

Tirohanga Whānui – Pedestrian and Cycling Bridge

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ABSTRACT

In the 1980's, the SH1 motorway was constructed by excavating a large cut into one of the highest ridges in the area, severing Spencer Road which ran along the ridgeline. This project introduces a shimmering 'noble red' bridge, tying the original landscape back together.

The Tirohanga Whānui Bridge (Te Reo Māori for panoramic views) is a spectacular multi-functional bridge constructed across SH1 on the North Shore of Auckland. Jointly funded by the NZ Transport Agency and Watercare Services Limited, it conveys a major water main across the motorway, and provides a shared walking and cycling path to encourage the community to walk and bike to school or work. The expansive views from the bridge at the top of Spencer Ridge extend out over the green hills of Auckland and Rangitoto Island, a culturally significant volcano that burst into existence 600 years ago.

We've learnt about the cultural nuances of the area from artist, Graham Tipene, a descendent of local iwi Ngāti Whātua. He guided us, and we listened, integrating his artistic concepts of the treasured valleys and ridges into the handrails and artwork imprinted into concrete. It was an engaging relationship that tied his work to ours and our work to his. In the architectural space, we worked with a local bridge architect, Jeff Wells. The design reflects extremely close collaboration between Jeff and our Aurecon Bridge Team, developing a vision together.

There is subtle, considered, detailing of almost every element of the bridge, for example using parametric design to vary the steel truss shapes, angles and void radii, giving it a natural balance that responds to the stresses in the 104m long structure. Designed by Aurecon, it blends creativity and beauty through innovation. We are fascinated by bridges. We are excited about this bridge. We are proud of this design.



Figure 1: Visualisation of Tirohanga Whānui Bridge across the large cutting. Produced by Aurecon's visualization team in Sydney.

1 INTRODUCTION

I remember a table with 30 or more concept drawings sprawled across it. I remember Jeff Wells, our premier New Zealand Bridge Architect, looking puzzled yet thrilled. John McNeil, our Auckland Bridge Team Leader, picked up at least 10 of these concept drawings seemingly at random and started adding or sketching adjustments with his talented pencil. "This is what we should be doing here" we would all be thinking. But alas...I knew not where we would end up. None of us did. That is design. That is innovation.

I've come to understand that bridge architecture is a process, rather than a few clever lines poured onto a sketch pad and *voilà*. It is something that starts somewhere and often morphs into something different, something better. We hope. This was the case with Tirohanga Whānui Bridge, where the finished product doesn't reflect any of those 30 or more concept drawings sprawled across the table.

This paper therefore aims to expand on that design process, a few of the main developments along the way are discussed and key technical challenges explained. Lastly the fabrication of this steel structure and the erection thereof is discussed. But first, the story of how it came to be.

1.1 Project Background – NZ Transport Agency and Watercare

Tirohanga Whānui began with Watercare Services Limited and the Albany to Pinehill Watermain and Pump Station Project. Investigations had established that crossing the motorway near Spencer Road and the Albany Reservoirs was necessary to carry a 508mm diameter watermain. This line would build resilience into the water supply network on the North Shore, allowing for potential repair of other critical Watercare infrastructure serving the region.

At the same time, Tirohanga Whānui had begun with the NZ Transport Agency and the Northern Corridor Improvements (NCI) Project in Auckland. NCI provides a new, continuous motorway route from the North Shore to and from the Western Ring Route and beyond. It is an alternative to travelling on SH1 through the central city. Approximately 4km of the SH1 motorway are being upgraded along with 2km of SH18. A free flow link between the north and west is provided, and the corridor width is increased to accommodate a north-south Shared Use Path (SUP) and the Northern Busway (a Bus Rapid Transit route). Apart from these direct improvements, the Project also aims to better link the people of the North Shore to their neighbours in Albany and create reliable safe services for walkers and cyclists.

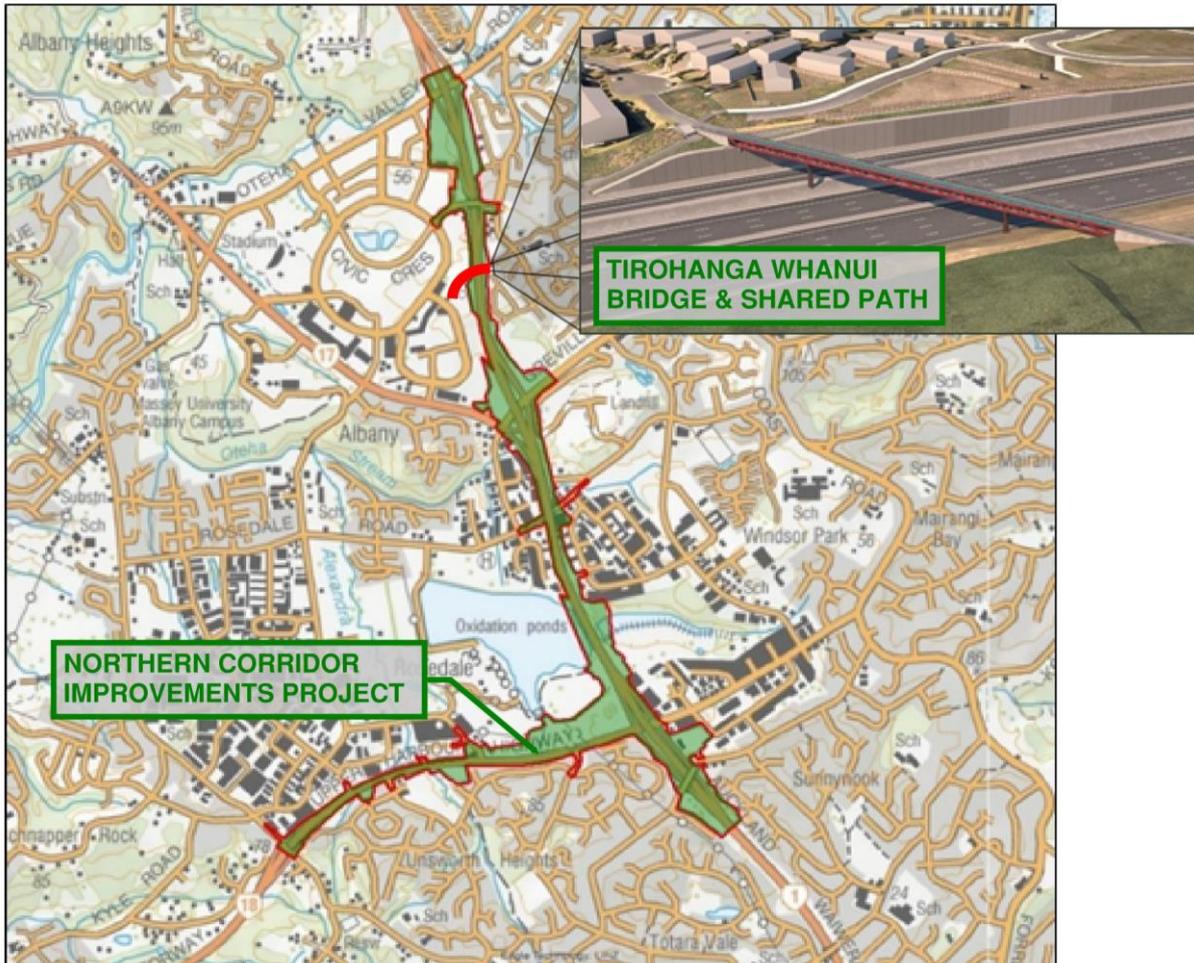


Figure 2: Locality Plan of Tirohanga Whānui Bridge in relation to the Northern Corridor Improvements Project on Auckland's North Shore (Source: Base Map from LINZ)

1.2 Collaboration Brain Wave

The NZ Transport Agency engaged Aurecon and started to sit at the table with Watercare. The first task was to conceptualize the bridge and confirm that fundamental drivers could be achieved. The team engaged with the NZ Transport Agency to define the brief, understanding that the project should serve to uplift the community and that urban design should be integral to any solution. We spoke to Watercare to understand what they required for access, the size of the services, the structural design life, and what their program targets were. Stripped to the bone, the brief was a dual-purpose bridge with strong urban design outcomes linking communities either side of the motorway via a 340m long shared path.

2 DESIGN EVOLUTION

Steel, precast concrete single arches, double arches, square boxes, triangular boxes, curves, lines, multiple trusses, cable stayed structures, pipe on the side, pipe underslung, pipe on top, curved alignments, straight alignments (see Figure 3). The concept routine was explored, and the 30 early options were cut down to a slender three intuitive solutions which were presented. They included an arch, a steel box and a truss (see Figure 4).

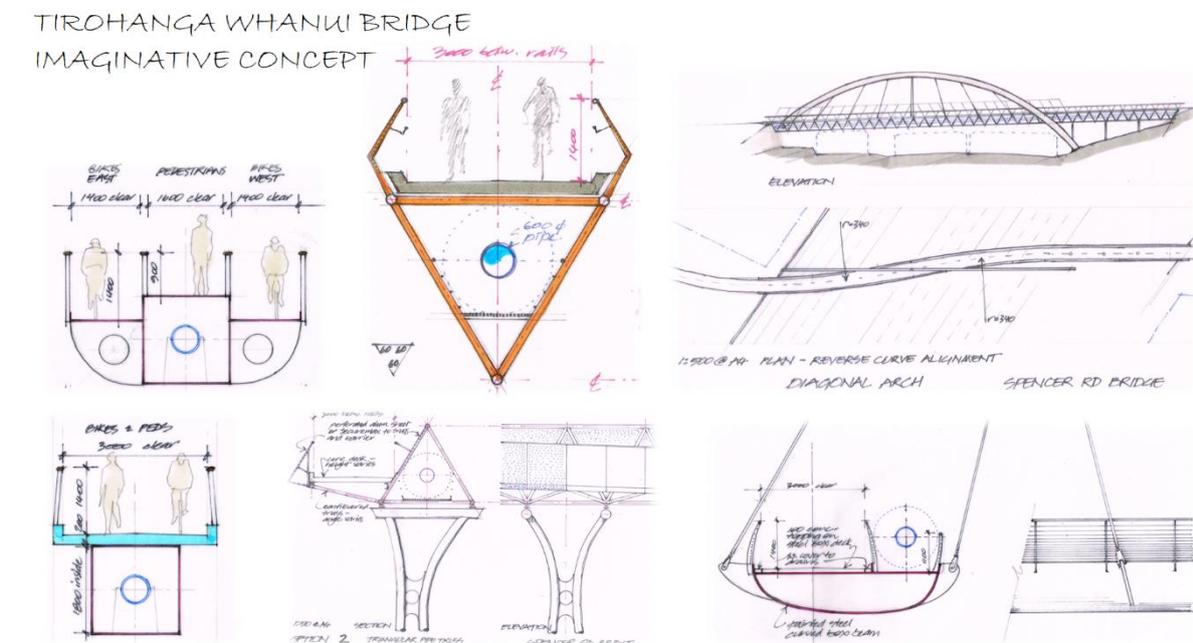


Figure 3: Imaginative Concept

2.1 The Losers

The steel box steel tonnage was assessed to be very high, and consequently the estimated price and sustainable use of materials of this option were poor. Structural diaphragms at supports would also encroach substantially on Watercare's clear perimeter around the watermain and the enclosed environment was a confined space hazard. Lastly the opportunity to cut a design or pattern out of the external face of the steel box was relatively limited and the structure was expected to look excessive and heavy.

The Arch had several positives including spanning the entire motorway corridor, which would allow more flexibility for the planned widening. On the negative side was a safety concern that an arch would encourage climbing, an adverse visual impact due to the height of the arch and lastly the complexity of the erection methodology which was expected to have an adverse impact on the customer (or road user).

2.2 The Winner

Although it consisted of circular hollow sections, equilateral triangles, a precast bridge deck and followed a lovely slow horizontal curve, the truss was the preferred option. It definitely met the brief, balancing the visual impact with a punch of unique and quite importantly to the Watercare team, the access to the pipe was bang on. In fact, the cross section was quite intuitive and is described below in Section 2.2.1.

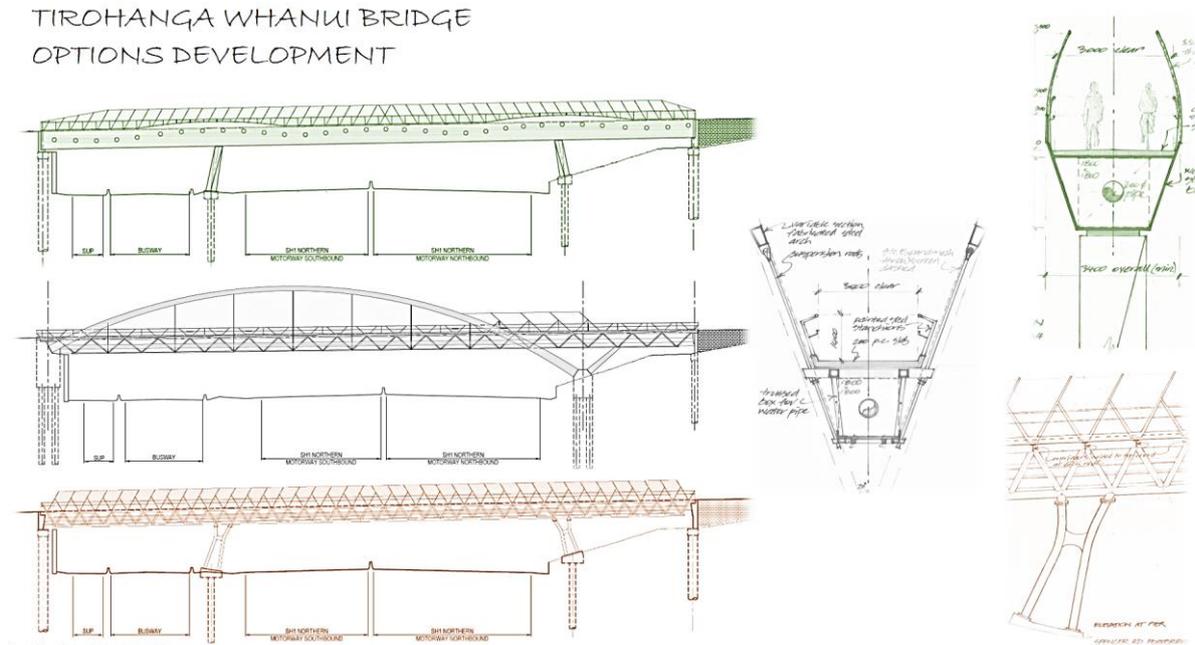


Figure 4: Final Bridge options considered

2.2.1 People and the Pipe

A large service is often suspended below the road/path and in our case, it was not different. The deep cut into the ridge to accommodate the Motorway allowed us to touch ground at the tops of the embankment and accommodate a relatively deep structure depth whilst still maintaining a 6.2m vertical clearance to the motorway. Watercare required an 1800mm wide by 1940mm high clear corridor for operation of the watermain. We proposed a 3000mm wide path to match Auckland Transport's shared use network. The team (reasonably) quickly bought into a trapezoidal shaped bridge cross section (see Figure 5) with Watercare's asset corridor through the truss and the path users on top.

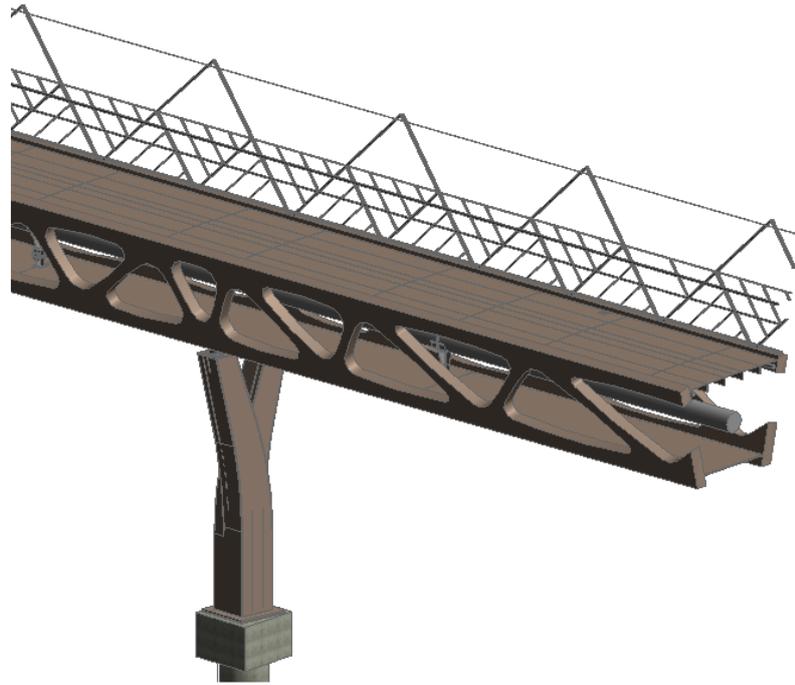


Figure 5: Trapezoidal shaped cross section with Watercare's zone through the truss and the path users on top. Image is directly from our Revit model.

2.2.2 Organic Variety

Two of the most intriguing 'evolutions' of the bridge design are the organic voids of the girders and the intersecting planes of the two girders when viewed in section. Both of parametric significance, and probably where our bridge team's ability to innovate came through strongest.

Moving away from the circular hollow sections, we wanted to create a truss that was softer and shapely rather than equal and utilitarian. The team wanted curves that changed and looked natural. We did this using a distinct fabrication methodology that was more labour intensive, but still focused on the balance between constructability and art.

The first step in the evolution was the use of rectangular hollow sections creating a single planar face on either side of the bridge. The boxes also created a depth to each of the two girders which added value. We opted to use thin plates to provide a curved fillet, rather than an angular corner. There was the tricky challenge of getting the rectangular hollow sections which have an approximately 25mm radius along its edges to meet a sharper welded plate fillet. The straight sections were also going to be too long with little infill fillets at nodes only.

TIROHANGA WHANUI BRIDGE
DESIGN EVOLUTION

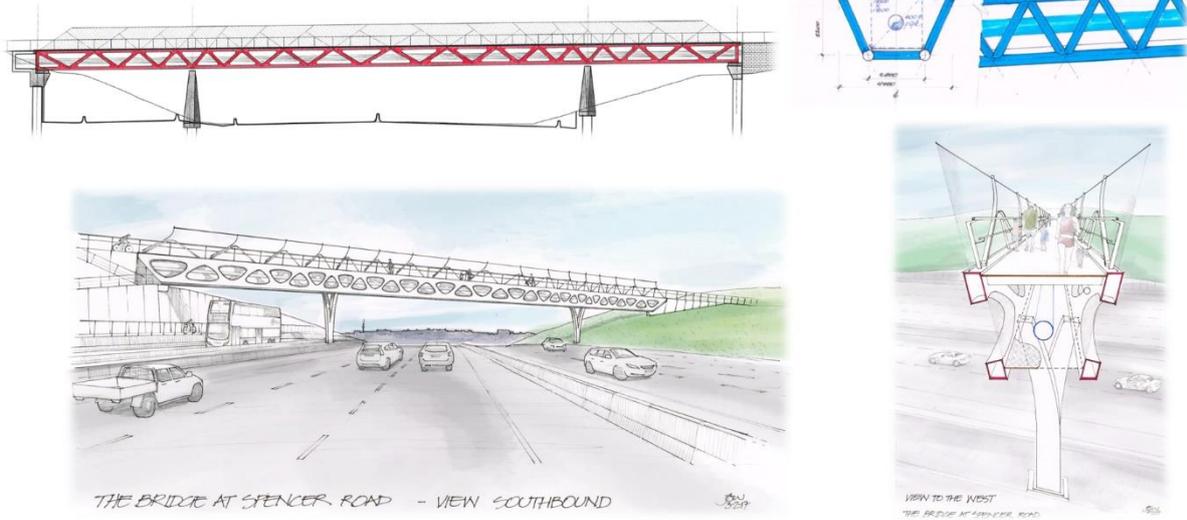


Figure 6: Design Evolution, initial concept (top right), first evolution (top left) and final concept produced towards the end of the preliminary design stage (bottom).

The second step in the evolution was switching to fabricated steel boxes. Two steel web plates would be plasma cut to produce voids of almost any shape. Stiffeners and top and bottom flange plates would be welded in place closing the box. We also modified the node spacing in response to the stresses in the structure. For example, the stresses are larger and more concentrated around the pier supports and so the spacing of nodes would be the tightest.

Drawing some inspiration from nature with its mathematically defined randomness (think of Fibonacci Sequences), we needed to create sensible organic shapes that would not look totally out of place supporting a bridge spanning over thousands of commuters every day. And of course, it needed to be constructible.

TIROHANGA WHANUI BRIDGE
PARAMETRIC DESIGN
BEAUTY THROUGH STEM

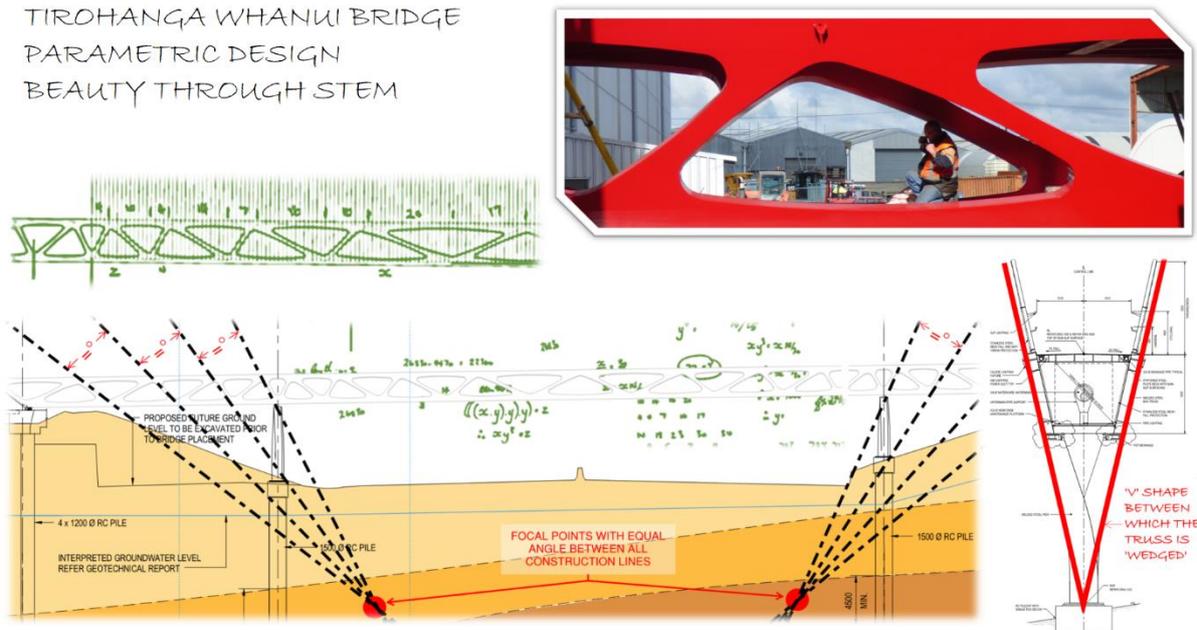


Figure 7: Parametric Design Concept of the Tirohanga Whānui Bridge responding to the stresses of the bridge.

That is where some innovative parametric design helped us (see Figure 7). A single focal point beneath the pier, radiates outwards with a constant increase in angle to define the diagonal truss chords. The result is horizontal chord lengths that vary by a ratio of nearly four as the truss chords stretch out away from the piers. With the truss nodes fixed in position, we used the lengths and angles of the chords and mathematical formulae to compute the radii of the curves that make up the voids.

It creates a natural balance across the bridge that the trained and untrained eye should inadvertently appreciate (see Figure 8). With a bit of poetic license used, the truss geometry and void cut-outs could all be calculated and updated using only the shear force diagram of the bridge. Simultaneously we were putting more structural strength where it was most needed.



Figure 8: Organic voids fabricated with a variable aperture in the three-dimensional truss.

The cross section of the bridge, following the guided widths of the path above and maintenance access below, is tied together by a single V-shape. The focal point of the V touches the motorway, from which the pier and edge of the truss diverge at a constant angle. The V is continued by the handrails and safety screens. The approach walls follow this exact same shape precisely, and even the eastern supporting corbel is linked back to the 'V'.

2.2.3 The Kōrero

The final piece of the puzzle was integration with the cultural heritage of the region, which is briefly described here. Auckland has a long narrow north to south shape flanked by the sea on both sides. The typical geography of the land consists of rivers and ridges that run east to west. Māori travelled this coastline north to south enjoying the bounty of the sea and then headed into the dense sub-tropical forests in search of food diversity and shelter using the east to west rivers and ridges. The rivers were used as they are the life of the forest and enabled easier navigation, whilst the ridges were traversed as they enabled a global view of the surroundings and the ability to map out and understand the territory.

With great support from Mana Whenua (iwi from this area), we are finally reconnecting this ridgeline. As was the case in the past, Mana Whenua wanted the community to have the opportunity to look out and appreciate the North Shore bays and understand where they were. In fact, within the main bay you can also see Rangitoto Island, a volcano that burst into existence 600 years ago and holds special significance to Māori.



Figure 9: Artist Graham Tipene's design imprinted into the concrete with a 25mm deep and 10mm deep recess system. This was done using a CNC custom made mold laid in the formwork of the precast panels.

Graham Tipene and Mana Whenua guided us in the cultural understanding of the kōrero (story) and we listened. We in turn collaborated in taking the artistic concepts of the valleys and ridges and integrated them into the handrail and safety screen design with triangular patterns. We also mirrored his artwork into the angled concrete retaining walls on the east and west approaches (see Figure 9). It was an engaging relationship that tied his work to ours and our work to his. The NZ Transport Agency is becoming ever more focused on working with the community on their projects and the work we did here was a great precursor, a bench mark setter, for the Northern Corridor Improvement Project that followed.

3 DETAILING THE DESIGN

As the design progressed several challenges arose. These included dealing with a vast array of interested parties and opinions on even the smallest of details, but certainly involved many technical challenges more relevant to an architectural footbridge. These ranged from the articulation of the bridge right through to the colour of each finish.

3.1 Bridge Features

3.1.1 General Arrangement

The bridge consists of three painted steel spans driven by the safety preference to avoid a support in the motorway median. The center span is 54m long, with two outside spans of 22m each. Beyond the abutment bearings, the shared path and top chords cantilever out a further 3m at either end, arriving at the 104m total length. Bored piles to rock support the structure, with virtually the entire dead load being carried by the two piers, a result of the short outside spans relative to a long center span.

3.1.2 Piers

Two Y-shaped steel piers whose diamond-shaped footprint mediates between the line of the motorway and the highly skewed bridge alignment rise-up from motorway level and carry two pot bearings that are fixed longitudinally (see Figure 10 and Figure 11). Their earthy colour chosen to allow the piers to disappear when the bridge is lit at night, leaving a 104m long bridge stretching out above the motorists.

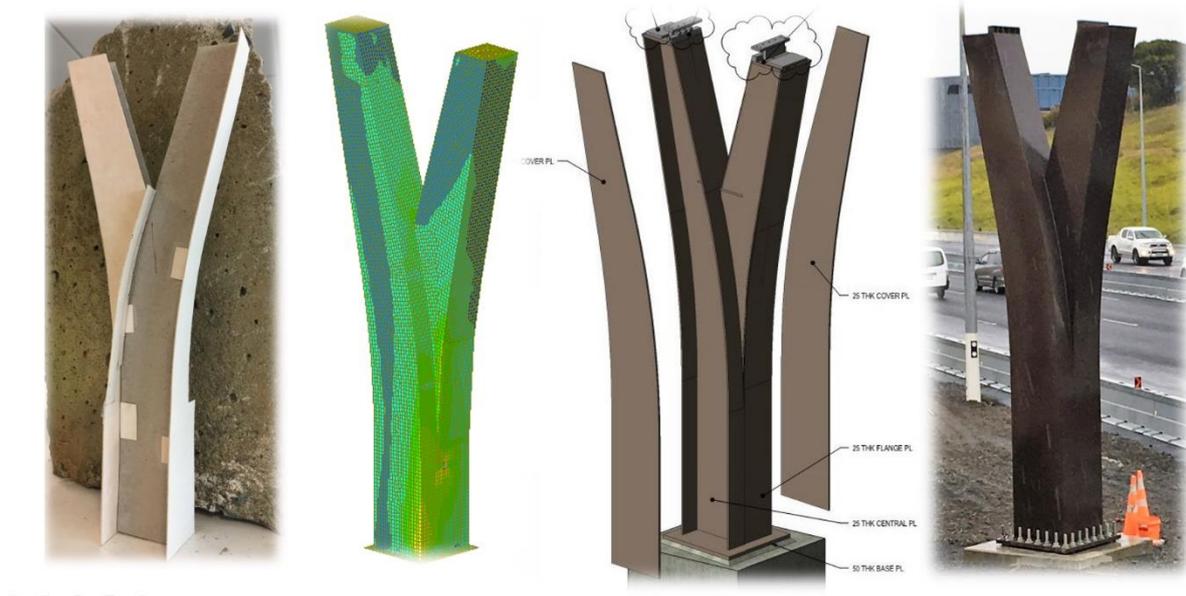


Figure 10: Twisted Y-shaped steel piers from concept modelling to erection on site.

3.1.3 Abutments

The concrete abutments differ west to east, each incorporating an access chamber to the watermain. The western end of the truss is seated on a concrete pile cap above a single 900mm diameter pile, whilst the east abutment doubles as a retaining wall on account of the new shared use path and Northern Busway. Four 1200mm diameter piles support the east pile cap.

3.1.4 Bearings and Articulation

Pier bearings are fixed longitudinally, and abutment bearings are free to move accommodating the roughly 20mm elongation and shortening of the bridge under positive and negative thermal conditions respectively. Importantly, and addressed in Section 3.1.10, the abutment bearings are designed to accommodate tension under both service and ultimate design loads.



Figure 11: Piers in place ready to accept the bridge superstructure on the small 600x600mm pier tops. V-Plane can be seen extending into the piers and abutments.

3.1.5 Superstructure

The three-dimensional truss consists of the fabricated steel box sections connected at deck level by a stiffened deck plate which provides significant torsional stiffness to the system via a horizontal diaphragm action. The bottom bracing is fabricated using off the shelf square hollow sections in a crisscross pattern (see Figure 12).

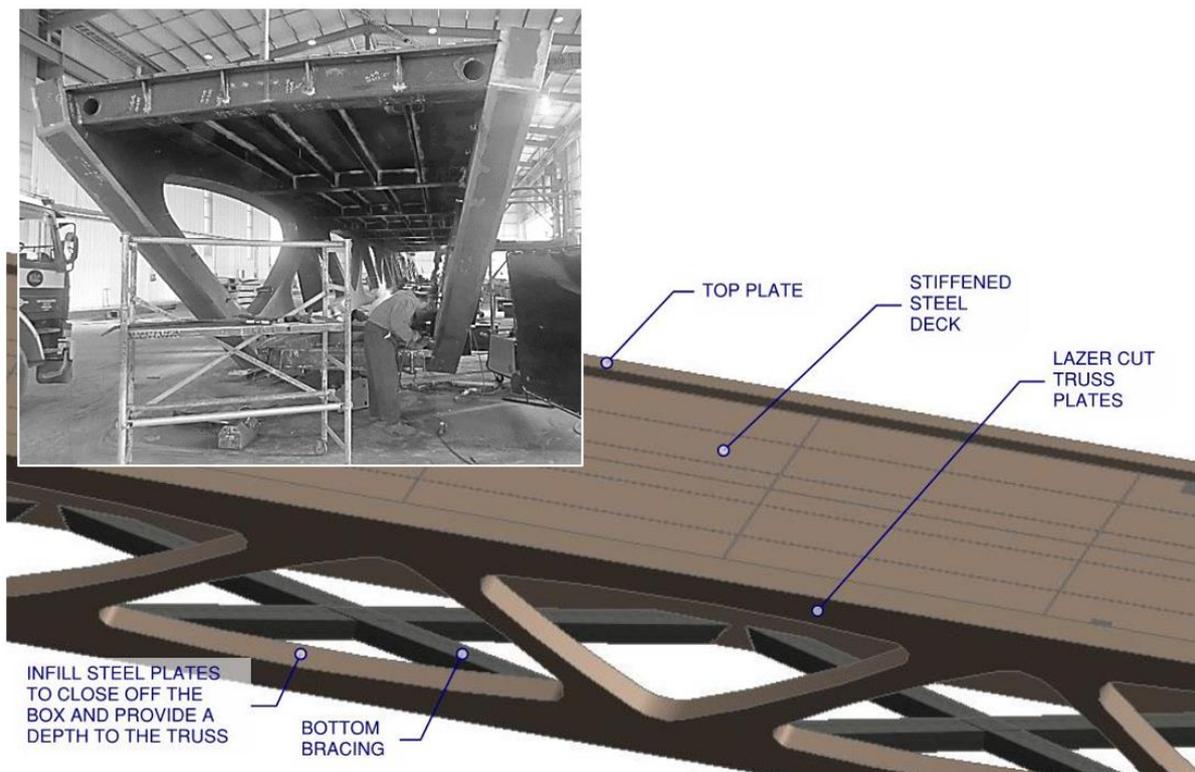


Figure 12: Superstructure consisting of girders, bottom bracing and deck which acts as a diaphragm plate.

Due to the cross section of the chord elements increasing near the nodes, the truss is designed as moment fixed at nodes, not pinned as for typical truss design. Imitating to some extent a Vierendeel truss. Where the truss elements become suitably slender, approximated to a $\frac{1}{4}$ of the chord length, a beam element was used for analysis.

3.1.6 Fall Protection

The handrails and anti-throw screen frames were made up of stainless steel flat sections positioned to best mimic the Graham Tipene's design. The flat sections used were also selected to keep the elevation of the bridge as light as possible considering the total height from top of screen to bottom chord of the bridge was just under 3000mm. A high quality, robust 2mm wire stainless steel mesh was used for the anti-throw screen and for safety from falling purposes.

3.1.7 Watermain

The watermain is completely isolated from the bridge via sliding bearings. The internal temperature of the water reducing the thermal expansion and contraction experienced by a water supply pipe. Cathodic protection of the pipe can also be introduced without any effect on the bridge. The number of supports was minimized across the bridge and are supported directly onto the bottom bracing elements. Each pipe support is tapered in all directions to save on material and make them look a little more slender.

3.1.8 Transverse Beams at Piers

One of the aesthetic details we introduced was the removal of the transverse 'tie' element between abutment bearings (see Figure 13). Normally a transverse tie takes the transverse loads into a single fixed bearing per support. Using in depth analysis and some Finite Element Modelling, we designed an alternative load path via the stiff diaphragm and stiffened bottom bracing connections near the pier.

The subtle change is a continuation of the crisscross bracing pattern across the entire 98m length, including an opening above the V-pier which looks really intriguing.



Figure 13: Bottom bracing continuing through the support, unbroken by any transverse elements.

3.1.9 Corbel Support and Truss Ends

The bridge is orientated at a skew of 35 degrees. We wanted the bridge to reach out and touch ground as opposed to being wholly attached to the abutment support. Consequently, the east abutment bearings, where future pedestrians will walk directly beneath the bridge, were designed to be 50% on land and 50% in the air. A reinforced concrete corbel was designed to reach out to the 'in air' bearing creating a unique concrete feature (see Figure 14)Figure 15.

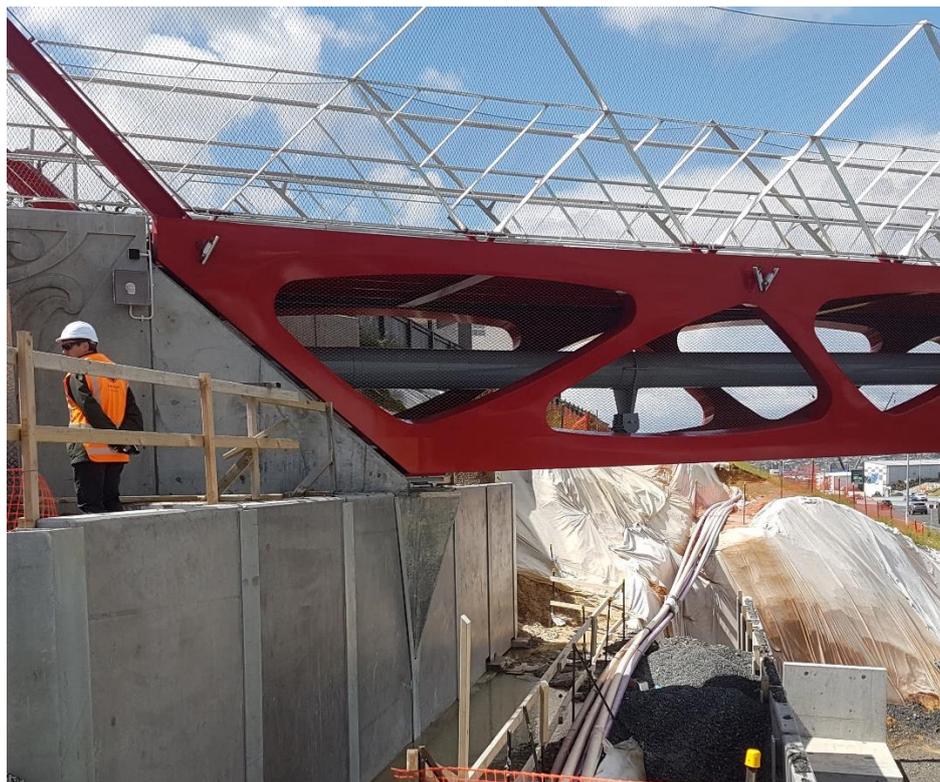


Figure 14: View looking straight down the future shared path with the motorway to the right (west). The concrete corbel is visible beneath the end of the truss bottom chord.

3.1.10 Abutment Uplift

Site geometry and design detailing both contributed to abutments being closer than usual to the piers (short outer spans) and the abutment bearings being closer than usual to each other (see uninterrupted V-planes in Figure 7). Analysis showed that the bridge experienced uplift at the abutments. The relatively tall structure, at least in theory, wanted to overturn. The bearings resisted this action as a moment resisting couple, with one of the bearings experiencing tension.

We didn't consider tension bearings to be appropriate to resist frequent wind gusts, with a possible rattling and wearing of the bearing components due to the 1mm – 2mm gap before engaging. Grout was pumped into the last 5m of the steel truss box sections and a secondary hold down device was introduced at the abutments (see Figure 15). This was tightened sufficiently to off-set any tension under frequent service loads. Occasional high wind events with a return period of approximately 5 years or more, may still cause some tension, but is not expected to cause a maintenance issue.



Figure 15: East abutment bearings with the secondary hold down device. The critical overturning action was wind, followed by collision on the piers and then seismic actions.

3.2 Material finishes

A key component to any bridge, but in particular to architecturally designed structures, are the surface finishes of materials. It is of course also true that the finish of materials and quality thereof, is often key to a structure reaching its design life with only routine maintenance carried out. A considerable amount of effort and attention was placed on the selection of top quality finishes on Tirohanga Whānui.

3.2.1 Protective Coatings and Colour

Steel is considered to be better to the environment than concrete structures when viewed from an embodied energy and recycling standpoint. Also, for longer spans needing quick erection methodologies, as is the case when constructing over a live motorway, a steel structure is often preferred and a protective coating is required.

Via extensive research and workshops, a performance specification was drafted. As application risk remains the greatest risk to any protective coating system, the specification focused heavily on quality assurance and environmental controls. The *NZ Transport Agency Protective Coatings for Steel Bridges* and AS NZS 2312 was followed and the following (see Table 1) has been applied to the structure.

Table 1: Protective coating specification, which includes a slight modification to the top coat to achieve better colour fastness

COAT	PRODUCT	DFT(μm)
1. PRIME COAT	Interzinc 52 (epoxy zinc-rich)	75
2. INTERMEDIATE COAT	Interplus 1180 (epoxy)	200
3. TOP COAT	Interthane (polyurethane)	60
4. TOP COAT	Interthane (polyurethane)	60

We used this PUR5 system for the following main reasons:

- A TSM (thermal metal spray) system with 40-year time to first maintenance carries greater application risk than a PUR5 system. This is because application of coats on the thermal metal spray is very susceptible to defects caused from moisture and powdering of the metal spray finish.
- TSM systems with a colour finish (also known as duplex systems) have a modified PUR system above the TSM system.
- Specialist opinion indicates that an aesthetic finish design life of 12-15 years is achievable. This does not mean that the coating system has failed, simply that the aesthetic finish requires repair.
- Slightly lower capital cost.
- Frequent (12-15 years) maintenance of a colour top-coat for aesthetic reasons will prolong the design life of the underlying coats. This is true for a 25yr PUR5 and a 40yr TSM system, making the added application risk with a TSM system avoidable without significant additional whole of life costs.
- We could modify the top coats by removing TiO₂ (white pigment) from the coating. This pigment has previously been shown to heavily influence colour fastness properties and a significant improvement in the paint performance is expected.
- High gloss finish of the top coat meant an anti-graffiti coat was not required.

The New Zealand climate is wet and damp during the winter months. Programme constraints lead to the bridge coating taking place mid-winter. Even with stringent environmental controls in place, some of the finished top coat displayed a blushing effect (matte finish, rather than specified gloss finish). This occurred most where internal stiffener plates met the external girder web plates and a local drop in the steel surface temperature occurred. In other words, the control of the steel surface temperature needed more heating and better controls, regardless of an acceptable paint shed environment. The blushing effect was overcome with further heating, better encapsulation meaning more constant steel temperatures.

3.2.2 Deck Surfacing and Grip

Within New Zealand only a few options exist for the non-slip coating of bridge decks. All consist of a primer (as for protective coating systems), a binder and various grades of aggregate. Usually, and to increase the colour performance, a seal coat or two is added.

Aggregates vary, and the first option is extremely tough and grippy and commonly used on the road network for high friction grip surfaces - calcined bauxite which is usually grey or light brown. Colour can be introduced via coating of the calcined bauxite, but the angular particles tend to lose the coating on the surface with the extreme point pressures and abrasion experienced. Synthetic alternatives include quartz and glass and, in both cases, the colour can be impregnated in the aggregate via the manufacturing process.

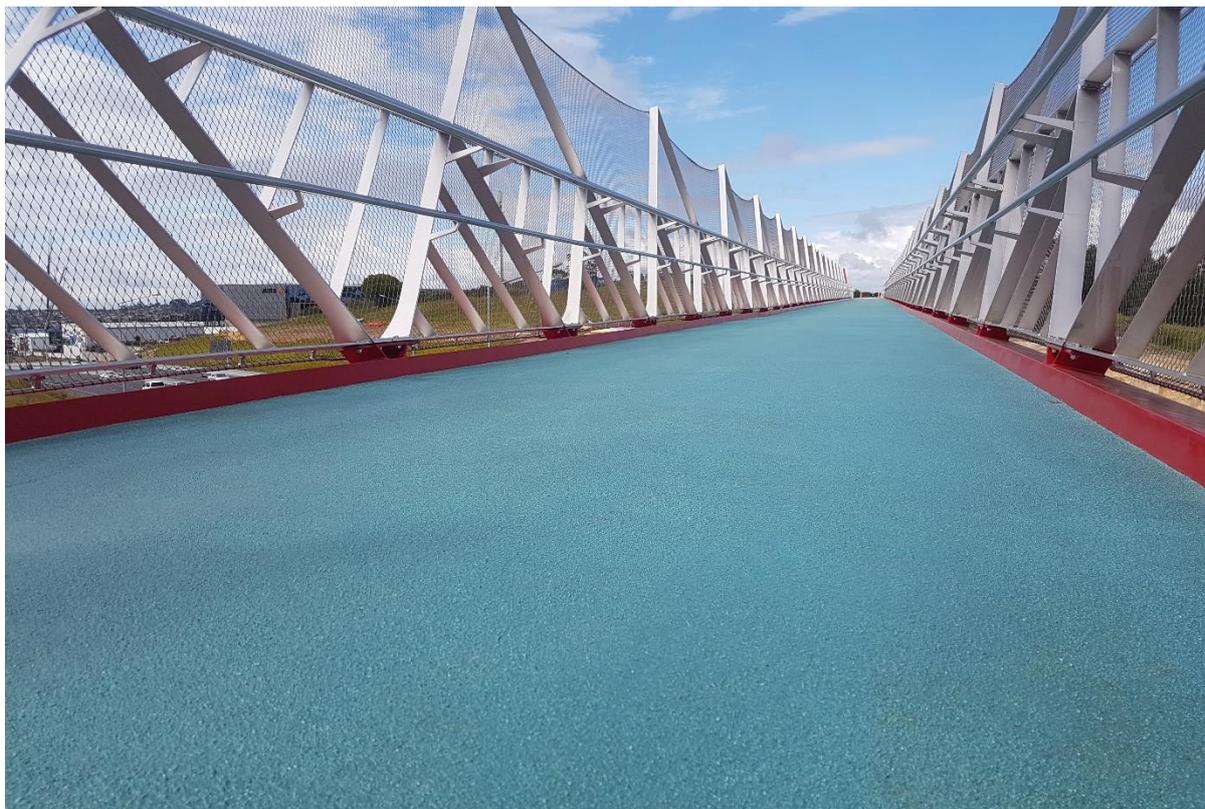


Figure 16: MMA deck surfacing with quartz scatter. The playful surfy green colour was embedded into the system. Clear seal coats offer added UV protection.

The binder would also usually have the colour impregnated into the chemistry, not unlike protective coating top coats. Options are not limited to, but often consist of either an epoxy resin, a polyurethane or methyl methacrylate (MMA). These three different binders each offer a range of benefits and are very clever products. However, concern exists within the industry over the use of each. For epoxy resin, cracking of the hard, rigid resin on a steel deck which can be considered 'flexible', is raised most. Polyurethanes are effectively a protective coating system with aggregate scattered across it. Their toughness and durability seem to make the product more suited to commercial or light industrial applications. In Britain the MMA's are reported to be slippery when wet, however testing seems to at least partially disprove this.

Right across New Zealand, non-slip surfacings can be found performing poorly. This is sometimes due to poor application procedures. Similar to the discussion on protective coatings, this is seen as a reason to avoid the use of TSM coating systems (primers) with a deck surfacing. Additionally, we found that failures are especially evident on concrete or asphalt substrates where escaping moisture can cause hydrostatic pressure that makes the surface blister or delaminate.

At Tirohanga Whānui, we utilized the following protective coating system (see Table 2 and Figure 16).

Table 2: Deck surfacing specification, which includes the Intermediate coat purely for protective coating purposes.

COAT	PRODUCT	DFT(μm)
1. PRIME COAT	Carbozinc 858	75
2. INTERMEDIATE COAT	Carboguard 690 include Natural Quartz	200
3. BINDER COAT	Flowcrete Flowfast Std Primer 2011	350
4. BINDER COAT	Flowcrete Flowfast Flex Binder 2102 include Colour Quartz	500
5. SEAL COAT	Flowcrete Flowfast Flex Sealer 2102	400
6. SEAL COAT	Flowcrete Flowfast Flex Sealer 2102	300

We used this MMA system for the following main reasons:

- Achievable Coefficient of Friction >>0.6
- Intermediate coat added to achieve the 25yr steel protection requirements.
- 8yr colour fastness – considered to be achievable with high quality products and the double seal coat offering improved UV protection.
- 8yr non-slip performance life.
- Maintenance involves a chemical wash of the bridge and then application of the next MMA and aggregate coats which will bond together extremely well.

3.2.3 Anti-throw Screen Stainless Steel

Stainless steel offers excellent corrosion resistance, however there are still different finishes that can influence the durability performance. These are broadly discussed in this section.

Two primary options exist, the first is mechanical preparation using various 'grit' profiles (like sand paper grades). Polishing of the grit finished steel can enhance the aesthetic and performance further, but these processes are quite labour intensive. The second option is electropolishing (note, this is the 'reverse' of electroplating). Electropolishing involves dipping the steel into an acidic bath. The surface and sharp points of the steel microstructure are eaten away by the chemical reaction and a smooth, durable surface is left. The Australian Stainless-Steel Development Association (ASSDA) confirmed that electropolished steel performs better than even a very fine 'grit' finish when subject to corrosive environments. Combinations of the above two processes may be used to achieve the best aesthetic outcome to complement the durability benefits of the electropolishing process.



Figure 17: Stainless-steel handrail and anti-throw screen frames were modular to allow for ease of installation and unexpected replacement or repair. One was fixed in place every ten minutes during construction.

On Tirohanga Whānui, we utilized electropolished anti-throw screen frames due to the frames being welded at most connection points (see Figure 17). Electropolishing, being a dipping process, allows a completed element to be treated, whilst mechanical process would result in an untreated weld zone. We also preferred the matt type finish of the electropolished steel with a slightly reduced sun strike effect. The hand and cycle rails were polished to a beautiful smooth finish due to the feel of the finish in hand.

4 THE VIRTUAL BUILD

We start discussing the construction phase of the project with a glimpse into the world of virtual reality (VR). We built the bridge in the virtual world first to engage with our clients and their stakeholders. Watercare put the kit on and were taken for a tour of the structure, allowing their operations team to completely understand the space they would be able to use to maintain their water supply asset (see Figure 18). Small adjustments could and were made to the design off the back of this experience.

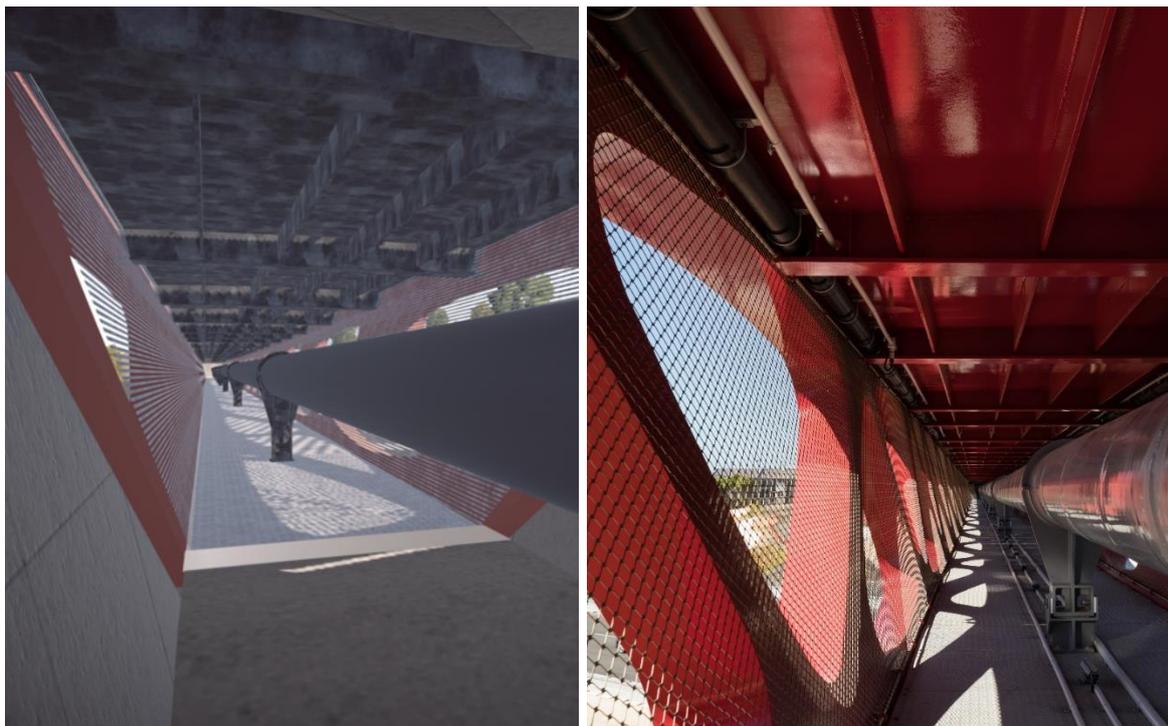


Figure 18: Virtual and real-world example of the maintenance area for Watercare. Also note the tidy detailing of the mesh supports, drainage and lighting supply all placed to completely avoid visibility from the motorway.

We also manipulated the full VR model experience into portable headset models, that could be taken anywhere and setup within the time it takes to open an app on a mobile phone. The NZ Transport Agency used this in presenting the final design to the Iwi with the bold 'Noble Red' bridge that could be seen from a multitude of vantage points. We also used the VR to work through safety in design and construction methodology with the Contractor and took the mobile headsets out to the community on NZ Transport Agency open days.

5 THE REAL BUILD

Some of the playfulness aside, the real task was to build a bridge and then erect it across the motorway.

5.1 Truss fabrication

Starting with the voids and the previously mentioned balance between constructability and art. Using digital models that fed into plasma cutting machines, we were able to cut out virtually any shape. This meant that there was little challenge in creating the outside face (or webs) of the organic shapes the team wanted. Filling in the cut out voids with a top flange and bottom flange would prove more challenging as the steel plate would need to be molded, rolled and welded into the shapes cut out of the webs.



Figure 19: Each section of the fabrication included two girders, the bottom bracing and the stiffened top deck. Once each component was complete they were put together as shown here.



Figure 20: Beauty is in the structural engineering and workmanship. No cladding is added masking the engineering which keeps the structure in the sky.

Our solution required skilled fabrication techniques to ensure that the curved plates were pulled into position and welded in place. Each void would comprise of three tight rolled radii forming the corners of a triangle and three large 'cambered' radii forming the sides of a triangle.

The deck system was fabricated separately, as were the bottom bracing elements and within a short couple of weeks the lot was brought together like gigantic Lego pieces (see Figure 19 and Figure 20).

5.2 Truss Erection Methodology



Figure 21: The eastern section of the bridge sitting on the sub-structure with temporary bearing and hold down devices in place.

In keeping with the strategy proposed during design, the abutments and piers were completed and erected ready to receive the bridge truss. The truss itself was constructed in three parts, one 44m long and the other two approximately 30m long each. These three pieces were practically complete prior to transport to the site laydown area around 500m from its final location at Spencer Road. At the laydown area all of the possible components including the watermain, the lighting, the drainage and the anti-throw screen frames were installed. A very smart safety driven decision by the Contractor erecting the bridge.

In three separate motorway closures, first the outside spans were erected onto the bearings with a 5m cantilever extending out into the center span (see Figure 21 and Figure 22). Finally, the center section was lifted using a dual crane lift and twisted into position where it was held in place for the bolted splice connections to be completed. Two separate teams installed 288 friction grip bolts at the 12 chord splice points. Having carried out a trial erection in the steel fabricators yard meant that the risk of misfit was substantially reduced, however the alignment and thermal effects could account for

significant movement from the set position. Fortunately, the quality of the fabrication and installation was good, and the structure fit with acceptable ease and lack of noise or on-site modification.



Figure 22: Truss erection was carried out in three lifts. The last lift included bolting up the splice points. Each splice point consisted of two 25mm plates with four 16mm splice plates and high strength friction grip bolts.

At this stage the bridge deck which contributes so much to the horizontal and torsional stiffness of the structure, was not yet welded up at the splice points. Weather conditions were monitored, and design analysis and calculations proved that all temporary load cases could be accommodated. Two days later, after some much needed rest, the deck was welded up and the structural system was working.

6 CONCLUSION

In conclusion, the bridge is something unique and born out of a fascination with bridge structures and the aesthetics of large infrastructure. It is vital to have this passion when delivering a bridge of this nature, and we hope this becomes more commonplace in our industry at large.

Below are some of the key points worthy of reflection.

- a) Always improve on the details. Through concept, preliminary and detail design. If the delivery model allows it, even together with a collaborative fabricator.
- b) PUR5 protective coating systems are a good option for use when colour finishes are required as they avoid the application risks of a TSM system and, with regular 12-15yr maintenance of the top coat should last as long as the TSM system.

- c) Environmental controls are critical and cold spots can occur where internal stiffener plates meet external plates due to the heating and dehumidifying being run intermittently or just before painting.
- d) Application of deck surfacing on any permeable or moisture containing substrate is not recommended. The MMA on the Tirohanga Whānui Bridge, though as yet unproven for durability, appears to provide excellent adhesion when tested insitu.
- e) Electropolishing offers outstanding corrosion resistance compared to even a very fine mechanically prepared stainless-steel surface. The microstructure is smoothed off, meaning that tea staining is reduced.
- f) Erecting the bridge using bolted splices at approximately third points was a good methodology that can be considered again.
- g) A major strength of this Project was embracing Māori culture and integrating the learnings / understanding / designs within the design. Watercare, NZ Transport Agency and Mana Whenua expressed their pleasure at the collaborative partnership between all parties noticeable in the design of the bridge. Some form of cultural understanding at the very least should become party to any design and promotes communities taking ownership of the product.

7 OPENING THE MOTORWAY

I recall the first vehicles to travel under the bridge on the morning after the center section was erected. They seemed happy, hooting either to voice their happiness at driving down a clear motorway for once, or out of excitement for seeing this beautiful bridge in place above them. I felt extremely tired. I felt relieved. I felt...fascinated.

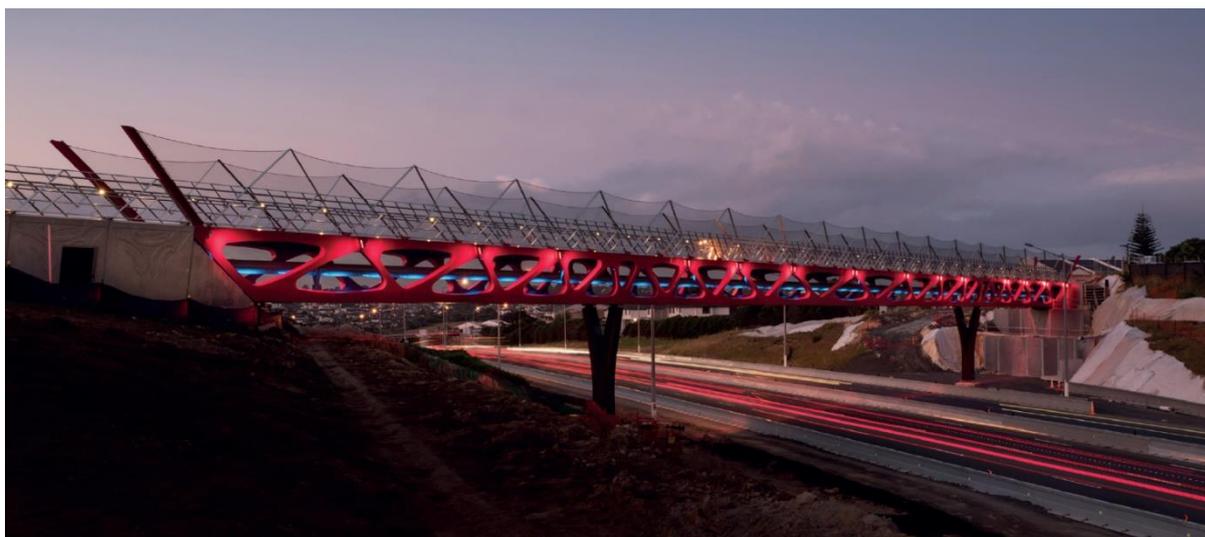


Figure 23: Tirohanga Whānui Bridge lit by night with the piers disappearing into dark horizon.

8 REFERENCES

- NZ Transport Agency, Auckland Northern Corridor Project Website and Publications, <https://www.nzta.govt.nz/projects/the-western-ring-route/auckland-northern-corridor/>

9 ACKNOWLEDGEMENTS

- New Zealand Transport Agency and Watercare Services Limited, our Clients.
- Northern Corridor Improvements Alliance who constructed the bridge.
- Culham Engineering who fabricated the bridge.
- Jeff Wells and Graham Tipene for their input into the concept and designs.
- John McNeil and Oliver de Lautour, from Aurecon's Auckland Bridge Team, for their input into the concept development.

- Australian Stainless-Steel Development Association for great guidance and reference on stainless steel components.

10 AUTHOR BIOGRAPHY

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Geoff Thompson has more than 10 years' experience in bridge design, management and construction. He has worked across multiple geographies including South Africa, Dubai, Fiji, New Zealand and Australia. He is passionate about all things 'bridge' and within Aurecon's Sydney office, leads teams in the delivery of civil structural and bridge projects.