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HISTORY OF CONCRETE BRIDGES IN NEW ZEALAND

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SUMMARY

Concrete is one of the most cost effective, durable and aesthetic construction materials and can provide many advantages over other materials. The history of bridge construction in New Zealand has proved that concrete is an excellent material for constructing bridges, and in particular bridges that use beams, columns and arches as the main load bearing elements. It is remarkable that New Zealand, as a remote country at the end of the Victorian period, made considerable early use of concrete in bridge construction. Kiwi engineers love new ideas and embrace new technologies. New Zealand bridge engineers, from the early days, were not afraid to take on the challenge of working with a new and innovative material.

The first reinforced concrete bridge was built over the Waters of Leith in Dunedin in 1903. In 1910 the Grafton Bridge in Auckland became the world's longest reinforced concrete arch bridge, 21 years later the Kelburn Viaduct was built in Wellington. Taranaki was especially forward-looking in using concrete arch bridges and has many fine examples. In 1954 another major development occurred when the Hutt Estuary Bridge used post-tensioned pre-stressed concrete for the first time in New Zealand. This led to the construction of New Zealand's first pre-stressed concrete box girder bridge on the Wanganui Motorway in 1962.

Pre-stressed concrete made slim and elegant construction possible, like the 1987 Hāpuawhenua Viaduct on the North Island Main Trunk railway line. In 1981 the south Rangitīkei viaduct was built with five twin-shafted concrete piers carrying pre-stressed concrete beams. At 78 metres high and 315 metres long, the south Rangitīkei viaduct is the fourth-highest and the second-longest rail viaduct in New Zealand. The Ngauranga Twin-curved flyover bridges built in 1980's, were the first incrementally launched prestress concrete box-girder bridges in Australasia.

This paper will provide a journey through the developments of concrete bridge construction in New Zealand, and recognise and celebrate some of the notable achievements of our pioneer bridge engineers and constructors.

INTRODUCTION

Concrete is one of the most cost effective, durable and aesthetic construction materials and can provide many advantages over other materials. The history of bridge construction in New Zealand has proved that concrete is an excellent material for constructing bridges, and in particular bridges that use beams, columns and arches as the main load bearing elements. It is remarkable that New Zealand, as a remote country at the end of the Victorian period, made considerable early use of concrete in bridge construction. Kiwi engineers love new ideas and embrace new technologies. New Zealand bridge engineers, from the early days, were not afraid to take on the challenge of working with a new and innovative material. Records show that casks of artificial cement were imported from England as early as 1842, and numerous concrete structures were built between 1840 and 1900, including many engineering and military structures, the scale and size of which increased with time. A wide range of lime, cement and aggregate was used, depending on what was available.

There are probably several reasons for the wide use in New Zealand of what was, at that time, still an experimental construction material: the rapidly growing country had urgent need of infrastructure; concrete was found to be a robust structural material comparable to both steel and timber; it could be constructed using a wide range of 'as-found' materials; there was a shortage of skilled tradesmen such as stonemasons and bricklayers, and concrete required less skilled labour; and it proved more durable and cost effective than either steel or timber in the often damp, humid environment.

Early settlers seemed ready to experiment with new possibilities in this new environment, and concrete offered ways of making structures fireproof and later, with reinforced concrete, earthquake resistant.

FIRST USE OF CONCRETE IN BRIDGES

Geoffrey Thornton in his Book "Bridging The Gap"[3] reported the use of concrete in piers and abutments of a bridge outside New Plymouth in 1859. The 1867 bridge over the Waiwhakaiho River, was built with concrete piers; the bridge was later replaced by a reinforced concrete structure in 1907 as part of a Taranaki County Council initiative.

The first significant use of reinforced concrete in New Zealand bridge engineering is recorded in the construction of towers for Skippers Canyon Suspension Bridge[17], over the Shotover River near Queenstown in Central Otago in 1901. The Skippers Canyon Suspension Bridge is a special and dramatic structure of engineering and historic value, because it is one of the highest (91.3m) and longest span (96.4m) late 19th and early 20th century New Zealand bridges.

Figure 1. Skippers Canyon Suspension Bridge

Figure 2. George Street Bridge

FIRST CONCRETE BRIDGE

The George Street Bridge in Dunedin is recognised as a landmark in the history of the bridge industry in New Zealand. Completed in 1903, it is thought to be the first reinforced concrete arch bridge in the country[3,7]. The bridge spans some 12m and springs from solid concrete abutments. Consistent with other contemporary arch bridges, it retains heavy ornamental detailing and stone facings on the abutments. In this manner, it appears similar to traditional masonry arches and disguises its 'modern' concrete construction medium. The bridge is recognised by the New Zealand Historic Places Trust as a pioneer example of engineering technology.

REINFORCED CONCRETE PIER AND GIRDER BRIDGES

Kiwis began using reinforced concrete in bridges construction from about 1899, and soon it became a preferred material the bridge construction. The Taranaki County Council provided a real boost for this mode of construction when it decided on a policy of replacing existing bridges with the newer material. Concrete was expected to be cheaper, quicker to build and would have a longer life with less maintenance than the existing timber bridges.

Tariki Road Bridge

Tariki Road Bridge over Manganui River about 14km south of Inglewood, was built in 1907[3]. It has end spans of 6.4m and 8.2m with a central span of 10.3m, the latter being under strutted with a set of four concrete-encased rolled steel joist. These struts are braced against the two concrete piers 9.8m above the river bed and there are horizontal braces between the piers and abutments, possibly a later addition. The 150mm deck has expanded metal as reinforcement. The structural configuration of this bridge was quite similar to timber beam bridges built in the late 1900 century, as can be seen from Figure 3 and 4.

Figure 3. Tariki Road Concrete Bridge

Figure 4. Ladle Bend Timber Bridge (1876)

Waiwhakaiho River

The timber bridge over the Waiwhakaiho River on the northern side of New Plymouth was replaced with a 58m long bridge, with 9.1m end spans and two 18.1m central spans in 1907. It was the longest reinforced concrete bridge at that time[3]. A total of nine bridges were built out of concrete as part of that particular replacement regime – each with a slightly different structural configuration. It is quite remarkable that the Taranaki County Council could undertake such a series of projects, using the design and supervisory skills of its engineer, E.C. Robinson[3], rather than a more prominent consulting engineer.

Waihenga Bridge, Martinborough

The Waihenga Bridge spans the Ruamahanga River on SH 53 between Featherston and Martinborough. It was built for the Featherston County Council and was open in January 1912. The bridge is made up of 14 spans of 12.2m, eight approach spans of 6m at the eastern end[3]. The piers are each founded on reinforced concrete piles driven into the river bed and they support three 925x400 haunched beams in each span. The ferro-concrete bridge with driven concrete piles was considered a substantial engineering achievement in its time. The total length of the bridge is about 170m.

This bridge is an early example of reinforced concrete Tee-beam construction that was employed widely throughout New Zealand from the early 1900's onwards.

Figure 5. Waihenga Bridge, Martinborough

Figure 6. Waihenga Bridge, Pier beams connection

Old Mangere Bridge

The current Mangere Bridge is a major motorway bridge over the Manukau Harbour in south-west Auckland. The first Mangere Bridge opened in 1875 to provide a link between Mangere and the bustling port at Onehunga. This bridge was a narrow wooden one-way bridge that deteriorated quickly and was prone to attack by ship worms.

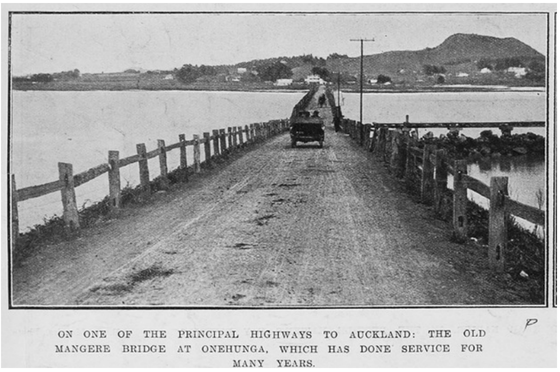

Figure 7. 1875 Timber Bridge

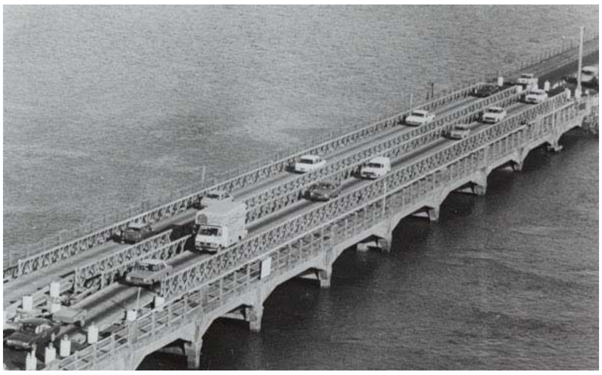

Figure 8. Old Mangere Bridge

The second Mangere Bridge (now known as the Old Mangere Bridge) opened in 1915, and this time it was built using reinforced concrete and driven piles. The bridge, however, did not provide enough clearance to let anything but small boats pass under it and the new bridge also soon proved to have too little capacity, and sinking foundation piles created issues. It is believed to be the oldest reinforced concrete bridge crossing a harbour in New Zealand. The old bridge was closed to motor vehicles in the 1970sand is slowly deteriorating, especially as it sustained damage when a ship accidentally rammed it some years ago. It is worth to note that the design is underway to replace the bridge with a new pesdestrian and cycle bridge.

Kelburn Viaduct, Wellington

The Kelburn Viaduct, a rather heavy bridge, which spans Wellington's Glenmore Street, was opened on 2 May 1931. The current concrete viaduct replaced a steel and timber truss structure and was built as part of a programme of major transport improvements in the city during the 1920s and early 1930s. The design of the Viaduct was a continuous concrete girder bridge on concrete piers[3]. There are three spans, the central span is about 22.6m, the overall length of the viaduct is 71.3m, and the height of the Viaduct is about 19.8m.

Figure 9. Kelburn Viaduct, Wellington

Figure 10. Old & New Kelburn Viaduct

CONCRETE DECK ARCH BRIDGES

Concrete deck arch bridges, where the deck is above the arch, were introduced in New Zealand in the early twentieth century. Some historical concrete deck arch bridges are discussed in the following section.

Grafton Gully Bridge

Grafton Bridge was built in 1910 and at that time, had the longest reinforced concrete arch span in the world[7] (97.6m). Grafton Bridge has the highest classification given by the New Zealand Historic Places Trust, in recognition of its outstanding technological merit and magnificence as a townscape element. In 2004, it was further recognised by the international engineering community when it featured in the American Concrete Institute publication, *Concrete: A Pictorial Celebration,* published to commemorate the American Concrete Institute's Centennial. The completion of Grafton Bridge led to a number of other concrete arch bridges being constructed.

The bridge has one central arch and two approaches. The western approach has two spans of 10.7m and four spans of 22.5m. The eastern approach consists two spans of 25.3m and one span of 12.8m. The piers are cylindrical and 30.5m tall with curved cantilever brackets at the top to carry the footpath over the pier and serve to embellish the pier head. The main span arch is a three hinged arch, and consists of two ribs which are tied together by beams which act as bracing.

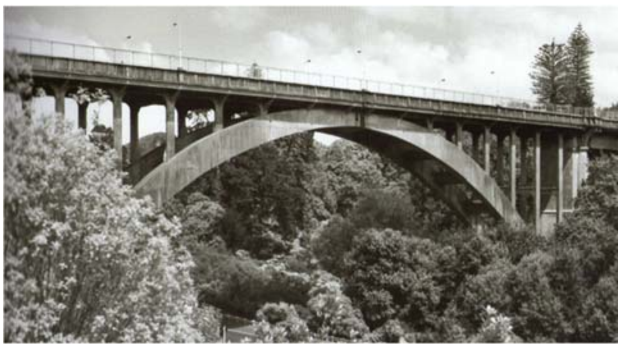

Figure 11. Grafton Bridge

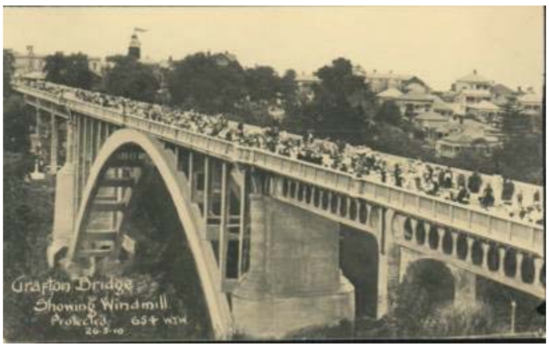

Figure 12. Grafton Bridge Opening

Kaipara River Bridge

Kaipara River Bridge at Helensville, an early multi-span arch bridge, was completed in 1916. The bridge had seven spans of 9.1m. The three arch ribs per span were carried on triple-pile pier and rested on granite blocks used as expansion joints at the solid concrete abutments.

The seven spans, with their open spandrels and slotted balustrades, show a lighter design approach then other early concrete bridges.

Leaning Rock Creek Bridge

Leaning Rock Creek Bridge in Cromwell Gorge, is one of three unreinforced concrete arch railway bridges on the Otago Central Railway[3]. The bridge was completed in 1917. The bridge had a main parabolic arch span of 15.2m with a rise of 7m, and it was flanked by pairs of secondary segmental arches of 4m with a rise of 1.2m, forming a heavy open spandrel effect. Interesting to note, these rail arch bridges were built with unreinforced concrete, when reinforced concrete was already firmly established.

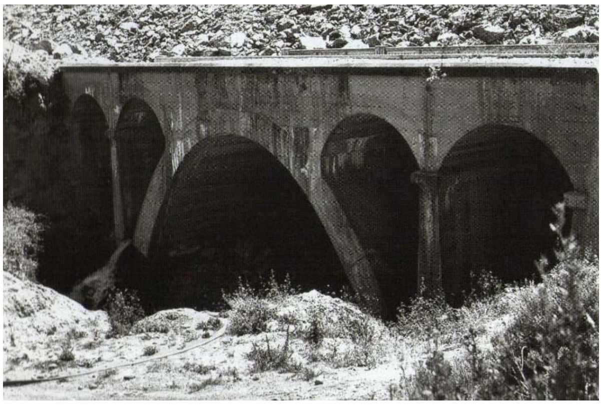

Figure 13. Leaning Rock Creek Bridge

Figure 14. Edith Cavell Bridge

Edith Cavell Bridge

Edith Cavell Bridge over the Shotover River at Arthurs Point, is an impressive structure opened in February 1919 replacing an 1875 timber bridge. Designed by the PWD, it has a two three-pin parabolic reinforced concrete arches of 30.5m span, and stands 27.4m above the river.[3] This was the second bridge of this type in New Zealand, the first being the Grafton Bridge in Auckland. Its open spandrels and pipe rail balustrades enhance the feeling of lightness.

Ruakokoputuna River Bridge

The Wairarapa region has many early reinforced concrete arch bridges, Ruakokoputuna River Bridge is an example, which was built in 1921. It is an open spandrel type, with an arch span of 18.3m and a road width of 3.6m. Its concrete post and pipe rail balustrade is more appealing than solid concrete[3].

Manawatu Gorge Bridge

Manawatu Gorge Bridge was built in 1931, with its four 24.4m arch spans, open spandrels and six vertical slabs supported the deck it has a pleasing rhythm. The total length is 118.6m and there is a 6m wide roadway[3]. Support for the arches comes from solid concrete piers, thicker at the springing to take the thrust.

Hautapu River Bridge

Hautapu River Bridge, Taihape, built in 1932, is another PWD design. It has open spandrels and an arch of 30.5m, with two end 12.2m girder spans.

Figure 15. Ruakokoputuna Bridge

Figure 16. Manawatu Gorge Bridge

Parawhaiti Stream Bridge

Parawhaiti Stream Bridge on the Stronvar Road was built in 1935. The bridge is an unusual arch design for two reasons: it is technically a skewed arch bridge, where the outer edges of the arch are off-set to allow the bridge to pass over the stream bed at an angle; and the spandrel panels are solid, with the void behind filled with earth[16]. The arch spans 23.8m; the total length is 30.1m and width 7.1m. The whole of the structure is reinforced concrete, including the balustrade which is pierced with narrow round-headed vertical openings.

Figure 17. Parawhaiti Stream Bridge

Figure 18. Tangahoe River Bridge

Tangahoe River Bridge

Tangahoe River Bridge in Taranaki is a fine deck arch bridge on SH3 opened in 1936. It is an open spandrel hinge-less arch bridge and has two parabolic arch ribs of 27.4m span and four girder spans, and stands 24.4m above the stream bed. The road width is 6m and total length of bridge is 66.1m.

Mangapurua Bridge

Mangapurua Bridge over Mangapurua Stream is better known as “The Bridge to Nowhere”. It is a reinforced concrete arch of 23m span with a total length of 39.6m and a deck height above water of 38m. Construction of the bridge was completed on 5 June 1936.

Figure 19. The Bridge to Nowhere

Figure 20. The Bridge to Somewhere

Whangamomona River Bridge

Whangamomona River Bridge in Aotuhia Valley, is locally known as “The bridge to somewhere”. This 1937 structure shared a similar fate to ‘The bridge to Nowhere’ when floods isolated the area and settlers departed. Much later a new road was extended to link up the bridge from the south.

Tangahoe Valley Road Bridge

Tangahoe Valley Road Bridge over Tangahoe River, sited upstream from the Tangahoe River Bridge on SH3 has an arch span of 24.4m. This is an interesting bridge, the deck passing through the arch at about mid-point with legs of the arch anchored into the abutments in a visually impressive manner. This is known as a half-through arch and was designed by PWD.

Figure 21. Tangahoe Valley Road Bridge

Figure 22. Fish River Bridge, Haast Pass

Fish River Bridge

Fish River Bridge on Haast Pass was opened in 1940 and has a deck arch of 31.1m and two land spans. Its straight alignment denies the speeding motorist the opportunity to appreciate the form of the bridge from the road. It can only be seen by descending an overgrown and water-worn track.

The Narrows Bridge

The Narrows Bridge over the Waikato River which opened in January 1941, is an open spandrel deck bridge with a clear span of 31m. On each side there are two beam spans of 4m and 2.7m wingwalls. The overall length of the bridge is about 43m. The deck is carried on curved longitudinal beams supported on concrete piers with no lateral braces.

Figure 23. The Narrows Bridge

Figure 24. The Kopuawhara Railway Viaduct

The Kopuawhara Railway Viaduct

The Kopuawhara railway viaduct is one of six major viaducts on the Napier-Gisborne Railway, which was completed in 1942[1]. The viaduct is a superb structure technologically, and a visual delight. The viaduct is 162m long, with an open spandrel parabolic arch of 54.9m and a height of 30.5m. There are five reinforced concrete girder spans of 12.2m and one of 9.1m on the south side. On the north side there are three 12.2m spans, all supported on reinforced concrete trestle piers. The viaduct is a completely monolithic construction, and the abutments have Mesnager hinges to accommodate temperature movements. Longitudinal forces are taken by compression in the arch ribs and lateral forces by bending of the bridge deck spanning to the main pier bents.

CONCRETE BOWSTRING ARCH BRIDGES

The bowstring arch bridge has top chords in compression and is tied at deck level, and the deck is supported by hangers in tension. Geoffrey Thornton in his book “Bridging The Gap”[3] described “Opawa River Bridge (1917)” as the first and “Westshore bridge in Napier (1918)” as the second Bowstring arch bridge in New Zealand. However, we believe that the configuration of these bridges are actually trusses as they have diagonal members. We consider that the bowstring arch bridges were introduced to New Zealand in the 1930s, and in the following section some key bowstring arch bridges are discussed.

<u>Pahiatua Bridge</u>

Pahiatua Bridge over Mangatainoka River, built in 1934, is the first bowstring arch bridge in New Zealand. The bridge has seven shallow arch spans of 20.7m and 6m wide road. It was designed by Seaton, Sladden and Pavitt, consulting engineers.

Figure 25. Pahiatua Bridge (1934)

Figure 26. Balclutha Road Bridge (1935)

<u>The Balclutha Road Bridge</u>

The Balclutha Road Bridge over the Clutha River in South Otago, is one of the best-known road bridges in New Zealand's South Island. Built between 1933 and 1935, this bowstring arch bridge was designed to be earthquake and flood resistant, thereby safeguarding it against the two most common natural disasters to occur in southern New Zealand[3]. The bridge was built from reinforced concrete, with six parabolic curved spans, each of 36.6 metres in length, and a total bridge length of 244.1 metres. A carriageway of 6.7 metres width is flanked on either side by a footpath of 1.4 metres; its total width is 11.8 metres.

<u>Fitzherbert Bridge</u>

Fitzherbert Bridge over Manawatu River in Palmerston North, was opened in 1935. When opened this was a significant urban bridge, and despite unsympathetic modification it was a sad loss for our engineering heritage when it was demolished[3]. The bridge had four bowstring arch spans of 34.1m and seven girder spans of 16.8m.

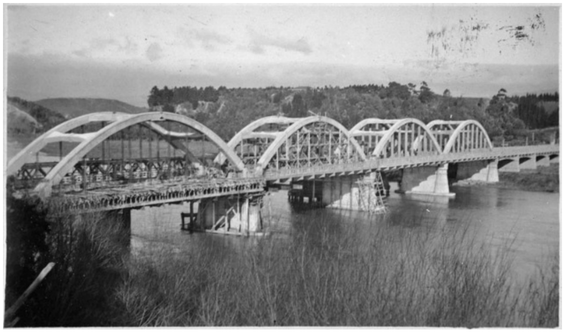

Figure 27. Fitzherbert Bridge

Figure 28. Fairfield Bridge

Fairfield Bridge

Fairfield Bridge over the Waikato River in Hamilton, was designed by Stanley Jones and completed in 1937. This superb bowstring arch bridge has one 39.6m arch, two 39m arches and two end spans[3]. The concrete balustrades have a pierced pattern, the curved approaches have metal balustrades and there is smooth transition at the lower arch ribs.

Mataura River Bridge

Mataura River Bridge in Mataura was built in 1939, and replaced the 1868 suspension bridge. This single bowstring arch is a dramatic and important visual element in the town. It has a span of 43.4m. The arch ribs pass below the deck and are tied at the top chord.[3]

Figure 29. Mataura River Bridge

Figure 30. Opawa River Bridge

CONCRETE TRUSS BRIDGES

Concrete truss bridges are an uncommon type of bridge due to the low direct tension capacity of the concrete and complex formwork for truss components as well as design factors. Geoffrey Thornton in his book “Bridge The Gap”[3] reported that two concrete truss bridges were built in New Zealand. As mentioned above, we believe that “Opawa River Bridge (1917)” and “Westshore bridge in Napier (1918)” are also concrete truss bridges, and have been included in this category of bridge.

Kaimarama River Bridge

It was built in 1910, at the settlement of Kaimarama, south of Whitianga in the Coromandel. It had a 3.4m roadway, a shallow 18.3m long reinforced concrete truss which formed the balustrade and two 10.7m reinforced concrete beam end spans[3]. The main span was a Warren truss but with vertical struts to every second bay. It also had two raked concrete piers. After 50 years of service the bridge was replaced as it developed an obvious tilt.

Opawa River Bridge

Opawa River Bridge built in Blenheim in 1917, is the first reinforced concrete through truss bridge in New Zealand. It was designed by PWD and has eight spans of 21.3m. The structure of the bridge is heavy as it has chunky diagonal members and piers have racking elements with infill wall.

Westshore Bridge in Napier

Westshore Bridge built in Napier in 1918, has only one through truss span of 17.4m. The other twenty-six spans being reinforced concrete girders[3]. It was designed for both road and rail use in parallel, but it was not until the late 1920s that trains used it.

Figure 31. Westshore Bridge in Napier

Figure 32. Gentle Annie Creek Bridge

Gentle Annie Creek Bridge

This reinforced concrete truss bridge was completed in 1922 for Gentle Annie Creek about 30km from Cromwell. The bridge was designed by PWD using a modified Pratt truss of 18.3m span with solid concrete end panels[3]. The smaller span on the south end is a 12.2m concrete girder and the piers consist of a pair of horizontally braced reinforced concrete bents.

PRESTRESSED CONCRETE BRIDGES

Prestressing has played an important role in extending the span capabilities and economy of concrete bridges. With advancement in the technology of prestressed concrete and construction techniques, New Zealand bridge engineers started refining their designs and pushing the boundaries to produce some state of art concrete bridges. In the following section we have listed some examples of prestressed concrete bridges (excluding balanced cantilever bridges) to recognise and celebrate some of the more notable achievements of New Zealand bridges engineers.

Hutt Estuary Bridge

The Hutt Estuary Bridge, completed in 1954, was New Zealand's first substantial bridge with a prestressed concrete superstructure[1,18]. At the time of its construction this road bridge was widely regarded as a significant New Zealand engineering project.

The Hutt Estuary Bridge is a two-lane road bridge consisting of five 32m spans and 9m approach spans at each end. It was designed with a pedestrian walkway on the south side, and on the opposite side a serviceway is provided carrying water pipes and other services, across the Hutt River. The bridge's marginally parabolic form was a design feature to allow for required flood clearances.

Figure 33. Hutt Estuary Bridge

Figure 34. Hutt Estuary Bridge Construction

Prestressed concrete was virtually unknown in New Zealand before 1952. In the 1960s it became one of the foremost bridge-building materials. Prestressing techniques have been mainly used in precasting components (largely beams) in factories. The Ministry of Works (MoW) had produced many standard plans to make factory manufacture easier. In 1970 the precast bridge beam designs were developed by the MoW and known as the “Blue Book”. Later it was updated internally in 1980s and known as the “Red Book”. These standard designs played a significant role in making concrete bridges more popular than other types of bridge. In the early 2000s NZTA, took the initiative to update the standard pre-cast pre-stressed bridge beam designs. NZTA Research Report 364 “Standard Pre-cast Concrete Bridge Beams” was released in December 2008 with updated designs of bridge beams including super T, hollow core beams and I beams.

Two major projects, Victoria Park Viaduct and Thorndon Overbridge Viaduct, constructed in the 1960s and 1970s using the standard design precast prestressed bridge beams, are still the largest projects in New Zealand involving prestressed concrete. At the same time bridge designers were making intensive efforts to apply prestressing to continuous-span, cast-in-place superstructures; for example, the Wanganui Motorway Bridge, completed in 1962, was the first prestressed concrete box girder structure in New Zealand.

Victoria Park Viaduct B ridge

Figure 35. Victoria Park Viaduct

Figure 36. Victoria Park Viaduct Construction

The Victoria Park Viaduct is a major motorway viaduct carrying the Auckland Northern Motorway (SH 1) over Victoria Park in Auckland. Construction begin in 1959 using post-tensioned precast beams and the bridge opened on 5 April 1962. The overall length of the bridge is about 630m and it is one of the longest concrete bridge in New Zealand.

Cobham Bridge, Wanganui

Cobham Bridge over Wanganui River on the State Highway 3, was designed by MoW and constructed in 1962 and is the first cast-in-situ prestressed concrete box girder structure in New Zealand. The 275m long bridge comprises 9 spans. The first three spans from each abutment are composed of four 27.4m post-tensioned precast concrete I-beams with a composite in situ concrete deck. The 4th span of 32.9m from both ends comprises a 3 web, post-tensioned, cast in situ, haunched concrete box girder cantilevering 9.8m into the central span. Four 24.4m long post-tensioned precast concrete I-beams complete the 43.9m long centre span[15]. Piers are full width reinforced concrete walls supported on a group of 400mm square prestressed concrete raked piles.

Figure 37. Cobham Bridge, Wanganui

Figure 38. Cobham Bridge Strengthening

In 2006 seismic assessment showed that this bridge can withstand a 1000 year returnn period earthquake event, provided that liquefaction does not occur at the abutments[15]. The assessment also showed that the structure can withstand a 2,500 year return period event, except for central span piers which would need to be strengthened for shear to provide a greater assurance that they will perform without failure. However, if liquefaction occurs, the abutment structure is expected to fail under large forces from the embankment fill. The risk of liquefaction is mitigated by improving the ground around the abutments by installing stone columns, and the shear strength of the central span piers was increased by through bolting the pier walls with the bolts anchored against steel straps at either wall face.

Thorndon Overbridge

Thorndon Overbridge constructed in late 1960's-early 1970's, is the largest concrete bridge project involving a prestressed concrete ever built in New Zealand[1]. The bridge utilised over 300 post-tensioned 'I' beams utilising some 800 tonnes of prestressing. The design was again carried out by the Ministry of Works. The Thorndon Overbridge off ramp onto Aotea Quay was constructed using insitu box girders[1].

Figure 39. Thorndon Overbridge

Figure 40. World's First "Catch frame"

In the mid 1990's, a seismic assessment was completed for Thorndon Overbridge and vulnerabilities to earthquake loads identified. Geotechnical assessment of liquefaction risks was undertaken and investigations carried out to locate the Wellington Fault which passes under the bridge. Linkage deficiencies were considered and a linkage bolt retrofit scheme developed. World first 'catch frames' were developed to mitigate against the loss of spans in the event of a predicted 5m local fault movement below the bridge.

Symonds Street Bridge

The Symonds Street Bridge constructed in 1972 and was the first major bridge in New Zealand to use the system of off-site segmental span construction followed by epoxy jointing and prestressing to make the finished structure on site. The bridge was built in two sections maintaining traffic flows through half the carriageway at a time, but this did not allow excavation to take place. Therefore construction of the bridge piers and foundation piling was carried out from road level prior to limited excavation been carried out. The continuous prestressed box girder was then precast in segments off site[1]. The individual segments, each weighing some 20 tonnes, were then brought to site, placed in position, epoxy glued together, prestressed into single spans, and then further connected together into a three-span continuous structure through a second stage of prestressing. The structure was completed with handrails, etc, and carried traffic before the major excavation took place for the motorway alignment below.

Figure 41. Symonds Street Bridge (1971)

Figure 42. Symonds Street Bridge

Shell Gully Bridge, Wellington

The Shell Gully bridges on the Wellington Urban Motorway, immediately north of the Terrace Tunnel leading into the CBD, were constructed around 1973. The Shell Gully bridges were designed with provision for future duplication of the Terrace Tunnel based on separate structures being provided to carry each carriageway of the motorway, but have only been constructed to the extent necessary to feed traffic into the single existing tunnel. The main motorway carriageway structures comprise twin continuous posttensioned spine beams constructed integral with piers comprised of twin column portal frames, with each column founded on a single cylinder foundation socketed into bedrock. This is one of the first bridge project where capacity design concept was implemented in the design. The on and off-ramp structures comprise single continuous post-tensioned concrete spine beam, again constructed integral with the piers, which are single columns founded as before, except for the upper end structure of the Clifton Terrace on-ramp, which is a slab structure supported on piles.

As a part of nationwide seismic screening project, the Shell Gully bridges were assessed in details in 2004 to determine its seismic performance. The assessment showed that the link spans are vulnerable to seismic damage and strengthening work has been carried out[23].

The similar design was adopted for Newton No 1 Bridge in Auckland, which carries SH1 northbound through Spaghetti Junction, as an alternate design against the confirming design of insitu box girder around 1975. The superstructure of the alternative design had 10% more material then the confirming design but it was 30% below the nearest conforming tender. This reflected the major trends of insitu box girder in bridge construction had become too expensive to build because of labour cost increase associated particularly with the internal formwork and the complexity of box girders. The similar concept was adapted for Sunset road bridge over SH1 in Auckland built in 1990s.

Figure 43. Shell Gully Bridge Construction

Figure 44. Shell Gully Bridge (underside)

South Rangitikei Viaduct

South Rangitikei viaduct constructed in 1981, is the 4th highest and 2nd longest railway viaduct in New Zealand[21]. It is a 78m high, 315m long viaduct spanning the Rangitikei River. It is an impressive all-concrete structure with twin-shafted vertical piers carrying a continuous prestressed hollow box superstructure of six spans. It incorporates an earthquake resistant feature that is unique in New Zealand and rare in the world. In an earthquake the pier bases could lift up to 13cm to allow energy and load to shift from one pier leg to the other. The rocking action is controlled by large "energy dissipaters" installed in the pier bases.

Figure 45. South Rangitikei Viaduct

Figure 46. South Rangitikei Viaduct superstructure

The construction method used a self-launching steel false-work system and involved only minor earthworks so there would be minimal disturbance to the surrounding landscape. The bridge is located in a seismically active area and was designed as the world's first base isolated structure; the tall piers stepping or rocking from side to side in the event of a major earthquake shaking. Special steel torsion energy dissipating devices were installed at the base of each leg to ensure satisfactory performance under large earthquakes.

Ngauranga Interchnage Bridges

Close to the end of 1982, another landmark structure was being constructed in Wellington, the Ngauranga interchange bridges. Designed by the Ministry of Works and built by Mainzeal Construction Ltd, these twin-curved bridges were the first use of the incremental launching method in Australasia[19]. At the opening, the Prime Minister, Sir Robert Muldoon referred to the bridge as a magnificent piece of engineering. In the language of its country of origin, West Germany, the bridge was called a Taktschiebeverfahren, a 20-letter word. Sir Robert dryly went on to add that an engineer had translated this to 'incrementally launched bridge' and yet another more down-to-earth engineer who worked on the job, further reduced it to a four letter description, a 'push bridge.' Subsequent to this project, four other bridges have been constructed in New Zealand using the same technique.

Figure 47. Ngauranga Flyover Bridge

Figure 48. Night view of Ngauranga Flyover

Hapuawhenua Viaduct

Figure 49. Hapuawhenua Viaduct

Figure 50. Hapuawhenua Viaduct

The Hapuawhenua viaduct epitomises the three aims of engineering: function, economy and (above all) grace. Completed in 1987, it is the longest high railway viaduct in New Zealand[21] being 51m high and 414m long. The viaduct is a major structure constructed from a combination of reinforced and prestressed concrete[1]. The viaduct consists of 21 prestressed concrete spans on 22 reinforced concrete piers. This slender structure is a 'state of the art' design, which takes advantage of the development of engineering knowledge of the behaviour of structures under extreme conditions, and especially those of a major earthquake. As a result of improved knowledge the amount of material used in construction has been minimised while the safety of trains has been enhanced.

Sylvia Park Viaduct Bridge

Figure 51. Sylvia Park Viaduct Arial view

Figure 52. Sylvia Park super T beams

Sylvia Park Viaduct, carries South-Eeastern Highway over the Sylvia Park, is a 475m long bridge with span lengths of 21m and 25m and was built in 1995. During the design stage the designer, Duncan Peters from Connell Wagner, carried out a comparative evaluation of the structural efficiency of commonly available standard precast beams in New Zealand at that time and the closed top Super-T beam, developed by VicRoads, for a span range of 21m to 26m to see which would be the most economical type to use for the project. The Super-T beam was found to be the most efficient and it also had the advantage of providing a complete working surface for casting the in-situ deck slab on. This was an added advantage for the viaduct spans over the busy road and railway line. Based on the investigation results, super T beams were adopted for the viaduct. The Super-T beams were the original closed top type with an expanded polystyrene void former. The constructor (Downer) developed a high slump 60 MPa mix for the beams and saw cut sections through a trial beam to prove that the concrete was fully compacted around the void. About 240 super T beams of span rang of 21 to 25m were cost for Sylvia Park Viaduct. This was the first use of Super T beams in New Zeeland Bridge Industry.

After successful use of super T beams for Sylvia Park Viaduct, super T beams were used for highly skew Southern Motorway Underpass, Mungavin Road Bridge in Porirua and Puhinui Interchange Bridge built on SH16 near Auckland airport in 2001. In 2005 Super T beams were also used for 413m long, 15 span Hewletts Flyover in Tauranga, here super T beams' design was based on Partial Prestress concept.

Central Motorway Junction, Auckland

Central Motorway Junction Stage 1 was built in 2003 and was required widening, live load capacity strengthening and seismic retrofit of three existing major bridges; Grafton Bridge #2, Grafton Bridge #3A and Khyber Pass Viaduct. All three bridges are major multi-span, post tensioned concrete box girder structures constructed in the 1970s with lengths respectively of 110 m, 110 m and 200 m.

Work on Grafton Bridges #2 and #3A included widening by 6.5m, strengthening of existing girder webs and seismic retrofit of pier foundations. Grafton Bridge #2 was widened on two sides and Grafton Bridge #3A on one side only.

Work on the Khyber Pass Viaduct included widening and strengthening the deck cantilevers with steel brackets, adding external longitudinal post tensioning to existing box girders, locking the northbound and southbound bridges together, infilling the deck between and seismic retrofit of all pier foundations. The team had to add new internal diaphragms inside the Khyber Pass Viaduct box girders and add additional width to the existing internal diaphragms. To get the concrete into these tight spaces and to get it to fill right up to the underside of the deck the team needed a flowable concrete, hence they used self-compacting concrete. It is believed to be the first application of self-compacting concrete in bridges in New Zealand, as the Firth had to develop the concrete mix design and the team undertook quite a lot of testing to be able to convince themselves it would work.

Figure 53. KPV-Cantilever deck strengthening with steel brackets

Figure 54. KPV- New external longitudinal post tensioning

Central Motorway Junction Stage 2, was built in 2006 and required the construction of five new bridges and retrofit/widening of four existing bridges. The new bridges range from 35m to 200m long and typically comprise continuous spans of 1500 deep concrete Super T girders supported on single columns and bored piles. Nelson Street off ramp, Beresford Street Viaduct and Newton No. 2 bridges of this project are the first application of integral Super T bridge beams in New Zealand.

Figure 55. CMJ2–1st Integral Super T Deck

Figure 56. CMJ2-1st Fomcrete application

The existing Ramp B structure, built in the 1970s but never put in service, required changes in level and cross falls to accommodate the new North/West link. This was achieved by constructing a lightweight slab and support walls with foamcrete having a density of about 1200 kg/m^3, on the existing bridge deck. This is considered as the first application of foamcrete in bridges in New Zealand.

Tauranga Harbour Link

Figure 57. Chapel Street Viaduct

Figure 58. Post-tensioning Super T Beam

Chapel Street Viaduct is the largest of the bridges on the Tauranga Harbour Link (THL) Project constructed in 2009. It is about 560m long and 40m wide at its widest point. Chapel Street Viaduct crosses over two major roads, one minor road and a railway. To overcome these obstructions and numerous site constraints the optimum pier spacing was determined as approximately 35.5m. This is a little beyond the normally accepted limit for 1500mm deep Super Tee beams with conventional pre-tensioned strand. Therefore the solution was to design the beams with a mixture of pretensioned strands and post-tensioned tendons. This combination optimised the beam design while still allowing daily casting cycles in the precast yard[11]. Self-compacting concrete was used for the manufacture of all the Super Tee beams on Chapel Street Viaduct. Although the material cost was little more than normal bridge beam concrete, savings come from the speed of concrete placement and the elimination of labour requirements for concrete vibration offset this additional cost. This was the first time post-tensioned Super Tee beams had been used in New Zealand and it is also a major application of self-compacting concrete bridge beams.

Northern Gateway Toll Road

The project completed in 2009 and key bridges in this project are Otanerua Viaduct, Nukumea Viaduct, Hillcrest Bridge and Waiwera Viaduct.

Otanerua Viaduct is a 256m long bridge that crosses the Otanerua Valley and provides an ecological corridor between two areas of regionally significant bush that the new motorway would otherwise bisect. The Viaduct superstructure comprises 8 x 32m spans each with ten 1500mm deep super T beams which are designed as partially prestressed.

Nukumea Viaduct is 180m long and comprises 6 spans of 30m. The cross section of the bridge comprises eight 1500mm deep super T beams with an insitu concrete deck. The deck was designed to carry 100 tonne earthworks vehicles during construction and as a consequence is more heavily reinforced than needed for legal traffic loads[10]. The design and construction of this Viaduct was very similar to Otanerua Viaduct. The only difference being, Nukumea has deck joints at both ends of the bridge while Otanerua has one deck joint at mid-length.

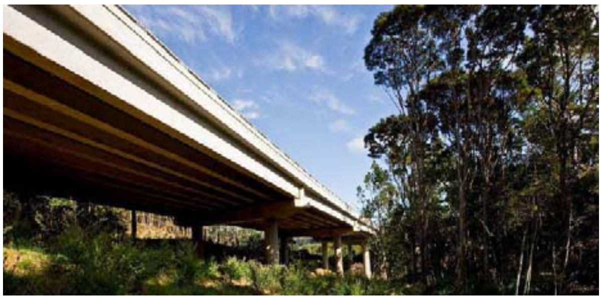

Figure 59. Otanerua Viaduct

Figure 60. Hillcrest Bridge

Hillcrest Bridge is a 115m long structure that carries a single lane of traffic and a footpath over the new motorway. The bridge superstructure is a continuous reinforced concrete tee-beam.

The underside of the superstructure follows the original ridge line. This allowed the superstructure to be poured on formwork at the original ground level and the bridge to be built using a top-down construction methodology[10] The 756mm diameter inclined steel tube columns supporting the bridge are structurally logical, but they did not suit top-down construction. To overcome this problem, four temporary bored piles were constructed near where the steel columns connect to the superstructure.

BALANCE CANTILVER PRESTRESSED CONCRETE BRIDGES

In early 1960s, New Zealand bridge engineers embraced another innovative technique in the design and construction of bridges. Bridges constructed from each supporting column as balanced cantilevers, progressively moving out from each side were developed. In the following section we have discussed some of the key balance cantilever bridges in New Zealand. These have included pre-cast segmental and in situ concrete bridges in a wide range of environments including river crossings, harbour crossings, urban and rural land crossings and an alpine deviation.

Newmarket Viaduct Bridge

Newmarket Viaduct, completed in 1966, was the first bridge designed as a balanced cantilever and the largest prestressed concrete bridge in New Zealand at the time of its construction. Of particular interest in the engineering world was a problem which occurred early in its life due to a temperature differential between the deck, which had a normal black bitumen wearing coarse, and the bottom of the beams. This caused unacceptable cracking in the continuous structure, due to differtial temperature gradient, that had not previously been considered in the design. The solution was to put in additional prestressed macallys bars and place a light coloured stone chip on the road surface to reduce heat gain to the deck. This led to bridges being designed for the effect of differential temperature gradients both in New Zealand and overseas.

Figure 61. Newmarket Viaduct construction 1964

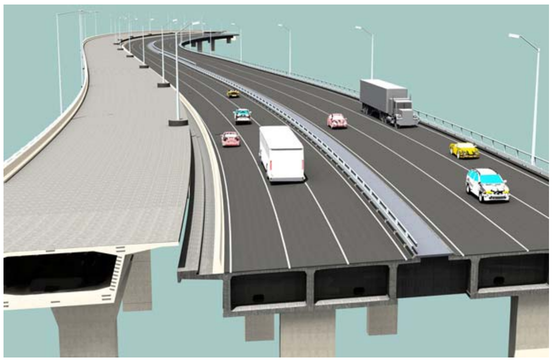

Figure 62. Replacement of Newmarket Viaduct

In 2007, the 1966 viaduct carried an average of 163,500 vehicles per day making it one of the busiest sections of Auckland's motorway system, and more lanes were needed. Rather than upgrade the original viaduct the decision was made to replace it. The replacement viaduct was designed to withstand an earthquake that might occur only once in 2500 years, and constructed in four stages. The first stage, completed in 2010, saw four new south-bound lanes constructed on the northern side of the original viaduct. Following this stage two involved dismantling of the original southbound bridge. Stage three was to build three new northbound lanes in place of the old viaduct's southbound bridge, and the final stage was the demolition of the original northbound section of the viaduct. Figure 62 illustrates the construction stages.

<u>Clarence River Bridge</u>

The Clarence River Bridge is a post-tensioned box girder bridge constructed using the cast-in-situ, balanced cantilever method. The depth of the superstructure varies from 3.2m at pier supports to 1.1m at mid-span. The superstructure is integral with the reinforced concrete piers and expansion joints are present at midspan of each main span. Design of the bridge was completed around 1968 by the Ministry of Works.

Piers, which are of an elongated octagonal shape, are each founded on a pair of 2.4m diameter cylinders with belled bases. The cylinders comprise hollow sections, in-filled with gravel, with in-situ concrete plugs at the top and bottom. Piers vary in height from 6m to 9m whilst the cylinders are 12m in length.

Figure 63. Clarence River Bridge

Figure 64. Clarence River Bridge

Elastomeric bearings support the end spans at the abutments. Tie-down bolts were provided to the end spans, at the abutment, in accordance with standard practice at the time the bridge was designed.

Waipuna Bridge

The Waipuna Motorway Bridge was constructed in the 1971. This was the first application of pre-cast segmental epoxy jointed box girder bridge construction in New Zealand using a self-launching overhead gantry for erecting pre-cast segments by a balanced cantilever method. The four lane and 528m long bridge consists of 7 spans with 43m end spans and five 75m central spans. The bridge is divided into three separate structures with halving joints provided at the mid-span of spans 4 and 6. The halving joints are provided with bearings and ties to prevent vertical separation across the joints whilst allowing rotation and longitudinal movement to occur. The central spans are supported on concrete box piers. The shorter end spans are supported on rectangular concrete piers and concrete abutments at each end. The piers and abutments are founded on 1.2m diameter piles of varying length.

Figure 65. Waipuna Bridge (east View)

Figure 66. Waipuna Bridge (west view)

The bridge has suffered from sagging of the cantilever spans at the halving joints due to creep effects, and modifications to the joints and surfacing were undertaken in the 1980's to improve the riding surface. This was a common problem among the first generation of balance cantilever box girder bridges which had joints at midspan.

Upper Harbour Bridge, Auckland

Figure 67. Upper Harbour Bridge Duplication Construction

Figure 68. Upper Harbour Bridge Duplication

The original bridge was designed and constructed in the early 1970s as a two-lane concrete balanced cantilever bridge. It is 457m long bridge, with five 73m long main spans and two 46m long end spans. About 400m of the bridge (all but the eastern end span) is over water with depths typically of the order of 8-10m at mid-tide and with a deeper navigable channel passing under the eastern main span. In 2005 a new bridge was built immediately adjacent to the existing. The new bridge with a 17.8m wide deck now carries the east-bound carriageway of the new motorway along with a footpath/cycleway, and the old bridge carries the west-bound carriageway. The new bridge was designed to match the existing 457m long, 7-span balanced cantilever bridge aesthetically with similar continuous box girder sections over its full length. A key difference between the original and duplicate Upper Harbour Bridge is the elimination of joints and bearing within the bridge length except at abutments. The micro-silica concrete was used in substructure and part of super structures to improve the durability[14]. The documents also showed that self-compacting concrete was used[20] in column with congested reinforcement. This is one of the early use of self-compacting concrete in the New Zealand bridge industry.

North Rangitikei and Kawhatau Railway Bridges

Two valleys in the Mangaweka and Utiku rail deviation are similar in size and nature allowing the same design to be used for the North Rangitikei and Kawhatau Viaducts in 1981. The bridges are unique three-span balanced cantilever bridges constructed over very deep river gorges. The design is a prestressed concrete box girder spanning 110m across the gorge, the longest span of any rail bridge in New Zealand. The bridges have shorter end spans giving a total length of 182m. The unusually short side spans are tied down at the ends with rock anchors. Construction was by the cantilever method using a mobile formwork system and cast in place concrete. The structural depth varies from 3m at mid-span to 7.75m at the main piers.

Figure 69. North Rangitikei Bridge

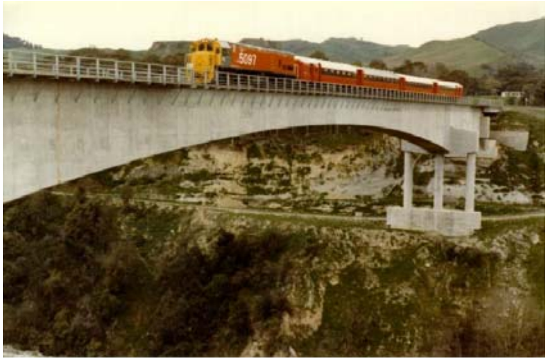

Figure 70. Kawhatau Viaduct

North Rangitikei Bridge is the 2nd highest railway viaduct in New Zealand[21] and is 81m high spanning the Rangitikei River. Kawhatau viaduct is the 6th highest railway viaduct in New Zealand[21] and is 73m high spanning the Kawhatau River.

Mangere Bridge

Figure 71. Mangere Bridge Construction 1980

Figure 72. Duplicate Manukau Harbour Crossing

In 1983 a new Motorway Bridge, known as the New Mangere Bridge was constructed using cast-in-situ post-tensioned and balanced cantilever techniques over Manukau harbour. In 2010 the New (Duplicate) Mangere Bridge, a 646m long, 21.5m wide motorway bridge, was constructed using balanced cantilever techniques alongside the existing crossing of the Manukau Harbour on State Highway 20. The bridge design employed twin (linked) cast-in-situ box girders with 100m main spans, the superstructure being continuous from abutment to abutment, and supported on flexible piers which allowed the elimination of bearings at piers. Particular attention was given in the design and during construction to achieving the desired whole-of-life performance and durability for the completed structure [12].

Pukete Bridge

Pukete Bridge is a prestressed concrete box girder bridge in Hamilton, spanning the Waikato River. This balanced cantilever bridge links Hamilton's eastern residential areas with the commercial and industrial facilities in the west. The bridge is 158m long and has a main span of 75m with landspans of 36m. The construction of the bridge was completed in October 1996.

Figure 73. Pukete Bridge

Figure 74. Pukete Bridge

Otira Viaduct

The Otira Viaduct constructed in 2000, in the Otira River Valley at Aurther Pass, is the longest span concrete bridge in New Zealand. The topography of the area required the construction of a 442m long, four-span viaduct, with end spans of 87m and central spans of 134m.

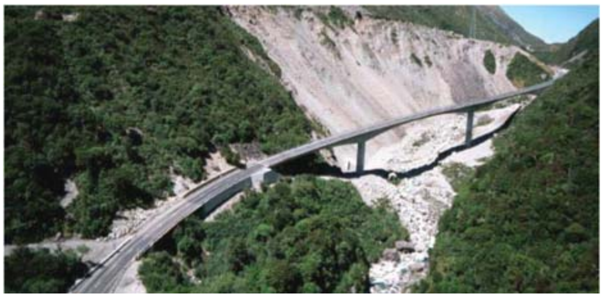

Figure 75. Otira Viaduct

Figure 76. Otira Viaduct - Construction

The super structure consists of a haunched single cell box girder with maximum depth of 7.75m at piers. The bridge is supported on single concrete box piers up to 45m high, constructed over 4m a diameter foundation cylinder.

The construction of the foundation cylinder[2] involved the construction of concrete pile secant wall around the outside of the permanent pile footprint allowing the later excavation inside the secant-pile wall coffer dam for lowering the permanent steel casing and reinforcement. The bottom of the pile casing was sealed with a tremie concrete plug and tremie in-fill concrete in between the casing and secant-pile wall cofferdam, so the pile could then be constructed in the dry.

For the reliable seismic performance of this bridge, the piers and superstructure are constructed monolithicaly, without articulation. The relatively short and stiff piers will attract high loads from creep, shrinkage and temperature deformations of the structure. To overcome this the superstructure was jacked apart locking large load into the end piers, before the final two cantilevers were made continuous by completing the mid-span closure pour. The bridge is supported on twin elastomeric bearings at each abutment.

To protect bridge piers from damage by rockfall, massive V-shaped protection structures, around piers 1 and 3, were designed to withstand a 4.5m diameter rock traveling at 10m/sec. The large V-shape structures are supported on steel encased concrete piles, which have been designed for the ductile actions required and can withstand several design impacts before their integrity is compromised.

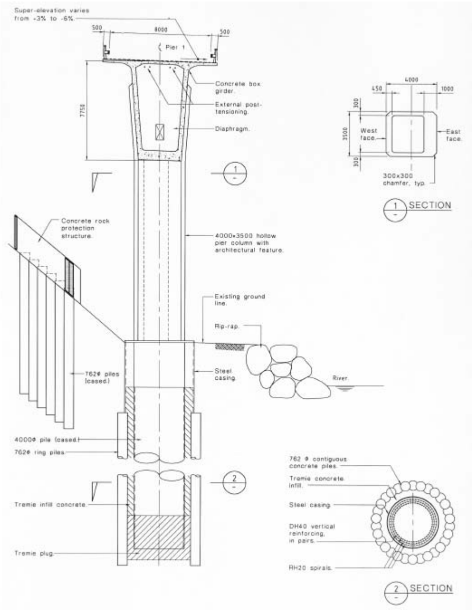

Figure 77. Otira Viaduct – Pier & Foundation

Figure 78. Otira Viaduct – Rockfall Protection

Waiwera Viaducts

This is a recent balanced cantilever bridge constructed in 2009. The project involved the application of a self-launching overhead gantry for erecting pre-cast segments by a balanced cantilever to form the 537m long Waiwera twin viaducts. This method was chosen since it allowed the superstructure to be constructed without access from ground level as it was off-limits to protect wildlife habitats. The piers were constructed from reinforced concrete, incorporating a microsilica additive for protection from the marine environment[10]. The Viaduct was constructed as two independent structures, which have a separation varying from 2.5m to 11m. The variable separation was necessary to split the northbound and southbound lanes before entering tunnels, which are situated immediately north of the viaduct.

Figure 79. Waiwera Viaduct Construction

Figure 80. Waiwera Viaduct

SOME SPECIAL CONCRETE BRIDGES

In this section we are discussing some of recent special concrete bridges, which are first of its kind.

Papatoetoe Station Pedestrian Bridge, Auckland

The construction of this pedestrian bridge in 2006, is the first use of Ultra-high performance concrete (UHPC) in New Zealand[9]. UHPC is the reactive powder concrete (RPC) type known under the brand name of Ductal® and originally developed by Rhodia, Lafarge and Bouygues. The constituents of RPC are cement, fine sand, silica fume, silica flour, superplasticiser, water with a low water-cement ratio, and may include either high-strength steel fibres or non-metallic fibres.

Figure 81. Papatoetoe Station Footbridge

Figure 82. Papatoetoe Station Footbridge Construction

The Papatoetoe[9] Footbridge has a total length of 175m consisting of ten simply supported spans, with the majority of spans being 20m long. There are two shorter spans of 8.2 and 10.2 m. The bridge spans are formed using two precast Ductal® segments. The deck is 50mm thick, contains no ordinary reinforcement, and has two symmetrical legs with large circular holes that provide architectural interest and reduce weight. Ribs protrude 350mm below the top of the deck slab at 2.7m centres along the beam to add torsional rigidity. The tension capacity is provided by ten 12.7mm post-tensioned strands in the bottom of each leg and six strands at the top to balance the prestress.

Ormiston Road Cable Stayed Bridge

Figure 83. Ormiston Road Bridge

Figure 84. Ormiston Road Bridge Construction

The Ormiston Road cable stayed bridge is a composite steel and concrete bridge constructed in the Sir Barry Curtis Park, Manukau City, in 2008. It is the first cable stayed road bridge constructed in New Zealand. The super structure consists of 70m-long steel box girder with concrete deck, suspended from 46m high inclined tapering concrete pylons. The 27m width of the bridge includes four traffic lanes, two cycle lanes and footpaths on both sides.

The inclined pylons are constructed in three sections. All of different materials. The lower 28m section consists of a reinforced concrete circular section tapering from 1800mm diameter at the pylon base to 1300mm diameter at the top of the concrete section. Above the concrete section, the cable stay anchorage itself consists of 4 fabricated steel boxes stressed to the concrete pylon[8]. A non-structural stainless steel and glass lattice frame in the form of a cone completes the top of the pylon, providing a visual effect of the tower tapering to a point, which was a key architectural feature. The reinforced concrete portion of the pylons was cast using self-compacting concrete. The concrete pylons are angled in two directions providing a dynamic element to the bridge. They are also positioned closer to the western abutment than the eastern, meaning the back span is considerably shorter than the fore span. This asymmetry generates considerable uplift on the western abutment which is resisted with deep tension piles.

The Ormiston Road Bridge is New Zealand's first modern cable stayed road bridge of any significance and it is expected that this pioneering structure will smooth the way for future cable-supported structures in New Zealand.

CONCLUSIONS

This paper provides a brief historical outline of the use of concrete in bridges and also provides a journey through the developments of concrete bridge construction in New Zealand. It recognises and celebrates some of the notable achievements of our pioneer bridge engineers and constructors. This journey shows that concrete is one of the most cost effective, durable and aesthetic construction materials for bridges and can provide many advantages over other materials.

Concrete is the most used construction material for bridges in the New Zealand. Prestressing has also played an important role in extending the span capability of concrete bridges. Construction of segmental concrete bridges began in the New Zealand in 1970s. By the early 1980s, pre-stressed box-girder spans reached a record 110m.

Kiwi engineers love new ideas and embrace new technologies. From the early days, they were not afraid to take on the challenge of working with a new and innovative material. This ingenuity has led to a number of outstanding and leading edge bridges, which were not only unique to New Zealand, but also the World. Among their many achievements, New Zealand bridge engineers built the longest span concrete arch bridge in the wolrd (at that time) in 1910, were the first to adopt the new technology of incremental launching in Australasia and designed and constructed the world's first base isolated bridge structure. They have also developed the world’s first catch frame to reduce the venerability of the exiting bridges against major earthquake.

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The authors also apologies for any errors and omission to the papers.

REFERENCES

[1] IPENZ, 1990: “Engineering to 1990”

[2] Ian Billings, 2000, “Design and Construction of the Otira Viaduct” 4th Austroads Bridge Conference, Adelaide, South Australia.

[3] Geoffrey Thornton, 2001: “Bridging The Gap” Early Bridges in New Zealand 1830-1939.

[4] Paul Wymer, 2005: “Cementing New Zealand position as innovators in Concrete Construction”. Concrete Industry Conference.

[5] K.Y, Ho and A Murashev, 2005:”Seismic Assessment of Clarence River Bridge”. 2005 NZSEE Conference.

[6] Peter Reed, Kate Schoonees and Jeremy Salmond, 2008, “Historic concrete structures, in New Zealand”.

[7] Rudolph Kotze, 2008: “Bridging Trends in New Zealand, Where Does Concrete Fit in”. Concrete Industry Conference.

[8] Alastair Blackler and Hugo Jackson, 2008: “Ormiston Road Cable Stayed Bridge”, New Zealand Concrete Industry Conference.

[9] M. Rebentrost and R. Annan, 2008: “Design of two reactive powder concrete bridges”. Tailor Made Concrete Structures – Walraven & Stoelhorst (eds), © 2008 Taylor & Francis Group, London, ISBN 978-0-415-47535-8

[10] Peter Lipscombe, 2009: “Bridges on the Northern Gateway Motorway”. 7th Austroads Bridge Conference, Auckland, New Zealand.

[11] Tracy Joseph, 2009, “Post-tensioned Tee-roff beams made with self-compacting concrete”. 7th Austroads Bridge Conference, Auckland, New Zealand.

[12] Ronald King, Andrew Dickson, Alex Parfitt and Juan Pretorius, 2009: ”Design and Construction of the New Mangere Bridge”, 7th Austroads Bridge Conference, Auckland, New Zealand.

[13] Tom Watson, Peter Holden, Nik Stewart and Rob Jury, 2009: ”Design and Construction of Bridges for the SH2, Dowse to Petone Upgrade, Wellington”. 7th Austroads Bridge Conference, Auckland, New Zealand.

[14] Andrew Dickson, Ian Billings, Mark Evans, 2009: “Design and Construction of the New Upper Harbour Crossing”, 7th Austroads Bridge Conference, Auckland, New Zealand.

[15] P. Brabhaharan, D.K. Kirkcaldie, 2009; “Earthquake strengthening and ground improvement of the Cobham Bridge, Wanganui”, 2005 NZSEE Conference

[16] Chris Cochran, 2010: “Historic Bridges of the Wellington Region”.

[17] Simon Daisley, 2013: ”Skipper Canyon Suspension Bridge”, IPENZ Engineering Heritage Register Report.

[18] IPENZ Engineering Heritage – Hutt Estuary Bridge

[19] IPENZ Engineering Heritage – Ngauranga Gorge Bridge.

[20] Upper Harbour Bridge, Wikipedia, the free encyclopaedia.

[21] New Zealand Rail Bridges, KiwiRail

[22] IPENZ Engineering Heritage – Mangaweka and Utiku Rail Diversion

[23] D.K. Kirkcaldie, J. Hobman, G. J. Saul, 2005: “The seismic assessment and retrofit of shell Gully Bridges” 2005 NZSEE Conference