BRIDGING TRENDS IN NEW ZEALAND
WHERE DOES CONCRETE FIT IN

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SUMMARY

Concrete has always played a major role in bridge construction in New Zealand. There are many examples of bridges and structures constructed in concrete, which is a testament to the virtues of the material. Like the previous Ministry of Works, Transit New Zealand is committed to achieving value-for-money outcomes in infrastructure investment. Concrete has been successful in establishing itself as a sustainable material for roading infrastructure. More recently there has been a dramatic increase in investment in roading projects and concrete has, and is playing a major part in ensuring that a sustainable network is developed. There are many examples of major bridges and structures in Auckland alone, and this paper will highlight the use of concrete in the most notable of these projects.

This paper will also examine future trends and challenges facing owners, designers and contractors. Climate change and sustainability are becoming more than buzz-words and concrete will be competing with other materials on more than just capital cost in future. Bridge research has declined in New Zealand over the last 10 to 15 years and the industry and research providers need to work together to establish a bridge research programme. This paper will explore areas for future research.

Introduction

With the merger of Transit New Zealand and Land Transport New Zealand a new organisation, the New Zealand Transport Agency (NZTA) has been created. While the NZTA has as much wider role in transportation, it remains responsible for maintenance and operations of the existing state highway network as well as delivering a substantial capital investment programme for new infrastructure. The overall objective is to operate the state highway system in a way that contributes to an integrated, safe, responsive and sustainable land transport system.

Increasing pressure on funding for the operation and maintenance of existing state highway assets as well as capital improvements will continue. Consequently there will be more focus on delivering fit-for-purpose solutions which can demonstrate value-for-money. This in turn will require greater innovation and optimum use of available resources.

The concrete industry has a proud history of being at the forefront of innovation and delivering quality and lasting solutions. Arguably, bridges and associated roading structures stand out as being examples of great achievements in the use of materials, including concrete. The concrete industry therefore has the opportunity to deliver solutions which will assist the NZTA in achieving its objectives through demonstrating compliance with, not only technical and whole-of-life requirements but also environmental and sustainability criteria.

Asset Description

Currently the state highway network comprises approximately 11,000 kilometres of roads, over 4,000 bridges and large culverts as well as 177 on-lane bridges. The combined length of bridges on the state highway network is over 140km. There are 177 kilometres of motorways in New Zealand with Auckland being the most extensive network.

A summary is given below reflecting bridge type/material on the state highway network:

In-situ concrete:	35%
Precast concrete:	18%
Culverts:	34%
Steel:	12%

The rest is made up of masonry, timber and other bridges. It is clear that at present, concrete (in-situ/precast/prestressed) is the dominant material used for bridges and culverts. Whilst this paper deals with bridge trends, it is necessary to also take into account concrete used in other associated structures such as retaining walls and tunnels.

In terms of age profile, it is interesting to note that the average age of the bridge stock is approximately 50 years. While substantial investment in bridges took place during the period 1950 to 1980 there are more than 150 bridges on the network older than 80 years.

Bridges and Structures Manager, New Zealand Transport Agency

Historical Overview

The use of concrete in bridges is strongly connected to the development of the concrete industry in New Zealand. Kiwis have a history of embracing new ideas and technology, and from the early days, engineers were not scared to make use of reinforced and prestressed concrete.

The early history of the use of concrete bridges in New Zealand is well documented in a number of publications, most notably *Bridging the Gap – Early bridges in New Zealand 1830-1939, Geoffrey Thornton*.[1] The development in bridge engineering through the Ministry of Works Department is evident in many structures still in service today. This overview highlights a few notable historical achievements and is not intended to be a comprehensive. Information supplied by Paul Wymer is gratefully acknowledged.[2]

The George Street Bridge in Dunedin, completed in 1903, is thought to have been the first reinforced concrete arch bridge constructed in New Zealand (Figure 1).

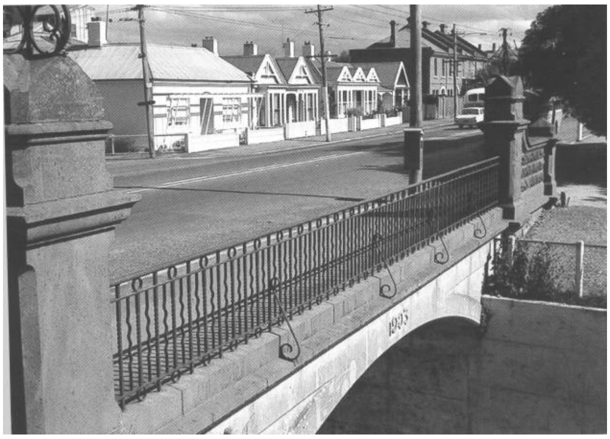

Figure 1: George St Bridge, Dunedin

The first concrete bridges on main roads in New Zealand appeared in the 1920's. An example of the use of concrete was "through truss" concrete bridge over the Opihi River on State Highway 1, which was demolished in 1978.

Grafton Bridge in Auckland (Figure 2) was started in 1907 and when it was completed in 1910 it was the longest (97.6m) reinforced concrete arch span bridge in the world!

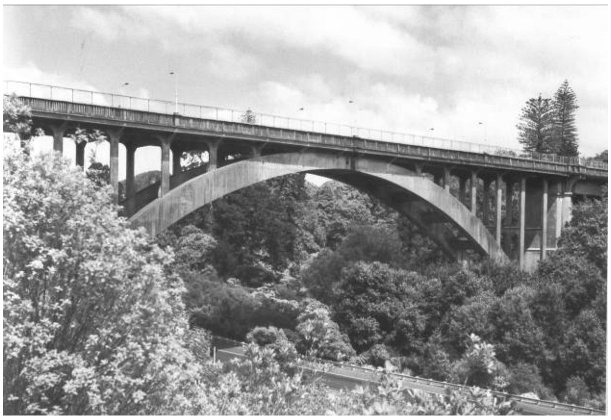

Figure 2: Grafton Bridge, Auckland

In the 1930's, standard, simply supported reinforced concrete T-beam bridges up to 12m spas became very common. Construction of these bridges continued to the late 1940's and given that they were designed for traffic loads much less than current design loading, they continue to preform well.

In the late 1940's and 1950's refinements introduced to reinforced concrete designs with continuous T-beam spans and haunched slab bridges. Prestressed concrete was introduced to New Zealand in early 1950 and after 10 years established itself as one of the most versatile bridge engineering materials. The Ministry of Works included a section on prestressed concrete in the Bridge Manual in 1956.

There are many examples of prestressed concrete bridges. The Hutt Estuary Bridge (1954) was the first major prestressed concrete bridge designed and constructed in New Zealand (Figure 3).

Figure 3: Hutt Estuary Bridge

The Wanganui Motorway Bridge, completed in 1961, was the first prestressed concrete box girder structure in New Zealand.

In the late 1960's- early 1970's a number of large motorway projects started in both Wellington and Auckland. The Thorndon Overbridge project in Wellington remains one of the largest undertakings involving a prestressed concrete roading structure ever built in New Zealand (Figure 4).

Figure 4: Thorndon Overbridge

In Auckland, a number of large structures were being constructed. The Newmarket Viaduct (1965) designed as a continuous prestressed concrete box-girder was only one of a number of structures constructed during this era. Construction of Central Motorway Junction commenced in 1970.

Another first for New Zealand was the construction of the Wellington Ngauranga 'flyover' bridges in the mid 1980's. The twin-curved bridges were the first use of the incremental launching method in Australasia (Figure 5).

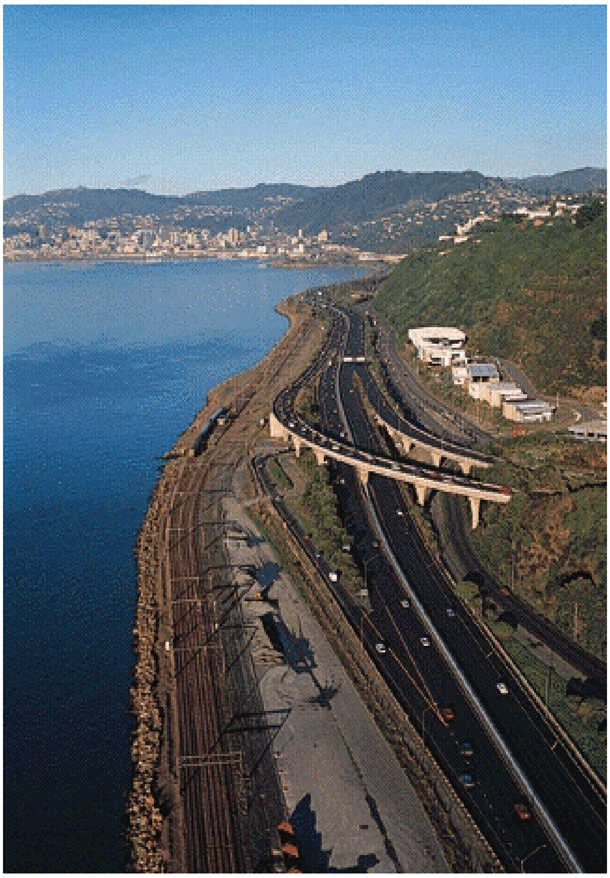

Figure 5: Ngauranga Flyover Bridges

Since 1990 a number of iconic state highway projects have been completed. With an increased focus on environmental and community impact, projects are becoming more complex as designers and constructors are required to produce sustainable, environmentally friendly and cost-effective solutions. In many instances, concrete solutions have delivered quality outcomes.

Completed in the late 1990's, the Otira Viaduct (Figure 7) and Candy's Bend (Figure 6) projects stand out as examples of the use of concrete to produce spectacular results.

Figure 6: Candy's Bend

Figure 7: Otira Viaduct

The Current Environment

To understand where concrete fits in it is important to consider the current and future drivers for infrastructure development. Concrete will be competing for a place in an increasingly complex environment.

Over the last 10 years there has been a dramatic increase in expenditure on roading projects. A large proportion of this increased investment has gone into the upgrading of the Auckland roading and motorway infrastructure. Whilst additional funds have also been provided for upgrading of the rail infrastructure, this paper focuses only on roading.

The pressure on value-for-money solutions has not changed over the last 50 years. The following quote is taken from a paper *Trends in Highway Bridging*[3], published in 1961. *"Design of the structure is closely associated with economics. This can not be over-emphazised. It has been particularly important in New Zealand in recent years when overseas expenditure has been under critical examination. With important structures, it is Ministry of Works policy to consider impartially all alternatives, checking total cost, amount if overseas expenditure and construction difficulties."*

The essence of the statement above remains valid. What has changed though is an increased focus on the environment and sustainability. Over the last 10 years, the impact of the Resource Management Act has resulted in the delivery of projects taking into consideration not only sensitive environments, but in the case of urban areas, the wellbeing of the local communities.

From an asset owner perspective, lowest cost options are not good enough. Whole-of-life principles are critical in delivering structures which will last a minium of 100 years and which will require minimum ongoing maintenance. The increased focus on durability is a challenge for all suppliers of materials and it becomes increasingly important to demonstrate sustainability of the product.

There are numerous examples of projects which have successfully delivered value-for-money solutions in sensitive environments. The introduction of Alliance procurement models has created the necessary contractual environment to successfully deliver major projects.

The following examples illustrate what some of the requirements are in order to achieve consent to deliver major infrastructure projects in urban and rural situations.

Northern Motorway Extension (ALPURT B2)

The project, 30km north of Auckland, involves the construction of 7.5km of dual lane motorway traversing a series of ridges and gullies, with a combination of viaducts (Figure 8), tunnels and earthworks. The project is being delivered by the Northern Gateway Alliance. In this model all parties, including the client take collective responsibility for delivering the project in accordance with the project vision – *to create a northern gateway that is a visual showcase of environmental and engineering excellence*.

Figure 8: Waiwera Viaduct

The Otanerua Valley is a heavily vegetated area of kauri and podocarp forest, mixed with manuka gumland – a prime habitat for native and endangered flora and fauna. Resident species include the semi-flightless fernbird, north island robin, green and forest native geckos and at least seven species of native freshwater fish. The key focus for the NGA was to preserve the ecological integrity of the area. This meant leaving the absolute minimum footprint on the ground, which in turn determined the need for a long-span bridge (Figure 9).

Figure 9: Otanerua Eco-Viaduct

Concrete has played an important part in delivering this complex project. The project team made use of pulverised-fly ash in the concrete mix, which is a waste material from the Huntly power station. Health monitoring was required during construction and the use of precast concrete elements made sense when it came to ensuring protection of the biodiversity the waterways.

The Johnstone's Hill tunnels eliminated the need for large-scale cutting into the environment Figure 11) and provided concrete mix design challenges in terms of construction of the concrete linings as well as protection of the structure against potential fire damage (Figure 10).

Figure 10: Johnstone's Hill Tunnel

Figure 11: Johnstone's Hill Tunnel Portal

In many ways this project has set the standard against which future projects will be measured. This is the environment in which concrete as well as other materials have to deliver value.

Central Motorway Junction

In 2001 Transit embarked on a series of major projects to address connectivity and congestion issues in Auckland. The initial objective was to connect existing motorway networks with the central business district and port, reducing congestion by separating through and local traffic. Delivery was undertaken through the Freeflow Alliance and what started out as the Grafton Gully Project turned into a wider Central Motorway Stage project.

The alliance embraced the vision of leaving a legacy through delivering sustainable urban design; centred on the project structures and their place in the landscape. According to Freeflow, "*Concrete was selected as the preferred material for the structures because of its ability to accept urban design without incurring a significant cost premium.*"

Figure 12: Typical precast Tee Roff application

The alliance took up the challenge to make use of all structural components to demonstrate and highlight the diverse application of the material. This would require a far greater focus on superior workmanship, innovation and attention to detail.

Figure 13: Innovative and elegant supports

Underpinning the "legacy" vision was the team's goal of paying respect to the area's rich history and incorporating this into an integrated urban design.

All of this could not have been achieved in isolation and ultimately meaningful relationships and wide consultation with stakeholders ensured collective buy-in and acceptance of a benchmark infrastructure project.

Figure 14: Pattens on retailing walls

The flexibility of concrete was demonstrated through the visible patterns, texture and forms produced. The invisible technical application of self compacting concrete in confined spaces made it possible to undertake difficult strengthening of Khyber Pass Viaduct and minimising traffic disruption.

In the same way that Alpurt set new benchmark standards for rural infrastructure, this project has set the benchmark for urban design.

Figure 15: Artwork

In the context of this paper, a detailed description of the project is not practical. However, given that a picture is worth a thousand words, a selection of photos is included.

The Future

History shows that the New Zealand engineering industry is able to embrace new ideas and technology and generate innovative solutions to new challenges. A very important element of the success of the concrete industry, is the value of a "*cohesive and motivated group of passionate people*"[2]. This will remain a key ingredient to face the bridge challenges of the future.

Rather than trying to predict future trends in bridging, understanding the future environment in which bridge solutions will have to be delivered is critical. The examples presented in this paper illustrate a number of important factors.

Funding pressures will remain and projects will be judged on the delivery of value-for-money outcomes.

The importance of climate change and sustainability will increase. While whole-of-life costs will remain crucial in selecting solutions, the suppliers of materials will have to include carbon costs as part of total costs of production and manufacturing of materials.

There will be an increased focus on durability and the need to minimise maintenance of bridges. It is becoming increasingly difficult to do maintenance under traffic. Products and materials will be required to deliver far greater performance than at present.

Furthermore, we face the challenge of upgrading and retrofitting a large number of existing aging bridges to ensure performance to future levels of service. Productivity trials of heavier trucks are already underway, seismic retrofitting is required due to better understanding of seismic risks, scour retrofitting of bridges will be required due to climate change effects.

The delivery of infrastructure projects in rural or urban environments will require increased sensitivity to the needs of communities they will ultimately serve. This will require more than just technical skills but an increased ability to engage with a wide range of people and professionals. The focus on integrated, multi-modal transport systems will provide new challenges for designers, contractors and suppliers.

In order to embrace the future it will be critical that research and development in the area of bridge engineering be undertaken. The success story of bridge engineering in New Zealand, and for that matter the concrete industry, was dependent on a vibrant and active research programme. During the last 10 to 15 years research in bridging has decreased significantly and there is a real need to establish an effective and focused research programme. Available funding for research has been very limited and difficult to secure. In order to ensure that effective research is undertaken, the broader engineering industry, including, major asset owners, universities, suppliers and practitioners will need to get together and develop a sustainable programme of focused research.

Conclusion

In order to understand the future trends in bridging and where concrete fits in, this paper provides a brief historical outline of the development of bridge engineering in New Zealand. It identifies that the future environment for the delivery of infrastructure projects will require increased awareness of the environment and the well-being of communities. Concrete, like other materials will have to demonstrate overall benefits against a more complex framework of carbon footprint costs. The ability of concrete to provide a holistic solution to increasingly complex problems will ensure that it fits into the future.

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