

WEATHERING STEEL RAILWAY BRIDGES IN NEW ZEALAND

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ABSTRACT

The purpose of this paper is to outline the design features of four new weathering steel railway bridges in New Zealand. The intention of this new bridge design is to address a number of challenges faced by KiwiRail when considering its existing bridge stock in a more holistic whole of life approach. These challenges are:

- The widespread hardwood timber pier bridges are fast approaching the end of their reliable services life and need to be replaced.
- Traffic density is increasing providing fewer and shorter opportunities to replace bridges;
- The very high costs associated with removing and re-applying coating systems in situ for steel bridges;
- The limitations of concrete bridges for online replacement during short track possessions or where construction depth is restricted.

The bridge design selected was inspired from the North American Ballasted Through Plate Girder and meets the following criteria:

- Ballast deck for ease of long term track maintenance and reduced bridge maintenance.
- Shallow construction depth to maximise flood freeboard without unnecessarily lifting the track and increasing project costs.
- High strength to weight ratio spans to allow:
 - Single long spanning bridge solution that can be easily transported to, lifted and assembled on site with HSFG bolted connections;
 - Enable swift changeovers of just one single span that is light enough to either be lifted or launched into position during line closures of less than 12 hours;
 - Longer span lengths in order to produce an economic bridge solution;
 - Lower vertical and lateral loading demands on the piles.
- Weathering steel superstructures and pier caps (headstocks) to provide:
 - Low long term maintenance bridge solution;
 - Bridge spans that are relatively easily repaired if damaged.
- Built in quality construction with maximising controlled workshop fabrication with qualified workers while reducing weather and train operations dependent site work.

By meeting these criteria this new design concept provides an economic whole-of-life solution that is robust and applicable to a wide range of sites. The only limitation of this design is the suitability of weathering steel at particular sites (e.g. chemically charged or severe coastal).

This paper presents the main challenges and key lessons harvested during this journey, from conception through to detailed design, fabrication and construction. Whilst some improvements can be made, this design which uses weathering steel is considered to be innovative and successful in the New Zealand context.

1. Introduction

In 2012 KiwiRail replaced 4 railway bridges in the Counties Manakau region of New Zealand. All these bridges featured (i) an all weathering steel superstructure, (ii) tough Eliminator waterproofing membranes and (iii) the configuration inspired from the popular North American designed Ballasted Through Plate

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Girder (BTPG). The design of these bridges can be considered to be innovative as it was the first time any of these design features had been used in the New Zealand railway industry and for the most part within New Zealand. New Zealand had only one other weathering steel bridge, namely the Mercer SH1 Off- Ramp, prior to 2012. More importantly these bridges have given KiwiRail another bridging option for them to tackle the considerable challenges that an aging bridge stock in awkward terrain, limited funding, and with ever increasing rail traffic bring.

In this paper firstly a brief overview of the New Zealand railway bridge environment is outlined, followed by more specific analysis of the bridge design issues pertinent to renewal of the 4 bridges that are the main subject of this paper. Then the design features of these bridges are described, followed by comments on constructability issues associated with these bridges. The overarching KiwiRail vision and strategic application of this type of bridge is then described and the paper is concluded by outlining the successful outcomes generated by these bridges.

2. New Zealand Railway Bridge Context

Kiwirail is the State Owned Enterprise (SOE) responsible for operating and maintaining New Zealand's railway. With regard to infrastructure KiwiRail is charged with maintaining about 4000km of track including approximately 1700 Bridges. Seven hundred of those bridges consist of riveted steel plate girders (SPGs) on Australian hardwood timber piers (typically 3 or 4 piles supporting a timber cap). SPGs are 2 riveted beams with a cross bracing between their "leafs" which are consist of a web plate and riveted angles to form top and bottom flanges. These spans are typically 20' (6.1m) to 50' (15.2m) long. Some timber piers support 80' to 100' (24.4m to 30.5m) long steel truss spans. The sleepers are fitted direct to the top flanges of the beam leafs. The average age of the timber pier bridges is about 80 years, with some over 100 years old. These bridges are rapidly approaching the end of their reliable service life and require large amounts of maintenance to keep them reliable and in service. It is this type of bridge that is frequently being renewed by KiwiRail.

In addition to the large stock of timber pier bridges, there has been increased customer focus by KiwiRail to match increased demand for rail freight. In particular freight volumes between Auckland and Christchurch, Auckland and Tauranga and Christchurch and West Coast have increased in recent years. As a consequence more freight trains are using these timber pier bridges allowing only limited opportunities for their planned replacement. Freight demands further restrict the duration of planned closures of the railway. That is both the opportunity and the duration for planned bridge replacements have been reduced with corresponding increase of rail freight traffic.

Alternatives to full bridge replacement, such as selected pier and span replacement with a new pier or span are considered but this is considered a life extension measure, where the full benefits of a new bridge are not gained until all piers and spans are replaced. It is also noted that these existing bridges were designed and constructed several generations ago when load demands were lighter, and bridge building equipment such as piling rigs and cranes had low capacity and were scarce when compared to today's loadings and equipment. In other words efficient and economic pier/span configurations of 80 years ago are often not efficient today.

3. New Railway Bridge Design Criteria

Determining an appropriate bridge renewal solution for a particular site is not a linear process. Four perspectives are often considered simultaneously in order to determine a range of suitable scheme designs for a particular railway bridge renewal. These four perspectives are:

- 1) **Railway Perspective** covering horizontal and vertical track alignment, deck type, network disruption, clearances, damage tolerance, replacement and whole-of-life cost, condition assessment, reparability, risk management;
- 2) **Engineering Perspective** covering design loadings, structural concept and efficiency, pier location, geotechnical conditions, hydrology, structural details, bearings, material durability, existing structure/services interfaces, design standards and codes;
- 3) **Construction Perspective** covering location and terrain, site access, working space constraints, access over water, staging requirement, crane pad requirements, crane lifting

weights and radii, specialist equipment requirements, ease of construction, preferences, previous experience, safety and quality requirements;

- 4) **Public Perspective** covering RMA/Environmental constraints, Historic Place Trust, hydraulics, road clearances, adjacent landowner & Right-Of-Way (ROW) issues, local iwi, Fish and Game, aesthetics.

4. New Railway Bridge Project Scope Fundamentals

From the previous section, there are many factors to consider in order to achieve a range of suitable schemes for a railway bridge renewal and they can all impinge on the others. There is however a smaller number of key decision points that essentially define the scope of a bridge renewal project and the methods used for construction. These more dominant criteria are:

4.1 Track alignment: Online versus Offline

- Online bridge renewals maintain the existing horizontal alignment to the extent that the new bridge and its construction activities will disrupt train services during the construction phase.
- Offline bridge renewals are on a track alignment a sufficient distance away from the existing track alignment so as to significantly reduce disruption to current train services.
- The perfect railway alignment is straight and level. Deviation from this are considered a compromise therefore horizontal radii are kept as large as possible and grades kept as shallow as possible when the terrain is uneven. As a consequence offline renewal can considerably increase scope and cost of a bridge renewal project by the addition of newly constructed formation as well as a new bridge.
- Online bridge renewals have no or little new formation work associated with them but these projects are constrained by the planned line closure duration.

4.2 Deck Type: Direct Fastened versus Ballast Deck

- Direct fastened (or open deck) bridges have hardwood sleepers directly fastened to the top of the SPGs or Through Plate Girders (TPGs) floor system or pre-stressed concrete spans. Direct fastened bridges are often the least costly deck system and free draining but the train live loads transfer more dynamic effects into the bridge than ballast decks. The maintenance of the timber sleepers is very expensive and very time consuming.
- On ballast deck (or closed deck) bridges the concrete sleepers are bedded into compacted granular rock ballast for drainage and track stability. Ballasted steel plate and concrete slab deck bridges are common in new railway construction in the Northern Hemisphere. However the 4 railway bridges under examination in this paper are the first steel plate ballast deck bridges in New Zealand as concrete slab decks have been used exclusively for ballast decks in New Zealand previously.
- While ballasted decks are more costly than direct fastening, they require less maintenance both in terms of track and bridge. This is because the ballast absorbs and distributes the dynamic effects of the train live load in a less severe fashion when compared to direct fastened bridges. Ballast deck bridges are often used on lines with high traffic volumes to minimise future disruption due to maintenance or when the track alignment is curved. Also, ballasted decks can easily accommodate small changes in track alignment (both vertical and horizontal).

4.3 Construction Depth: Shallow versus Deep

- Construction depth is measured vertically between top of rail level and the bridge soffit. The constraints on the construction depth are from the top and the bottom. Keeping track grades as shallow as possible and restricting track lifts to sections only where a lift would improve vertical alignment constrains the top of construction depth. Flood freeboard requirements (rail over water) and headroom clearances requirements (rail over road) constrain the bottom of construction depth.
- Moderately shallow construction depths can be achieved with direct featured spans because the minimum ballast depth under sleeper requirement of 300mm is not required. However with the SPG depth making up part of the construction depth, as the sleepers are directly under

the sleepers, the construction depth available dictates the maximum span achievable by using economic span-to-depth ratios. This in turn affects the pier locations which are often subject to other site constraints. Through plate girders (TPGs) have a transverse spanning floor system, the depth of which is dictated by the construction depth. The floor system spans transversely between deeper side girders to achieve longer spans. Therefore span length is independent of construction depth for TPGs. The TPG floor system increases the bridge cost significantly while the limitations of direct fastening are retained.

4.4 Span Material: Pre-stressed Concrete versus Steel

- Traditionally in New Zealand all ballast deck bridge spans have been pre-stressed concrete decks with a number of different configurations employed depending on track alignment, line closure duration and construction depth requirements. Direct fastened SPGs and TPGs have been made from wrought iron up until the early 1900's and then from mild carbon steel. Carbon steel is still used today with yield strengths improving from less than 200MPa to 355MPa over the last century however it requires an applied protective coating at time of fabrication and for 2 to 3 re-applications during its 100 year design life.

5. Four Railway Bridges

The four bridges replaced have official railway titles of bridges 299, 300, 312 and 332 on the North Island Main Trunk (NIMT) between Auckland and Hamilton, the busiest section of the NZ railway network. For the purposes of this discussion bridges 299 & 300 NIMT are located at Kellyville (off Pioneer Road between Mercer and Pokeno). These bridges are essentially side by side but at a skewed alignment to each other and cross the Mangatawhuri River. They are both identical to each other as 36m single span BTPGs carrying a single track. Bridge 312 NIMT is located in Pukekohe adjacent the southern end of Pukekohe Raceway. It consists of two 14m BTPG spans side by side on common abutment piers. Each span carries a single track. Bridge 332 NIMT is located at Papakura (just south of the Boundary Road level crossing). It consists of a single 17m span BTPG carrying two tracks side by side. All bridges are over waterways.

In terms of the key decision points outlined in section 4 the following apply to all 4 bridges. The reasoning behind the above key design features is explored in the following sections.

- All are online renewals to minimise track formation work and project costs.
- All are ballast deck for ease of track maintenance and reduced maintenance costs.
- All are shallow construction depth as only minimal track raise was achievable at Kellyville and to maximise available freeboard in flood conditions.
- All bridge spans are constructed from 350MPa grade weathering steel (JIS G3114 SMA490 BW) on the basis that:
 - a. Shallow construction depth ballast deck bridges based on proven North American BTPG designs could be developed and value engineered with the contractor and the steel fabricator;
 - b. Calculated corrosion rates were less than 1.5mm per surface per 100 years;
 - c. Correct detailing implemented to ensure minimal long-term maintenance.

The use of weathering steel (WS) makes these bridges the second to fifth WS bridges in New Zealand; the Mercer off ramp being the only WS precedent in New Zealand. Stemming from the fact that all bridges were online renewals on one of the busiest sections of the NIMT, the single most important design criteria was being able to changeover the bridges in less than a 12 hour planned closure.

6. KiwiRail's Vision : Bridge Standardisation

With the above project scope defined for these 4 bridge sites KiwiRail was also conscious of their many other timber pier bridges that would require renewing in the future. There was a desire to replicate the standardised approach to bridge construction that was present from 1900 to 1940 when SPGs on timber piers were the default solution. This brought about the proof-of-concept for standardised railway bridging that not only dealt with:

- Online renewal to minimise the cost of formation work;

- Ballast deck to ease future mechanised track maintenance;
- Shallow construction depth to deal with flood freeboard/road height clearances;
- Lower maintenance costs for bridges and;
- Speedy changeovers to minimise disruption to train services.

But also could cope with sites where:

- Limited site access/lay-down for bridge construction equipment;
- The constraints and characteristics of the site are such that long spans (>15m) are required.

While improving:

- Quality by maximising offsite fabrication and minimising site work to little more than the piles
- Economy through economic span configurations so that total bridge cost can be optimised.

Quite simply a standardised concept was desired to suit mass-customisation manufacturing techniques that could cope with wide ranging site conditions economically.

7. Selection of Bridge Material and Type

The selection of weathering steel BTPG was based on the limitations of incumbent precast concrete ballast deck solution and the desire to achieve a standardised bridge solution to suit a wide variety of site conditions. Based on previous experience the shortest realistic changeover duration of a concrete ballast deck was 18 hours either by lifting or launching techniques. Concrete ballast decks are better suited to offline construction. In terms of construction depths 1125mm to 1275mm was achieved with these 4 bridges. This compares to 1100mm to 1600mm for various suitable configurations of pre-stressed concrete bridges. Therefore construction depth was a factor but less significant than changeover duration.

The economic length of concrete ballast deck lengths is 12m to 16m. Longer spans up to 20m can be achieved while maintaining construction depths similar to that of the shorter spans but become restricted to transverse launching techniques because of their lifting weight in an online renewal situation. A single 36m span in concrete is neither practical nor economic at Kellyville. Concrete ballast deck solutions using multiple spans were feasible at the sites under consideration if 24 hour changeover durations were permitted. Coupled with these limitations of the concrete ballast decks was a growing recognition from modern publications, contractor feedback and consultation with railway authorities in the North Hemisphere that BTPG's were of common use in North America and composite ballast deck were of common use in Europe.

This led to an investigation into steel plate ballast deck bridges of North America. During this investigation weathering steel was suggested in lieu of painted carbon steel as this had become the bridge span material of choice for a number of North American Railroad companies for which commercial imperatives are foremost.

It was a necessary prerequisite to find a suitable waterproofing membrane to protect the steel deck from the rigors of near continual wetness and abrasive grinding ballast. British Rail in conjunction with Stirling Lloyd in the 1970s developed "Eliminator" precisely for this purpose. It has since been approved by the American Railway Engineering and Maintenance-of-Way Association (AREMA), and a large number of Rail Authorities around the world. KiwiRail has adopted AREMA as its steel railway bridge design criteria.

8. Weathering Steel

Weathering steels are high strength, low alloy steels that can provide corrosion protection without additional coating. Increase in alloying elements, primarily copper, provides an arresting mechanism to atmospheric corrosion in the material itself. This resistance is due to the fact that this steel will develop a durable, tightly adherent protective surface patina comprised of corrosion by-products that act as a skin to protect the steel substrate. Cycles of wetting and drying allow the patina to form. If weathering steel is continuously damp or wet, its protective patina will not form. Surface corrosion loss of the order of 0.1mm can be expected before the patina sets up, but this is negligible to the structural performance. In terms of making allowance of a 100 year design life NZS 3404.1:2009 was used to determine the surface specific corrosion categories. The ISO 9223:2012 was used to

determine the equivalent international corrosively category and then ISO 9224:2012 used to determine the corrosion loss based on the chemical composition of the weathering steel.

The benefits to KiwiRail using weathering steel are:- initial cost savings of about 5% over carbon steel with a thermally sprayed zinc coating, less whole-of-life maintenance and access requirements over coated structures, reduced fabrication time if plate is in stock because of no coating is required, reduced maintenance costs as bridge remains in service and does not need a re-application of an applied coating, no site containment of blasted protective coating is required and less maintenance means greater safety for the structures staff involved with bridge maintenance in the rail corridor.

Fatigue is an important consideration in railway bridge design because of the larger live to dead load ratios and the greater transfer of dynamic effects into the structure when compared to the road bridging. Fatigue in weathering steel is not of any more concern than with other carbon steel. Although the corrosion pits on a weathering steel surface would lead to lower fatigue resistance in elements that are unwelded and free form holes, at stress concentrations the defects or implications inherent in welded details invariably govern fatigue life.

The girders and connections were designed to encourage drainage and allow good ventilation. Specific design features include 1200mm spacing of transverse cross beams, intermediate web stiffeners terminated 50mm above top of bottom flange, and 50m radius copes. Inaccessible or poorly ventilated headstock bottom flanges adjacent the concrete abutment were fully enclosed and hermetically sealed to prevent moisture ingress. Weed mat, with overlaying quarry scalplings have been placed under the bridges around the abutments to prevent vegetation growth and to allow plenty of under bridge ventilation. After 5 months of service it is noted that bridges quickly dry after rain due to sun and airflow. All bridges are fortunate to have an approximate north to south orientation to allow sun on both main girders and westerly cross flow breezes.

As part of the design, an inspection and maintenance manual has been developed and produced for these bridges. Considering the fact that WS is new to KiwiRail, the inspection requirements for the first few inspection cycles are very thorough. The KiwiRail structure inspector will check and report on the following: accumulation of dirt and debris, leaks, areas of permanent wetness (and their cause), excessive crevice corrosion at bolted connections, nearby vegetation preventing drying by sun or wind. The thickness of the plates will be monitored every 6 years and compared to the "as-built" thicknesses to ensure that the patina is forming. This monitoring will be performed by a Certified Board of Inspection Personnel (CBIP). The patina is expected to be fully formed after 6 years and remain tightly adherent thereafter. As KiwiRail learns more about the actual performance of the WS at the various sites, the inspection and maintenance requirements will be reviewed over time.

9. Eliminator Waterproofing Membrane

Weathering steel will not form a protective patina when permanently wet. This is the situation at the interface between the ballast stones and the top of the steel ballast tray. To protect the steel ballast tray interface from permanent wetness and abrasive grinding by ballast, a robust proven railway tough waterproof membrane was required.

In the selection of the Stirling Lloyd flagship Eliminator product the same philosophy that was used with the selection of the weathering steel and North American BTPG was adopted; that is to transfer the proven technology from the Northern Hemisphere to New Zealand. Eliminator was developed in the 1970s by Stirling Lloyd in conjunction with British Rail. The Eliminator waterproofing system is an elastomeric cold spray system based on methyl methacrylate resin. It comprises of a steel primer and two separately applied coats of membrane each of 1.5mm dry film thickness in contrasting colours. The primer is an anti-corrosive zinc phosphate that is applied within 3 hours of a Sa 2 ½ abrasive blasted ballast tray formed by deck and kerb plates. The application of Eliminator is only permitted by Stirling Lloyd approved applicators to ensure rigorous on-site QA procedures are followed without exception. The Eliminator remains tightly adhered to the ballast tray. Should the membrane ever be perforated, any corrosion will be confined to the steel below perforation. An additional protective heavy filter cloth (ELCOMax 900R) was laid over the water proof membrane before the ballast filled the membrane lined tray as a precaution against perforations.

10. Constructability

The constructability or method of construction employed with these 4 bridges was all focused on achieving bridge renewal in less than 12 hours, even though longer closures were available. This was in keeping with the proof-of-concept approach adopted by KiwiRail for this bridge project. Constructability as a subject is open to many different preferences depending on the contractor. For this reason it is best dealt with under the more general sub categories, namely: duration of line closure, construction methodology, site conditions and equipment.

Railway bridge renewal constructability is invariably driven by duration of line closure. Due to the high volumes on traffic on the NIMT, line closures less than 12 hours could be made available on almost any weekend with sufficient planning and advanced notice. Longer closures are generally only available at Easter and between Christmas and New Year.

Construction methodology is subordinate to the duration of construction or in the case of these bridges the duration of line closure in that the bridge details are focused on allowing the speedy changeover to be completed within the allotted time. During the design process the overarching philosophy that was adopted was consistent with the duration of track closure. For this reason the design and construction methodology was such that each bridge would maximise the site work that could be done prior to changeover, and enable work to be done during changeover in 3 work areas simultaneously. That is at each of two abutments and the span installation. These three work areas would be available as soon as the existing bridge was removed. This was greatly advanced by "skeletonising" (removing all but the minimum required track fastenings) the bridge to the minimum for the safe operation of trains in the days leading up to changeover. The piles and wing-walls of the abutments were positioned at sufficient offset from the track centre line to enable them to be fully constructed prior to changeover. The head-walls that horizontally span between the abutment piles were precast and designed to be quickly lifted into place once the existing track was removed and the approach behind the headwalls was fully excavated.

Site conditions such as the hard-standing area and steepness of the surrounding terrain, the presence of overhead and under-ground services, site access and lay-down areas affect equipment that can be employed during a changeover. Three of the four bridge sites had sufficient space on site to allow cranes to be used to lift in the bridge spans. One of the bridges was transversely launched into place. Many of the future bridges to be renewed on the NIMT are either in the electrified section or have very steep surrounding terrain. While the transverse launching techniques have been successfully used for concrete ballast installation there was benefit in determining how the technology could be applied for a first time to a structure with steel pier caps. In many situations concrete caps behind existing abutments cannot be constructed in-situ and under the track. For this reason steel pier caps were designed for these four bridges that weighed only 5 tonne compared to an equivalent 25 tonne precast concrete pier cap. The crane demand to lift in a steel cap is very modest.

The final factor in constructability is equipment. It is firstly acknowledged that each contractor have their own equipment, preferences and previous experience. That said the distinct advantage of steel spans over concrete is its relative light weight nature. The proliferation of large crawler (max. 400 tonne) and mobile (max. 550 tonne) cranes in New Zealand over the last decade must also be acknowledged. Ten years ago the largest crane available was 200 tonne and if then none of these 4 bridges could have been lifted in. The use of relatively light steel spans becomes advantageous and speedy with the proliferation of large cranes.

11. Owner's Perspective

Wrought iron and carbon steel have been for a long time the preferred material for railway bridges in NZ. Protected by an excellent protective system based on lead paint, these bridges have performed really well over the last 80 to 100 years. However, in recent years, KiwiRail has come to realise the difficulty and costs associated with extending the life of painted steel bridges particularly around the need to remove the lead based paint system and apply a new protective system. On the other hand, it must be emphasised that steel bridges offer distinct and significant advantages over concrete bridges for railway bridges in New Zealand which run a single track network on most lines; the option

of relatively light, shallow, long-spanning decks is particularly useful. Therefore, steel bridges that do not need painting are a very attractive proposition for asset owners, as the on-going maintenance costs over the life of the structure are significantly reduced. Weathering steel is the answer – or is it?

Unfortunately for KiwiRail, this material has not been used extensively in New Zealand until now and the following challenges had to be addressed:

- Weathering steel is a “new” and “unproven” material in NZ despite having been used extensively in other countries since the 1970s;
- Limited knowledge and expertise in NZ about this material;
- Pre-conceived ideas about this material, its performance and durability (for the layman, steel needs to be protected to last or it will rapidly corrode).

On the other hand, KiwiRail also acknowledges that:

- This material has been used extensively and successfully around the world since the 1970s by various agencies and asset owners – so this material and its performance have been proven but outside NZ.
- The material itself has improved since it was first developed, increasing its performance and durability. Also, steel production (carbon steel and weathering steel) has also improved since the 1970s and meets very high quality standards.

After a detailed analysis, KiwiRail came to the conclusion that the use of weathering steel would deliver value for money (VFM), even though the true value of these bridges will not be fully realised for another 60 to 80 years (i.e. when the first major refurbishments would have happened for standard painted steel bridges). While some uncertainties remain about the actual performance and durability of the weathering steel bridges (which will depend on a number of factors such as site-specific conditions – humidity, water levels, temperatures, wind – and to a lesser extent the maintenance regime), there is sufficient evidence from offshore experience to justify using this material in NZ (once a site-specific assessment has been undertaken and confirmed the suitability of the material for this particular location). There are a lot of guidelines, reports and technical literature available on the use of weathering steel and its performance. The challenge for KiwiRail has been to form a balanced view, considering all the positive aspects without ignoring or over-stating the potential pitfalls. In the end, KiwiRail made an informed decision weighing the different factors, considering the risks and benefits.

Like most asset owners, KiwiRail is faced with the challenge of doing more for less, to continuously improve its services whilst reducing its costs. The use of weathering steel ballast deck bridges offers definite advantages for some sites compared to a concrete ballast deck bridge or to direct fastened bridges for a similar or lesser cost.

There remain some challenges and opportunities with regards to the use of weathering steel in NZ:

- Site-specific assessment of various sites, refinement and clarification of guidelines;
- Potential use of marine grade weathering steel (e.g. for sites where the suitability of weathering steel is deemed to be marginal due to their relative proximity to the sea);
- Accurate assessment of whole-of-life costs (inspections and maintenance).

12. Costs

KiwiRail undertook a detailed analysis of the costs, including whole of life costs over 60, 80 and 100 years and using different discount rates. While useful, this analysis can be misleading as current values of painting in 30 or 40 years' time are low. In its analysis, KiwiRail compared various options (concrete bridge, box culverts – where applicable, painted steel bridges and WS bridges). The key findings were:

- The construction costs of these WS bridges are comparable to standard painted steel bridges (for same design) – whole of life costs are less than painted steel bridges but possibly slightly higher than that of concrete bridges.
- The construction costs of these WS bridges are comparable to concrete bridges in NZ for railway bridges; using top quality weathering steel sourced from a highly reputable mill in Japan and fabricated in NZ using one of the best steel fabricators – in other words, driving the costs down wasn't the focus on this project.

- Whilst the construction costs of these bridges were not significantly cheaper, the savings will be realised in the future by not having to maintain / re-apply the protective coatings. Concrete bridges were not a viable option for two of these bridges; the additional costs associated with lifting the track substantially (over long distances) to accommodate flood levels were prohibitive.

For future projects, savings could be made by:

- Considering alternative supply sources and fabricators for the weathering steel (without compromising on quality)
- Improving the design (limited opportunities)
- Standardising the design (and therefore simplify/standardise fabrication)
- Developing an alternative design (more efficient, particularly where construction depth is not so critical)

It is expected that some of the savings listed above could be significant and could lead to an overall saving of between 30% and 50% for the superstructure.

13. Conclusion

This project has taken KiwiRail and its designer Novare Design on a journey of discovery, challenging the status quo in terms of bridge solutions available to replace existing railway bridges online. The characteristics and constraints of the three sites where four new bridges needed to be built were such that a new concept was required to achieve speedy bridge replacement using long shallow spans that can carry a ballasted track. A new design was born – the steel ballast tray bridge, inspired from the North American Ballast Through Plate Girder (BTPG).

KiwiRail was also particularly conscious of the significant costs associated with long term maintenance of painted steel bridges and considered seriously the use of weathering steel. Following an extensive research and review process, the benefits and potential pitfalls were carefully considered, along with the construction costs and whole of life costs. KiwiRail made an informed decision to proceed with this very innovative bridge design: a weathering steel ballast deck. In terms of costs, this new design is comparable to painted steel bridges but obviously cheaper in the long term and comparable to (or cheaper than) concrete bridges depending on the site and any associated track / formation work involved.

It was a brave decision for KiwiRail to make, as this material is new and unproven in NZ despite its widespread and successful use in other countries over the last 35 years. KiwiRail and its designer have demonstrated visionary leadership in turning the idea of using weathering steel into reality – whilst delivering a successful project.

The development of this new bridge concept and the construction of these bridges is only the first step on a long journey. There remain some challenges and opportunities with regards to the use of weathering steel in NZ, namely:

- Site-specific assessment of various sites, refinement and clarification of guidelines for the use of weathering steel;
- Potential use of marine grade weathering steel (e.g. for sites where the suitability of weathering steel is deemed to be marginal due to their relative proximity to the sea);
- Accurate assessment of the whole of life costs (inspections and maintenance).



Bridge 332 NIMT – Twin track on a single deck (17m span)



Bridge 312 NIMT – Two single track decks side by side (14m span)



Bridges 299 and 300 NIMT – Two single track decks (36m span)



Bridges 299 and 300 NIMT – Two single track decks (36m span)