA

Bridge Detailing

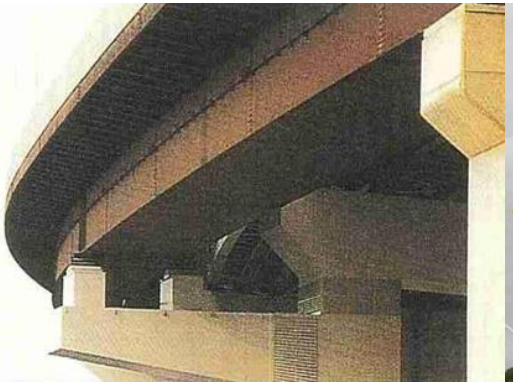
- Welding
  - Weathering steel has similar welding characteristics to conventional structural steel
  - AS/NZS 1554.1 is applicable
  - Welding consumable selection
    - Welding consumables from Table 4.6.1(C) of AS/NZS 1554.1 providing consistent corrosion and colouring
  - BlueScope Technical Bulletin 26 Weathering Steel
  - BlueScope Technical Note on the Welding of Weathering Steels
- Bolting
  - Galvanic reaction, zinc galvanised bolts sacrificed
  - Weathering grade bolts to ASTM A325 Type 3 equivalent to property class 8.8

Bridge Detailing

- Aesthetics
  - Colour and texture varies over time
    - Initially orange-brown as the patina develops to the uniform characteristic dark brown
  - Post fabrication blast clean with non-metallic grit
  - Urban design aspect is subjective



2 months



1 year

29 years

NSSMC website

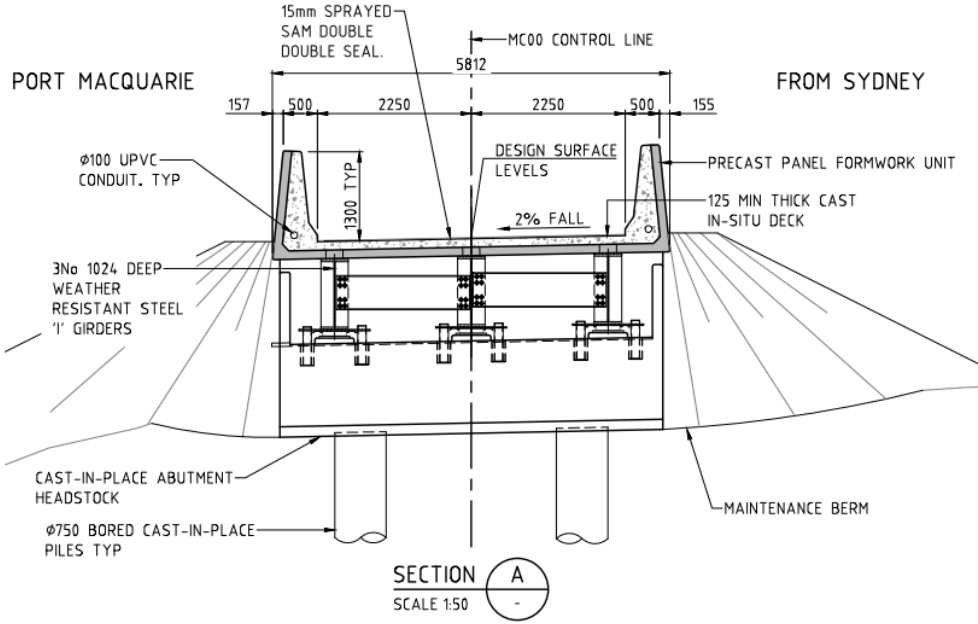
Recent Experience – Nooroo Overbridge

- Overbridge on Nevilles Road at 263.816km over the North Coast Line
- Jacobs appointed by JHR-CRN to provide design for the replacement
- Existing timber bridge 22.9m length and 3.8m width
- New low-maintenance structure that meets the needs of the asset owner and the local government authorities
- Preferred Option - composite weathering steel I-girder superstructure with precast deck panels

- Construction methodology
- Lighter girders
- Comparable whole of life cost

Recent Experience – Nooroo Overbridge

- Overall deck length of 20.67m and width between barriers of 4.5m
- 3 x 1024mm deep I-girders AS/NZS 3678-WR350 at 2.0m c/c
  - 400 x 32 thick top flange
  - 16 thick web
  - 400 x 32 thick bottom flange
- Precast concrete 125mm thick formwork full width panels that include upturns on each side to act as formwork for the in-situ concrete traffic barrier.
- 125mm thick in-situ concrete slab to form a total 250mm concrete deck.

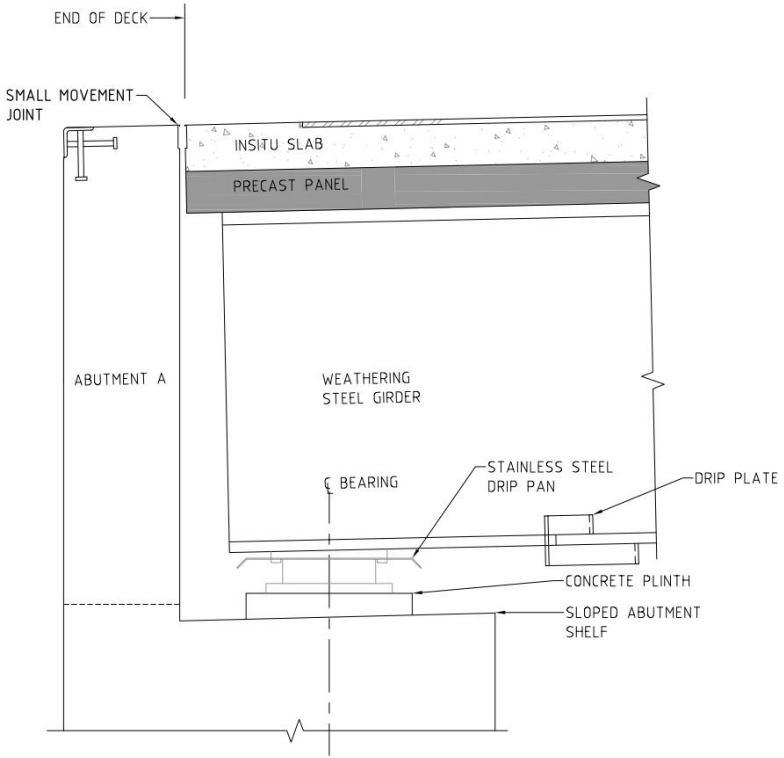


Recent Experience – Nooroo Overbridge

- Atmospheric corrosivity category is C2: Low in accordance with AS 4312
  - Bridge site approx. 42km from coast
  - Topography provides shielding from salt spray
  - Rural and remote from sources of pollution
  - Adopted a 1.0mm per exposed face corrosion allowance

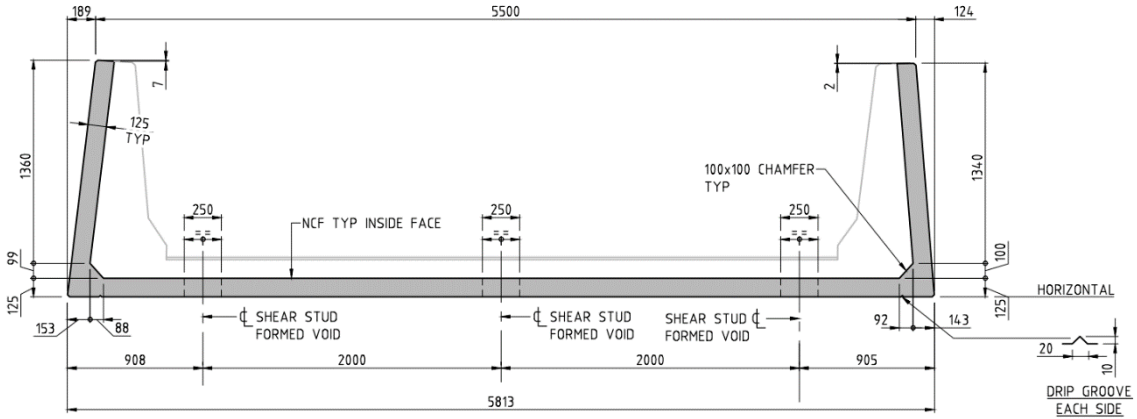
Recent Experience – Nooroo Overbridge

- Bridge detailing adopted includes
  - Concrete plinths to avoid any debris retention
  - Intermediate stiffeners minimised
  - Drip plates at low end of outer girders to deflect any runoff and prevent debris accumulation
  - Sloping abutment to control run-off
  - Fully sealed small movement joints
  - Stainless steel drip pan to protect the laminated elastomeric bearings



Recent Experience – Nooroo Overbridge

- Precast concrete deck panel
  - Fully decked to provide a safe working platform during construction
  - Upturns on each side to act as formwork for the in-situ concrete traffic barrier
  - Ease of construction over rail line during track possession
  - Mass of panel 6.8 tonnes
- Formed holes within deck panel for groups of shear studs
  - AS5100.6 requires complete shear interaction
  - Spacing and size of voids balanced with concrete width required for strength



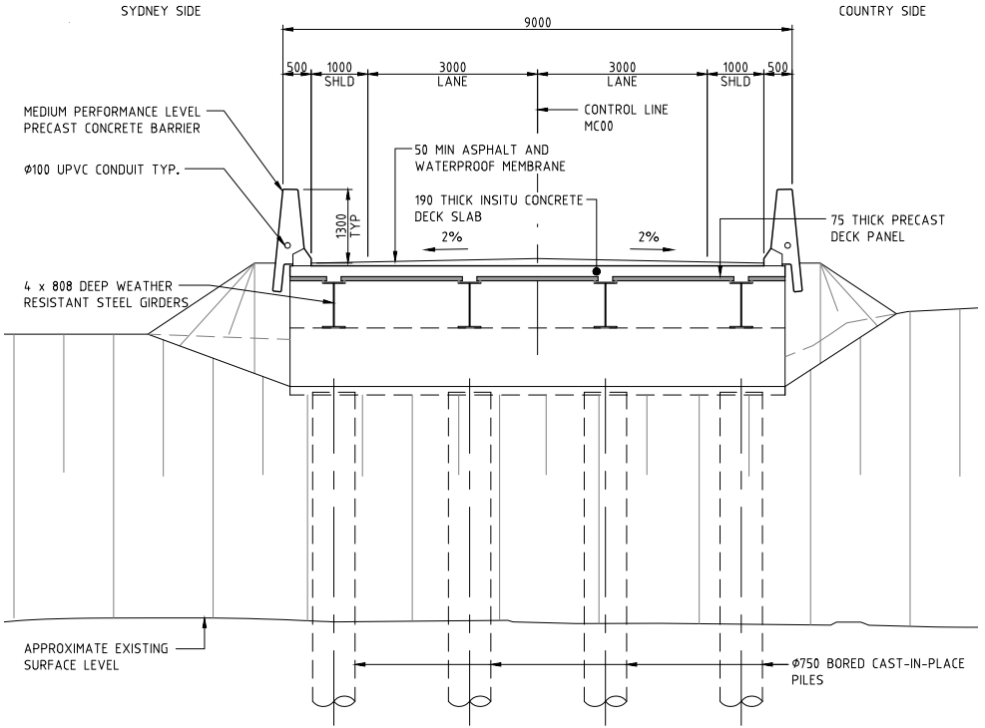
Recent Experience – Michelago Overbridge

- Overbridge on Kelly Road at 363.533km over the Goulburn to Bombala Line
- Jacobs appointed by JHR-CRN to provide design for the replacement
- Existing timber bridge 20.1m length and 7.1m width
- New low-maintenance structure that meet the needs of the asset owner and the local government authorities
- Preferred Option - composite weathering steel I-girder superstructure with integral abutments

- Low maintenance structure
- Lighter girders
- Comparable whole of life cost

Recent Experience – Michelago Overbridge

- Overall deck length of 20.5m and width between barriers of 8.0m
- 4 x 808mm deep I-girders AS/NZS 3678-WR350 at 2.4m c/c
  - 400 x 20 thick top flange
  - 16 thick web
  - 400 x 28 thick bottom flange
- Composite concrete deck of 265mm overall thickness, 75mm thick precast ‘Humeslab’ and 190mm thick in-situ
- Full height precast concrete bridge barriers

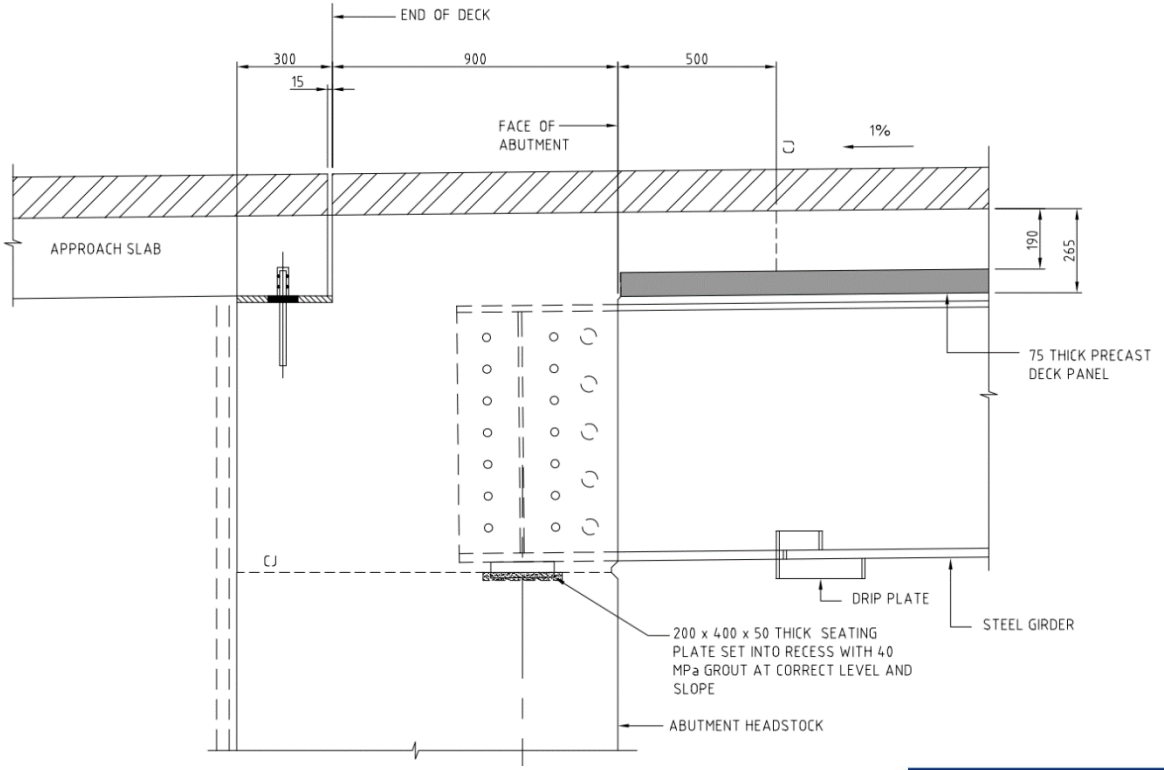


Recent Experience – Michelago Overbridge

- Atmospheric corrosivity category is C2: Low in accordance with AS 4312
  - Bridge site >50km from coast
  - Rural and remote from sources of pollution
  - Adopted a 1.0mm per exposed face corrosion allowance

Recent Experience – Michelago Overbridge

- Bridge detailing adopted includes
  - Intermediate stiffeners minimised
  - Drip plates at low end of outer girders to deflect any runoff and prevent debris accumulation
  - Integral connection eliminates any runoff issue through joints



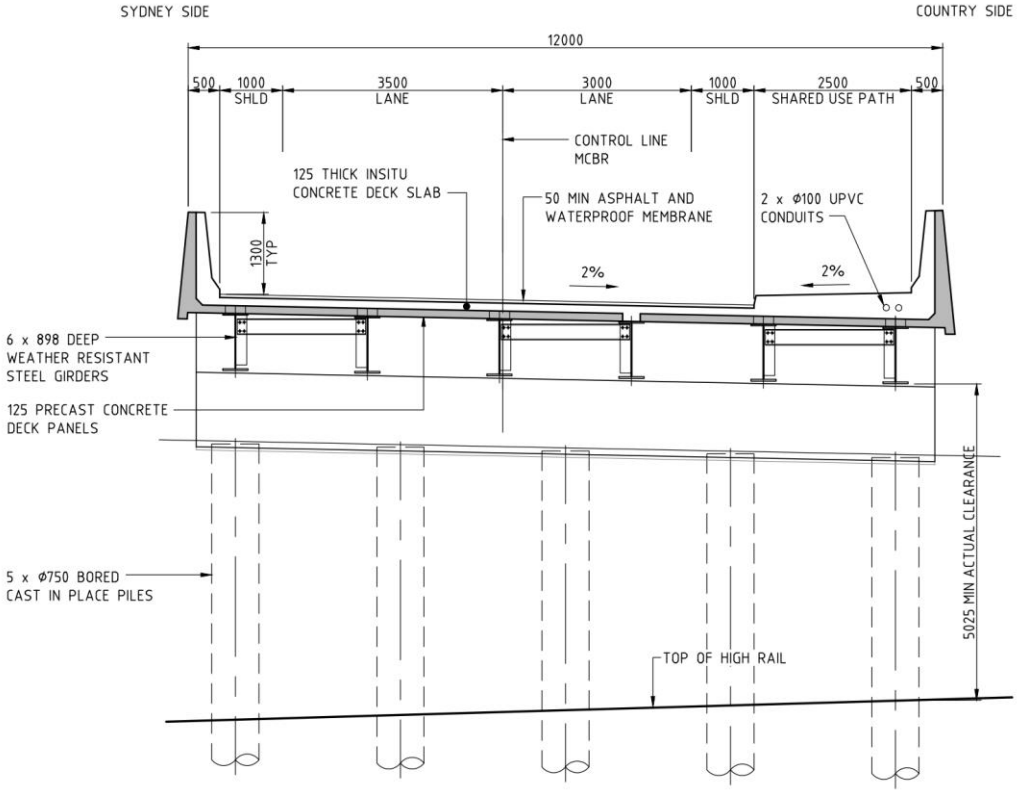
Recent Experience – Cooma Overbridge

- Overbridge on Thurrung Street at 432.700km over the Goulburn to Bombala Line
- Jacobs appointed by JHR-CRN to provide design for the replacement
- Existing Bailey Bridge 21.35m length and 3.57m width between trusses and 6.27m overall width with the pedestrian walkway.
- New low-maintenance structure that meet the needs of the asset owner and the local government authorities
- Preferred Option - composite weathering steel I-girder superstructure with integral abutments

- Low maintenance structure
- Lighter girders
- Comparable whole of life cost

Recent Experience – Cooma Overbridge

- Overall deck length of 24.65m and width between barriers of 11.0m incl. shared use path
- 6 x 898mm deep I-girders AS/NZS 3678-WR350 at 2.0m c/c (braced in pairs to assist with stability in transportation and erection)
  - 400 x 20 thick top flange
  - 16 thick web
  - 400 x 28 thick bottom flange
- Precast concrete deck panels providing total a total 250mm composite concrete deck



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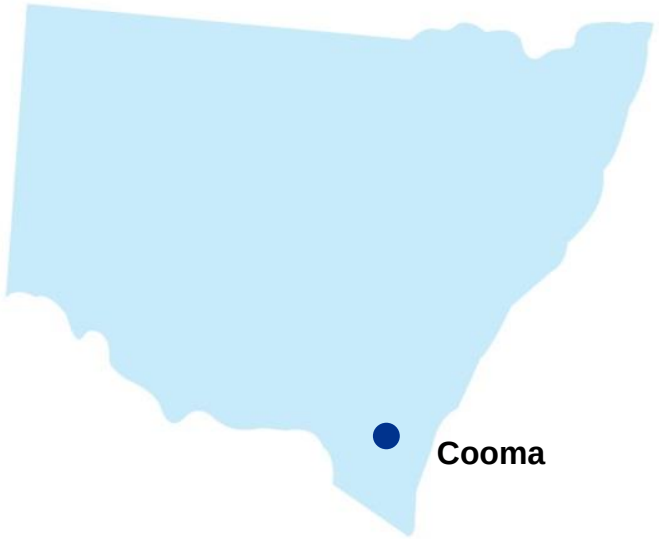

Recent Experience – Cooma Overbridge

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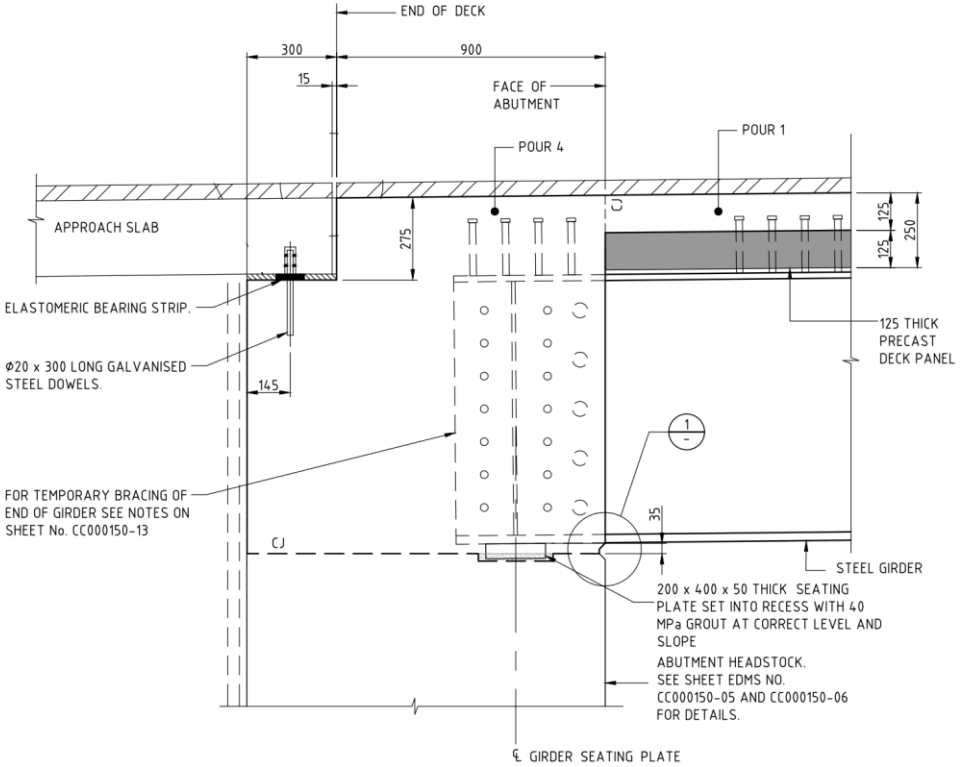
  - Drip plates at low end of outer girders to deflect any runoff and prevent debris accumulation
  - Integral connection eliminates any runoff issue through joints



Weathering Steel Opportunities

- Composite Weathering Steel Superstructure
  - Longer spans
  - Variable depth
  - Splice connections for continuous spans
  - Eliminate heavy concrete girders
  - Less demand on substructure design

Modern Steel Construction March 2012

Conclusion

- The availability of weathering steel in larger plate sizes from BlueScope Steel warrants the use of steel bridge designs to be revisited for Rail Overbridges
- We have demonstrated that weathering steel bridges can be cost competitive against concrete alternatives
- We hope this will generate discussion and exchange of ideas for weathering steel bridges

Acknowledgements

- John Steele – Jacobs Technical Director Bridges
- Felix Lie – Jacobs Bridge Engineer

Weathering Steel in Bridge Replacement of Rail Overbridges

Thankyou

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