Weathering Steel in Bridge Replacement of Rail Overbridges

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ABSTRACT

In 2014, the Institute of Public Works Engineering Australasia (IPWEA) undertook a road asset management project in consultation with the Local Councils of NSW. The Councils reported back that there were 1894 timber bridges under their ownership and of these, 504 were in poor condition. A further 950 of these bridges were in fair condition, but deteriorating rapidly and soon to be classified as poor. The required funding to continue the service life of these bridges was estimated to be in the order of $220 million, with a continuous $30 million per year to maintain a satisfactory standard. Most of these timber bridges are unsafe and inadequate for loads of modern traffic. The cost to replace the bridges was estimated to be in the order of $470 million. There is a similar situation with bridges on the NSW Country Rail Network where 84 of the 373 overbridges in 2007 were timber bridges with an additional number of the steel girder bridges having timber decks. These bridges are gradually being replaced to improve the safety and load capacity of the rail crossings and reduce the maintenance commitment.

The challenge for the industry is to come up with solutions to replace these bridges that have low construction and ongoing maintenance costs. Despite advantages with lighter weight and speed of construction, steel girder bridges have not been included in the mix of these design solutions due to the cost of applying and maintaining the coatings on the steel. With BlueScope now producing weathering steel in larger plate thicknesses, the use of weathering steel longer span (15 metre plus) bridges is becoming a viable alternative to the conventional precast concrete plank and girder bridges.

Jacobs have recently designed three bridges in weathering steel for the replacement of timber rail overbridges on the Country Rail Network in NSW. With careful detailing of the weathering steel and innovative use of precast concrete decking with the steel, modular steel composite bridge systems should be a viable option for bridge designers, constructors and owners.

INTRODUCTION

Steel in bridge construction in Australia has declined significantly over the last 40 years from around 25% of bridges to as low as 5% of bridges in recent years. The main reasons for this have been the proliferation of precast prestressed concrete girders systems with the development of the Super-T girder in the early 1990s being the most notable, the high demand and cost of steel around the world and the higher ongoing maintenance cost of steel bridges to maintain the corrosion protection coatings. Steel bridges are typically only used now on road and rail bridges where site constraints on the handling of precast girders prohibit their use.

BlueScope Steel has recently commenced production of weathering steel in larger plate sizes and is investigating its manufacturing capability to provide the ability to manufacture welded I-beams in weathering steel for a small additional cost compared to the conventional steel welded beams they produce and at a net saving when the cost of coating the conventional steel is taken into account. The cost of steel is also reducing with the increase in production and reduction in demand for steel from China. The removal of the need to recoat the steelwork with the use of weathering steel and the lowering of the cost of steel production warrants a relook at the use of steel in our bridges.

Though the use of weathering steel as a bridge material is not new, its use in Australia has unfortunately been limited to façade material. Jacobs have recently designed three bridges in weathering steel for the replacement of timber rail overbridges on the Country Rail Network in NSW. With careful detailing of the weathering steel and innovative use of precast concrete decking with the steel should promote the use of steel, particularly for regional bridge replacement in the 15 to 40 metre span range. The paper will outline why weathering steel is a viable option for timber bridge replacements and highlight the key detailing measures adopted in the design of weathering steel in view that their use may be more commonly adopted in Australia.

TIMBER BRIDGE CONDITION

In 2014, the Institute of Public Works Engineering Australasia (IPWEA) undertook a road asset management project in consultation with the Local Councils of NSW. The Councils reported back that there were 1894 timber bridges under their ownership and of these, 504 were in poor condition. A further 950 of these bridges were in fair condition, but deteriorating rapidly and soon to be classified as poor. The required funding to continue the service life of these bridges was estimated to be in the order of $220 million, with a continuous $30 million per year to maintain a satisfactory standard. Most of these timber bridges are unsafe and inadequate for loads of modern traffic. The cost to replace the bridges was estimated to be in the order of $470 million.

There is a similar situation with bridges on the NSW Country Rail Network where 84 of the 373 overbridges in 2007 were timber bridges with an additional number of the steel girder bridges having timber decks. These bridges are gradually being replaced to improve the safety and load capacity of the rail crossings and reduce the maintenance commitment. Over the last ten years, Jacobs has been involved with the replacement of 1a number of overbridges as the technical advisor, first to Transfield Services for five years, then as a panel member with other consultants to John Holland Rail who are currently holding the maintenance contract for the Country Rail Infrastructure Authority of NSW. In all of these cases, a single span bridge has replaced the original three span timber bridges.

The preferred replacement bridge design has been the Queensland type precast planks with transverse stressing and bolt-on, full height precast concrete traffic barriers with stitch pour connections to minimise the amount of work over the rail line. Four bridges have been or planned to be replaced using steel girder construction with composite concrete decks, in which the last three are of weathering steel type. Case studies on these three weathering steel bridges are discussed in this paper.

The sheer number of timber bridges that are in poor condition and need to be upgraded, as well as the limited funding available requires a rethink of our bridge designs by Councils, Road and Rail Authority, Consultants and Contractors and their steel fabricators and precasters to reduce the cost of these bridges.

In response to the challenge to manage and replace the Council and RMS bridges in NSW, the NSW Roads and Maritime Services (RMS) developed a modular precast concrete bridge system (Country Bridge Solution or CBS) with the intention that the bridge system would be used by Councils for the replacement of many of these timber bridges. Proceeding this development, proprietary girder or deck system had been developed by precast manufacturers. These are all good systems and certainly earn their merit in many bridge replacement applications. The systems are however limited to 12 metre span lengths and weight restrictions will prevent this length being increased much further in the future. There is a need for steel bridge options where longer spans are needed or more efficient for the site.

The cost of maintaining the coating systems on the steel girders over the 100 year design life of the bridge rules steel out for many bridge projects before the concept options are even developed. The availability of weathering steel in the larger plate sizes should allow the development of cost competitive modular steel composite bridge options to compete against precast concrete modular bridge system where longer spans lengths are beneficial or required.

WHAT IS WEATHERING STEEL

Weather resistant steel is a structural steel alloy specially formulated to enhance its corrosion resistance. It develops a stable oxide ‘rust’ layer called the Patina, which prevents further oxidation under ideal condition, effectively protecting the steel underneath from adverse environmental effects. The alloying elements of weather resistant steel consist of higher copper, silicon, chromium, nickel and in some cases phosphorous content than the typical structural mild steel.

Current adaptation of weathering steel in Australia has been limited to façade application. This trend has driven the demand for weathering steel, stimulating the market and the production of weathering steel in Australia. This has led BlueScope to lower production cost of weathering steel and broaden the plate sizes available in the market from 8 to 80mm. This allows welded beams to be made in weathering steel, which makes them cost competitive for their use in steel bridges in Australia.

The practice of using weathering steel for bridges has existed for quite some time. The first weathering steel bridge was built in the United States in 1964 with the construction of the Moorestown Interchange on the New Jersey Turnpike. The United Kingdom followed in 1967 with York University Footbridge. Since then, many countries in the European and Asian Continents have adopted weather resistant steel including Germany, France and Japan. New Zealand has also followed this trend, building their first weathering steel bridge in 2006 with Mercer to Longswamp Off-ramp.

Though weathering steel carriers higher premium than conventional steel, a study by the American Iron and Steel Institute (AISI) in 1995 stated that the cost of weathering steel is around 9.2% less than that of conventional steel, thanks to its lack of painting requirement. In the United States over 2,300 weathering steel bridges were built in between 1964 and 1995.

Many of the bridges have performed well in service while some bridges have issues with excessive ongoing corrosion due to the environment at the bridge site, local problems with corrosion or staining of the substructure due to poor detailing. With over 50 years of data on the performance of the bridges, the design guidelines for weathering steel bridges are well understood and are discussed further below.

THE BENEFIT OF STEEL BRIDGE REPLACEMENT

During concept stage, designers in Australia typically look at the possible span or span configurations for a bridge. Concrete is often preferred, and where available, they will select the appropriate proprietary precast, plank or Super-T girder system to suit the spans. Where the spans are longer than the the maximum span of Super-T girders (38 metres), other precast concrete girder options are considered, such as segmental box span or voided slab. This is generally the case for span that requires allowance for navigational clearance on rivers, or road or rail crossings.

Steel is typically only considered where weight and/or structural depth prevent the use of precast concrete. Steel would rarely be considered otherwise as the whole of life cost would be more expensive due to the need to recoat the steel at least twice during the design life of the structure.

The introduction of weathering steel in the Australian market should change this as it eliminates the need for costly maintenance regime. Further, for the reasons stated above in the AISI study, the lack of coating requirement should see weathering steel as having a competitive life cycle cost against steel and concrete for most bridge designs.

The cost benefit for steel can be seen clearly in a rail overbridge replacement project over the North Coast Rail Line, near Stroud Road in country NSW, constructed in 2010. Steel was chosen due to load restriction on a timber bridge over a nearby river, which had to be crossed to reach the site. The timber bridge could not support the weight of the crane required to lift the precast girder option into place. The simplicity of the design in steel, precast concrete formwork and composite cast in-situ concrete deck was such that it was $200,000 or 18% cheaper than the equivalent concrete plank bridge. The same design in weathering steel would guarantee a whole of life cost less than concrete bridges even for sites where access is not an issue.

WEATHERING STEEL DESIGN CONSIDERATION

The Australian Standard Bridge Design AS5100.6-2017, for the first time, provides specific reference on the allowances of weathering steel with respect to a corrosion allowance that needs to be considered representing a loss of thickness of material used for structural purposes. It also provides specific fatigue considerations when weathering steel is used. All applicable requirements, such as strength and serviceability are valid as would be for conventional steel bridges, provided the steel material complies with AS/NZS 3678 Structural steel – Hot-rolled plates, floorplates, and slabs. Weather resistant steel that complies with this standard can be procured through BlueScope.

Other requirements relating to the use of weathering steel and the detailing would also be applicable to ensure the bridge durability. These specific requirements may not normally be found on conventional steel therefore the designer should familiarise themselves by consulting available guides. The main source of the detailing requirements and guidelines relating to weathering steel bridges can be found in the following literature:

- HEARA Design Guide: Weathering Steel Design Guide for Bridges in Australia
- 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.

Under suitable exposure conditions, the atmospheric corrosion rate of weathering steel is sufficiently low to achieve the 100 year design life. Other sources have stated that 120 years is feasible given ideal site condition. The unavoidable corrosion requires weathering steel design to allow for section loss of each surface. This section loss is negligible in structural analysis but important for stress and strength calculations. Reduced net section properties should be used for these checks.

Attention must be given to durability design of weathering steel. The two key considerations in the design of weathering steel bridges are the atmospheric environment at the bridge site and the design detailing of the bridge. Both these considerations relate to the formation of the patina which directly affects the weathering steel's durability. These will be discussed further in the sections below.

SUITABLE SITE CONDITION

The atmospheric environment is a key factor in the formation and long term performance of the patina. Under appropriate conditions, the patina will form providing the durable protective oxide coating. The condition where weathering steel is not appropriate as the patina cannot develop is under constant dampness, locations with high chloride concentrations and locations with high concentration of pollutants. The high chloride concentration can be directly related to the distance to the coast and therefore weathering steel is not suited in near coastal environments. It is also not suitable near industrial areas where there is the potential exposure to corrosive industrial and chemical fumes. Continuous contact with moisture is to be avoided, such as constant dampness, water ponding on steel element, permanent submersion and/or buried in soil of within 2.5 m of water crossings [ref BD 7/01]. The detailing of the steel work to minimise water retention and prevent prolonged dampness is, therefore, a key factor in the design.

The environmental classification for each bridge site is determined in accordance with AS 4312 – Atmospheric corrosivity zones in Australia taking into account both macro-climate factors and micro-climate factors to determine the appropriate corrosivity category. The corrosivity category follows ISO 9223 with a range from C1 – very low corrosivity typical indoor environments up to C5 – very high corrosivity typical offshore and coastal areas. Weathering steel should not be used for categories C5 and C4, as recommended in the Guides and stated in AS5100.6. For category C3 factors such as wind and topography will need to be investigated to determine its suitability. Generally, weathering steel can be used in locations that are more than 2km from the open seacoast, where the maximum first year corrosion rate (taking into account both the macroclimate and microclimate effects on sheltered surfaces) of mild steel is less than 50 µm/yr.

The corrosivity category determines the section loss allowance, as previously discussed. AS5100.6 in clause 3.7.2 specifies 1.0mm for C1 & C2 and 1.5mm for C3, per exposed face.

DETAILING

Detailing is critical for weathering steel bridges. A study on 20 weathering steel bridges was undertaken by AISI in 1995 to gauge the durability performance of weathering steel bridges around the United States. The study showed that the weathering bridges were performing well despite the adverse environmental condition, such as low-level water crossing, marine, industrial, frequent high rainfall, high humidity and persistent fog environments. Where problems were identified, they typically relate to poor detailing such as deck leakage, poor drainage, and ponding of moisture on bridge elements.

The Design Guides provide useful recommendations for bridge designers on the detailing of weathering steel bridges. Weathering steel bridges should not be permanently wet or damp. Therefore detailing should minimise wetting and provide means for water to drain away. Special attention must be given to the following bridge elements;

- Bridge expansion joints are a common area of problems with weathering steel bridges. Avoid expansion joints where possible, by using integral abutments (for shorter bridges) and continuous deck. Selection of joint type is important to minimise the risk of failure that cause water leaking. Terminating the girders short of the joint or coating the steel locally at the joint also minimises the risk.
- Web stiffeners should be terminated above the bottom flange to prevent trapping of water and debris at the stiffener. Full height stiffeners such as those over supports should be angled to direct the water away. Alternatively, provide angled drip plate in front of the bearing stiffener to direct the bulk of the water off the girder before it reaches the stiffener.
- Where possible, runoff from the girders should not flow onto visible concrete surface to avoid visual staining. Drip plates and drip pans can direct any run off away from concrete faces, such as columns and abutments. The abutment shelf should be sloped away from the front face so that any run off from the girders can be controlled.
- Butt weld splices should be ground smooth to avoid catching water and debris.
- The webs of box girders should run past the bottom flange to avoid moisture collecting on the bottom flange projection.

AESTHETIC

The appearance of the patina layer on weathering steel bridges is typically not an issue for overbridge replacements in rural areas which tend to attract less traffic, reducing its visibility. The girders are often hidden or obstructed from the motorist, especially for small bridges over creeks or rail lines. The appearance of the wreathing steel may not be acceptable to the Urban Designers and the public for urban bridges, major river crossings and prominent locations in the country. Its appearance may not give the public the perception of durability and robustness with the sight of “rusting” bridges. There will always be applications where weathering steel will not be acceptable from an aesthetic point of view.

Concerns have been raised whether there is the potential for the patina layer to not develop uniformly over the entire surface. This would create an uneven colour shade, which may affect its aesthetic value. After fabrication a blast clean with non-metalic grit will assist in ensuring the patina develops evenly. It is acknowledged that different surfaces will be exposed to varying wet/drying cycles affecting the patina appearance initially however eventually it will converge into a uniform layer of indistinguishable shades. Any graffiti will be difficult to remove and its removal will blemish the patina, however it would not have any adverse effect on the weathering steel’s durability.

RECENT EXPERIENCE

Jacobs has recently been involved in three timber overbridge replacement projects at Michelago, Nooroo and Cooma. A number of structural design solutions including typical precast concrete planks and girders were considered for the superstructures during the design investigation stage. The preferred solution for all structures was weather resistant steel girders with a composite concrete deck. The design features and detailing adopted for the weather resistant steel superstructure are discussed below.

Michelago Overbridge

The Michelago overbridge is located over the Goulburn to Bombala Line at 363.533km approx. 6 km north of the Michelago township, on a non-operational rail line with no rail possession to coordinate with. The existing bridge was a 3 span timber arrangement on timber trestles with an overall length of 20.1 m and width of 7.1 m. The new bridge is a single span structure with an overall deck length of 20.5 m and deck width of 8.0 m allowing for two traffic lanes. The new bridge structure comprises of weather resistant steel I-girders with composite concrete deck made integral with the abutments. The substructure is a spill through arrangement with the abutments supported on bored cast-in-place concrete piles. The bored piles were required due to the shallow depth to bedrock which eliminated driven piles as a suitable option.

The brief specifies a low maintenance structure, which was met by the weather resistant steel lack of protective coating requirement. The absence of permanent bearings and expansion joints due to integral abutment further adheres to this brief.

The girders comprise of four numbers of 808 mm deep Welded Beam I-girders, which are made up of 400 mm wide by 20 mm thick top flange, 400 mm wide by 28 mm thick bottom flange and 16 mm thick web plate. The flange to web connection is provided with 12 mm fillet welds on both sides providing a total weld effective thickness greater than the web thickness. Load bearing stiffeners at the temporary support location and web stiffeners at quarter points are 12 mm plate. The intermediate cross bracing elements are made up 250 mm deep by 90 mm wide by 12 mm thick channel sections.

One of the challenges in using weathering steel girders is a bolted connection. The bolts must be of the same material to avoid galvanic reaction. If galvanised bolts were adopted, the protective zinc coating would be sacrificed at a faster rate due to the presence of a more noble material, which is the weathering steel. The effect would be exacerbated due to considerably larger cathode surface area. To avoid the effect of dissimilar metals, the bolts have been specified as weathering grade to ASTM A325 Type 3 which is the equivalent of property class 8.8. Given the current use of weather resistant steel in Australia the bolts will need to be procured from overseas suppliers where they are commonly available. Given time and increase use of weather resistant steel local supplies should become more readily accessible.

The welding of weather resistant steel is specified to conform to the requirements of AS/NZS 1554.1 with additional requirements as documented in BluesSope's Technical Note on the welding of Weathering Steel. In general, the welding characteristics are similar to conventional steel. However, to ensure consistent corrosion resistance and colouring welding consumables should be selected in accordance with Table 4.6.1(C) of AS/NZS 1554.1. Conventional consumables may be used for small welds or for multiple weld runs since dilution during the welding process provides the finished weld with the same weather resisting property. This tends to occur in weathering steel with high phosphorus content or with smaller weld passes. The last weld run however may use welding consumables specified in Table 4.6.1(C) of AS/NZS 1554.1 to improve the durability.

The composite action of the steel girders is developed with complete shear interaction using 22 mm diameter shear studs connected to the top flange and at the ends of the girders where they are cast into the abutment headstock for the integral connection. The shear studs are not required to be weather resistant steel and do not require special welding consideration.

The embedment of the weather resistant steel into the concrete at the abutment does not require special attention as the patina will not develop due to high alkaline environment inside the concrete, passivating the weathering steel similar to reinforcement.

The key detailing measures adopted for the Michelago overbridge which is also consistent with Design Guides include detailing the web stiffeners with a gap to the bottom flange to avoid moisture and debris retention and detailing drip plates on the bottom flange of the outer girders to deflect any runoff and prevent debris accumulation at the girder end. The integral connection with the girders cast into the abutment headstocks eliminates any issues associated with runoff through joints and debris retention on the abutments. The potential for staining from patina runoff is primarily a visual concern only for concrete elements. The key detailing measures relate to runoff, debris and moisture retention which can all impact on the performance of the patina and/or on other structural components of the bridge structure. It is, therefore, crucial that these receive the appropriate consideration when design and detailing weather resistant steel superstructures.

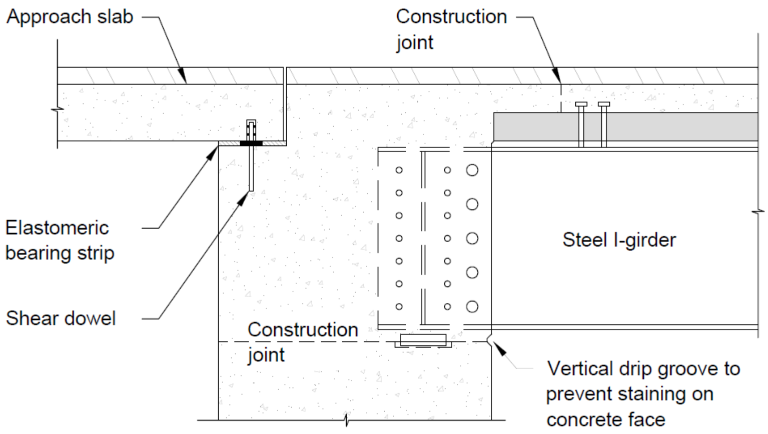

Figure 1: Steel girders with integral abutment

Nooroo Overbridge

The second of the projects is the Nooroo overbridge, on Nevilles road, which is located over the North Coast Line at 263.816km approx. 8 km north of the Stroud township. The existing bridge is a three span single lane timber structure with an overall length of 22.9m and a deck width of 3.8 m. The new bridge is a single span structure with an overall length of 20.6 m and a deck width of 4.5m for single lane traffic. The new bridge structure comprises of simply supported weather resistant steel I-girders with composite concrete deck. The substructure is a spill through an arrangement with the abutments supported on bored cast-in-place concrete piles. As with Michelago the shallow depth to bedrock precluded the use of driven piles.

The new overbridge is required to provide a minimum vertical clearance of 7.1m, as required by the operator of The North Coast Line, ARTC. The final clearance provided was 5.9m, with the condition that the superstructure can be lifted to 7.1m, eliminating integral abutments as an option.

The weather resistant steel I-girders are three numbers of standard 1000WB322 with 12mm fillet welds. Load bearing stiffeners and web stiffeners are 16 mm and 12mm thick respectively. The intermediate cross bracing elements are made up of 250 deep by 90 wide by 12 thick built up channel section of weather resistant plate, which are bolted to the web stiffeners with 4 M24 structural bolts of weathering grade. Similarly, the end diaphragms are made up of 500 deep by 100 wide by 12 thick built up channel section with 8 M24 structural bolts of weathering steel grade.

The concrete deck is made up with full-width precast concrete deck panels that incorporate upturns on each side to act as formwork for the in-situ concrete traffic barrier and also provide a safety barrier during construction. Formed holes within each panel allow for groups of shear studs connected to the top flange of the girders providing the shear connection. A 125 mm thick in-situ concrete deck slab is provided over the panels to form a total 250 mm composite concrete deck. The precast deck panel arrangement offers a significant advantage in construction program and onsite safety by providing a completely decked bridge, including safety barriers within a single track possession. There is also no need to remove any walkways or safety barriers upon completion.

The number of groups of shear studs along the steel girders needs to satisfy the minimum spacing requirements of AS5100.6 for complete shear interaction and therefore special attention of the precast concrete panels with corresponding formed holes needs to be considered. The arrangement adopted for Nooroo overbridge was unique in that only partial shear interaction was provided for under SM1600 loading and complete shear interaction for T44 loading. This concession was granted on the basis that Nevilles road is a rural dead end road with very little road traffic. In hindsight, the top flange could have been widened to accommodate three rows of shear studs instead of two. We took this as lesson learned for future bridge optimisation.

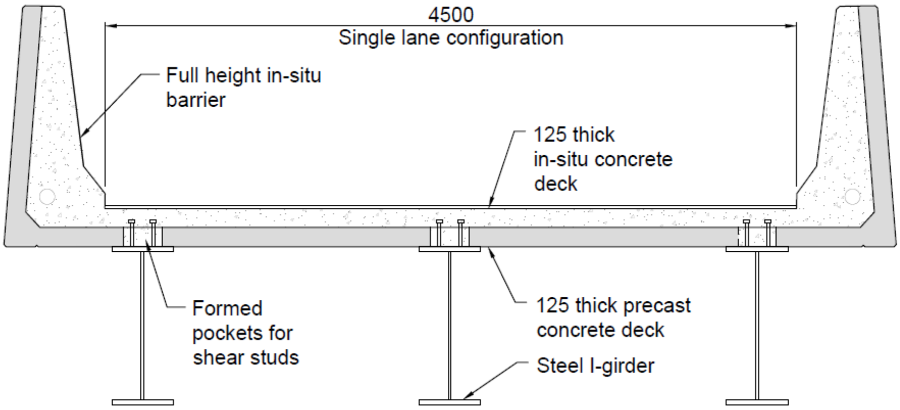

Figure 3: Typical cross section for single lane arrangement

The girders are simply supported on rectangular laminated elastomeric bearings. A stainless steel drip pan is provided in between the elastomeric bearing and the bearing plate at each girder end. The stainless steel drip plate serves to prevent direct contact between the weathering steel and the elastomeric bearing, and to channel water away from bearing.

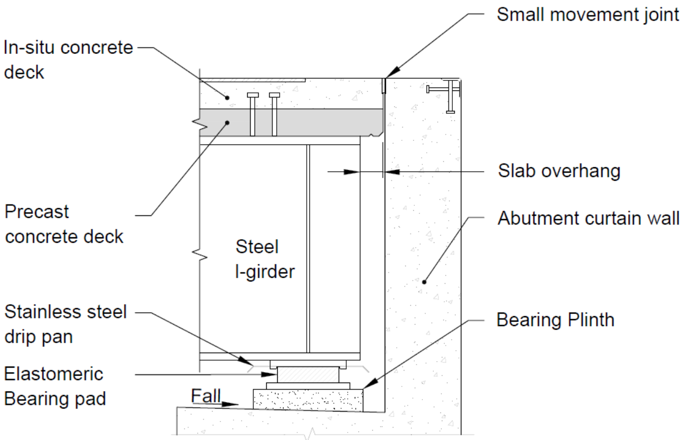

Figure 4: Abutment detailing for simply supported girders

The key detailing measures adopted for the Nooroo overbridge are similar to Michelago Overbridge and include detailing the web stiffeners with a gap to the bottom flange and detailing drip plates on the bottom flange of the outer girders. In addition, the abutment has been detailed with concrete plinths and shield walls to prevent debris retention around the bearings and girders. Any runoff on the abutment is collected with the abutment headstock sloping back and discharged though a pipe in the shield wall at the low end which projects beyond the concrete face. Fully sealed small movement joints have been detailed to prevent runoff through the joint onto the steel work below. A small overhang of the concrete deck beyond the end of the steel girder has also been provided to help prevent moisture retention through deck joints.

Cooma Overbridge

The third project is the Cooma overbridge on Thurrung Street located over the non-operational Tuggeranong to Bombala Line at 432.700km. The existing bridge is a single span single lane steel truss structure with an overall length of approx. 25 m and a deck width of 4 m. The new bridge is a single span structure with an overall length of 24.7m and a minimum width of 11 m allowing for two traffic lanes, shoulders and a 2.5 m shared path. The new bridge structure comprises of weather resistant steel I-girders with a composite concrete deck made integral with the abutments. The substructure is a spill through arrangement with the abutments supported on bored cast-in-place concrete piles. The bored piles were required due to the shallow depth to bedrock which eliminated driven piles as a suitable option.

The girders comprise of six numbers of 898 mm deep welded beam I-girders, which are made up of 400 mm by 20 thick top flange, 400 mm wide by 28 mm bottom flange and 16 mm thick web plate. The intermediate cross bracing elements are made up 250 deep by 90 wide by 12 thick channel sections.

The 250 mm thick concrete deck is made up with 125 mm thick precast concrete deck panels that incorporate upturns and a 125 mm thick in-situ deck slab pour similar to the Nooroo overbridge. At the ends the steel girders are cast into the abutment headstock for the integral connection. The combination of the precast deck panels and integral connection at the abutments is the preferred superstructure arrangement offering the greatest benefits.

The key detailing measures adopted for the Cooma overbridge which is also consistent with Design Guides include detailing the web stiffeners with a gap to the bottom flange to avoid moisture and debris retention and detailing drip plates on the bottom flange of the outer girders to deflect any runoff and prevent debris accumulation at the girder end. The integral connection with the girders cast into the abutment headstocks eliminates any issues associated with runoff through joints and debris retention on the abutments.

OPTIMISATION

A number of lessons and design initiatives have been learned through the authors' recent experience with the design of weathering steel bridges and the intention is to further refine the designs through consultation with industry. The areas where we see scope for refinement are discussed below.

- The standard welded beam profile is not the most efficient section for girders. We are working together to develop some standard girder types with wider top flanges to suit shear stud groups in pockets within precast formwork, thicker and or wider bottom flanges to make the girder more structurally efficient in final composite section and thicker webs to minimise the need for stiffeners.
- The precast concrete deck unit is the other key component to achieving efficient design. We have found that the proprietary precast decking systems are unlikely to be feasible for small bridge replacements. We are looking to work with regional based precasters to develop a range of shell systems that allow rapid deck placement to minimise work on site to suit different bridge widths and bridge barrier requirements.

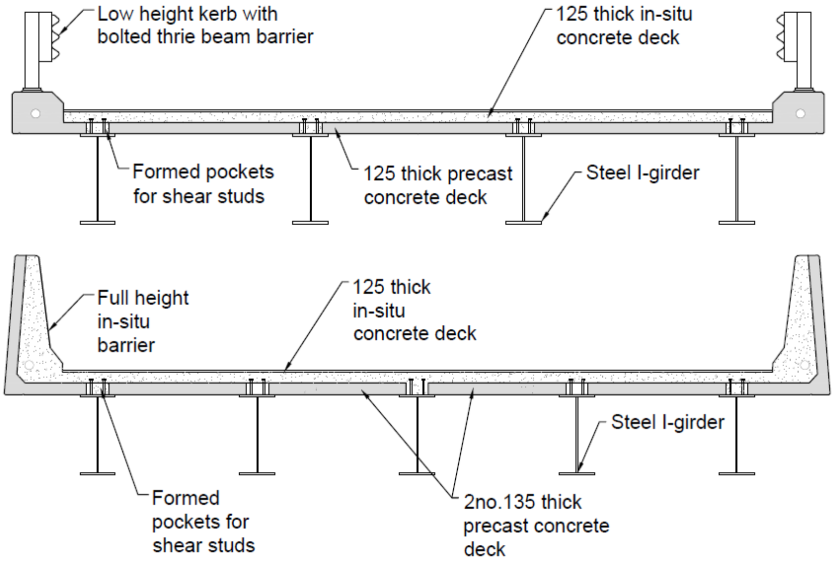

Figure 5. Typical cross sections for two lane arrangement

- Full depth deck units with stitch pour connections over the girders and between deck units using high strength concrete are popular in the United States. This is something we will also be looking into for new bridges.
- Integral abutments should be always considered to reduce the girder depth and to minimise maintenance associated with bearings. It also has the added advantage of not requiring deck joints, a potential issue for weathering steel if not maintained properly. Alternatively where deck joints cannot be avoided the detailing of the deck termination is a critical detail to prevent run off and significantly improve the design detailing.

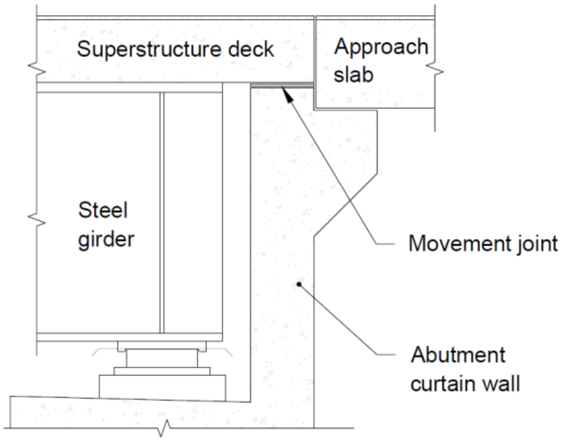

Figure 6. Superstructure deck cantilevers over the curtain wall to prevent water ingress onto the weathering steel girder

CONCLUSION

The availability of weathering steel in larger plate sizes from BlueScope Steel warrants the use of steel in our bridge designs to be revisited. We have demonstrated that weathering steel bridges are cost competitive against concrete alternatives for overbridge bridge replacements. We are looking to further refine these designs through further consultation with industry for use in bridge replacements and new bridge construction for Councils and the Road Authorities.

The option is now available for larger spans with lighter girders using weathering steel as the structural girders. This could mean the difference in providing an economic design or satisfying a single clear span avoiding piers all while still providing a low maintenance structure with comparable whole of life cost to concrete alternatives.

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AUTHOR BIOGRAPHIES

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Peter has over 10 year’s professional experience in Civil Engineering associated with infrastructure and building projects. Principal areas of expertise include structural analysis and design of short to medium span bridges including associated civil works, bridge load rating assessments, bridge maintenance inspections and design verification of civil structures. His exposures to bridges include pre-stressed concrete girder and plank, post-tensioned box girder and composite steel superstructures.

John Steele

John is a structural engineer with over 25 years’ experience working firstly in building structures then in civil infrastructure for the last 20 years specialising in bridges and other civil structures. He has been involved in the bridge designs on the Pacific Highway, Hume Highway and Great Western Highway Upgrades, the Cross City Tunnel and Art Gallery Landbridge on the Eastern Distributor as well as numerous rail bridge assessment and replacement projects. John is currently the Jacobs Technical Director for Bridges for Australia and New Zealand.

Felix Lie

Felix graduated with First Class Honour in 2016. He has over three years of experience in engineering consultancy as a structural designer. He joined Jacobs in 2015 during the final year of his degree as a Graduate Bridge Engineer. In his time with Jacobs, Felix has been involved in a variety of bridge projects including design and construct of a major road project, detail designs, load rating assessments and concept design. His exposure in bridge design includes pedestrian truss bridge, weathering steel bridge, precast girder bridge and steel box girder.