AN INGLIS PORTABLE BRIDGE SURVIVOR

Paul Mahoney[1] and Kate Zwartz[2]
[1] Department of Conservation, Head Office, Wellington; pmahoney@doc.govt.nz
[2] Department of Conservation, Head Office, Wellington; kzwartz@doc.govt.nz

Abstract
This paper considers a significant early design of portable bridge, the Inglis Bridge. Portable bridges play a vital role reinstating crossings over waterways when bridges are destroyed by events such as flood, earthquake or warfare. The Inglis Bridge deserves special consideration in 2014, as it was developed by Charles Inglis for the British Army in World War 1 which started a century ago. The Inglis Bridge played a key role in 1918, supporting the advance of Allied forces that led to the end of World War One. An Inglis Bridge recently discovered in New Zealand is one of the last of its type in the world which remains in use. This paper looks at the war history of the bridge, the designer, the design concept, and the surviving examples. The New Zealand survivor deserves heritage recognition as an example of significant WW1 military engineering.

1. Introduction

Addressing the current World War 1 (WW1) commemoration theme, this paper considers an aspect of WWI bridging, the Inglis Bridges. It has been produced at short notice, following the rediscovery and identification of an Inglis Bridge in New Zealand a few weeks before the deadline for papers.

The common image of WW1 is of trench warfare, and tunnelling through muddy fields. However, portable bridging played a significant role in the ability of the Allied Forces to advance rapidly into territory vacated and systematically destroyed by the retreating Axis Forces.

The Inglis Bridge is a Warren truss bridge constructed of standardised steel components. The components are assembled into modules 3.66 metre (12 feet) long. Inglis Bridges could be built to any length by joining multiple modules. However, the allowable load decreased for longer spans. The Inglis design is significant as the world's first portable mass-produced bridge. Inglis bridges were used in France, Italy, and Palestine during WW1. An example has also been identified in Germany, on the Dutch border.

2. Charles Edward Inglis (1875—1952) - Chronology

The Inglis Bridge, invented by Charles Inglis, predated the Bailey Bridge as a portable military bridge design. Inglis developed the portable bridge for the Royal Engineers, while he was an instructor at the Royal School of Military Engineering.

1875	Birth in UK
1895	Scholarship to Kings College, Cambridge
1899	Designing steel railway bridges as apprentice civil engineer
1901	Accepted as associate member of ICE
1901	Commences academic career at Kings College, specialising in the study of vibrations
1913	First version of Inglis Bridge developed for Cambridge University Officer Training Corps
1913	Published the first serious modern work on the fracturing of materials
1916	In charge of bridge design & supply, War Office
1919	OBE for war service
1919	Appointed head of the Cambridge University Engineering Department. Under Inglis' supervision the department became one of the best engineering schools in the world.
1923	Elected an ICE member
1924	Awarded ICE Telford Medal
1928	Elected ICE council member
1942	President of ICE
1943	Retired as Department Head, Cambridge
1945	Knighted
1952	Death: obituaries described him as the greatest teacher of engineering of his time.

3. Development of the Inglis Bridge

The Inglis Bridge was specifically developed for the British Army during WW1. The bridge was design to enable troops, artillery and tanks to continue to advance, and to be sustained with supplies.

Components were manufactured from 1916 onwards and taken to the Western Front. This type of bridge played a strategically important role in 1918, enabling the Allies' sustained momentum of the advance which ended the war. Speed was vital in preventing the Germans from regrouping and forming a new front line.

TUESDAY, FEB. 23, 1943

War News and Views

HIGH-SPEED BRIDGE CONSTRUCTION BY BRITISH ARMY ENGINEERS: This elaborate network of steel girders represents the construction of an Inglis Bridge by the Gan v method, by Royal Engineers at a School of Military Engineering.

Figure 1: Bay of Plenty Beacon, Volume 6, Issue 50, 23 February 1943, Page 3

In retreat, the Germans blew up existing bridges to stop the Allied advance. The stock of Inglis Bridges had been specifically designed to meet this challenge. Bridges could be customised for any situation, and quickly assembled from components by a team of engineers using a cantilevered gantry, made of the same components, and supported on rails.

4. Inglis Pyramid Infantry Bridge

Inglis first designed his 'Light Type' portable bridge in 1913 as a triangular section with Warren trusses as the two sides, and girder transoms supporting a narrow walkway for infantry. All the truss members were made of tubular sections for lightness of transport. The central top chord and the lower chords were shorter than the diagonal members.

Two of these triangular sections could be placed up to 4.8 metres apart, with a wider deck, for vehicles up to three tons, supported between them. This was called the 'Inglis Light Type Double Span'.

The Inglis Heavy Type Bridge was designed in 1915, in response to a request from the British Expeditionary Force for use in France. However, its triangular profile restricted the height of vehicles able to pass between the inclined trusses.

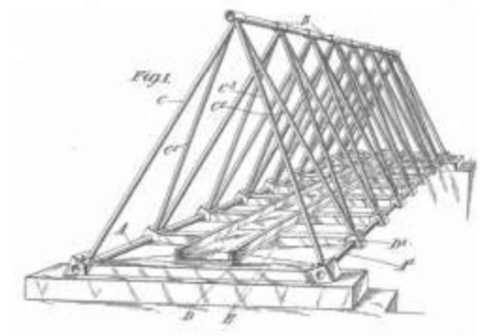

Figure 2: Patent drawing of Inglis Pyramid Bridge.

5. The Inglis Bridge Mark I, II, & III

As military vehicles became larger and heavier, military bridges had to evolve to cater for the growing live loads. Inglis maintained the use of steel tube members for the diagonals and top and bottom chords of his truss, but added steel girders between the top chords to make the trafficked area a more practical rectangular shape. The junctions were cast iron sockets which the tube pin ends were slotted into, with a flat face for connecting the transverse girders.

The bays were standardised to a 3.66 m (12 foot) length, and up to eight bays could be used in a single span. These were widely used in Europe in 1918, replacing road bridges destroyed by the retreating German Army.

Another significant use in 1918 was the Allenby Bridge across the Jordan River, connecting Jordan with the West Bank (now in Israel). It was replaced in the 1930s, with a larger steel truss structure. The current concrete bridge forms an important border crossing between Jordan and Israel.

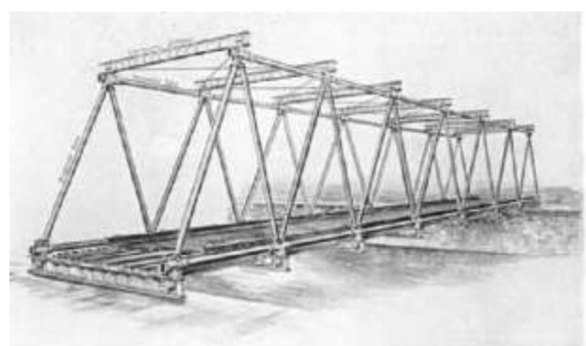

Figure 3: drawing of Inglis Mk II Bridge

The Mark II used stouter tubes, but a very similar design. Inglis made all the tubes 4.57 m (15 feet) long, to avoid confusion between different lengths of tubes.

Here is a field description from the record of the Canadian Engineers Corps: *Fortunately a new bridge, called the "Inglis Portable Military Bridge, Rectangular Type," had been invented by Captain*

Inglis, R.E., and was adopted by the British Army. This bridge was the Warren girder type and was composed of a number of identical bays, each twelve feet long, twelve feet high, and twelve feet wide. It was designed to carry a dead load of eighty-four tons distributed over a clear span of eighty-four feet.

Each part could be easily manhandled and the span could vary in multiples of twelve feet, ... *to suit the gap. The bridge was built on blocks in skeleton form with a counterbalance arm and jacked up on to a two-wheeled trolley. It was then pushed over the gap, the counterbalance removed, then jacked down on the abutment, and the decking laid.*

On the 28th of September, 1918, a bridge of this type was erected complete over the Canal du Nord at Marquion in twelve and a half hours actual working time under severe shell-fire. A party of approximately two hundred sappers was employed on the construction of the bridge with the necessary approaches and abutments. The span was one hundred and eight feet clear and the safe distributed load fifty-one tons.

The Mk II continued in the 1920s to be used in training, and developed into assault and floating bridges.

Figure 4: Building the Inglis Mk II Bridge over the Canal du Nord at Marquion, France, in 1918.

Increasing vehicle loads led to the development of the Inglis Mark III in the early 1940s, where the trusses were doubled or tripled, to raise the carrying capacity. At this stage, the top transverse members were removed to allow taller vehicle traffic. The lateral restraint to the trusses was replaced by inclined outriggers, bolted to short cantilevered extensions to the deck transoms.

The 1943 newspaper article in Figure 1 shows that the use of Mark III bridges for training continued well into World War 2 (WW2).

Figure 5: Inglis Mk II Bridge as a mobile bridge in WW2

6. Bridge at Simpsons Reserve

Figure 6: Entrance to of Simpsons Scenic Reserve with a vehicle coming off the Inglis Bridge

Simpsons Reserve Bridge is located 2 kilometres (km) north of Hunterville on State Highway 1, and then a further 2 km along Murimotu Road.

Simpson Scenic Reserve encompasses 38 hectares and protects an outstanding area of lowland podocarp forest that is a rare survivor of a vast forest burned off by early Pakeha settlers when they began establishing farms. The Reserve's public opening was celebrated in 1933 and included performance from the local Scots Pipe Band.

The bridge spans the Porewa Stream, a tributary of the Rangitikei River, whose confluence is east of Marton. Vehicle access to the reserve was initially a wooden beam bridge. The replacement steel Inglis Bridge was erected in 1985 because the condition of the wooden bridge had deteriorated. The Inglis Bridge was assembled by Project Employment Programme workers under instruction of the Rangitikei County Council, using components supplied by the Council. In 1995 management of the Inglis Bridge transferred to the Department of Conservation.

The history of the bridge parts prior to 1985 is not at present known.

Figure 7: Inglis Mk III Bridge in 2014

A possible earlier use of this road bridge was on State Highway 34, across the Rangitikei River at Vinegar Hill. The end span on the left of the Figure 8 looks very like an Inglis truss. This span was later replaced with another steel truss, before the old bridge was finally demolished in the mid-1970s. Tracing the history of a particular bridge is difficult because the modular Inglis concept allows interchange of components.


Figure 8: Rangitikei Bridge at Vinegar Hill from Scally, *Hunterville & District*, undated picture

It may be that when the Bailey Bridge superseded the Inglis as the popular modular military bridge, the British Army disposed of their stock of Inglis Bridge parts. Somehow they found their way to the Rangitikei County Council (and maybe other councils around New Zealand).

7. Technical Details

The beauty of the Warren truss lies in its simplicity. It is statically determinate, with no redundant members. The hollow pipe section, in our case a 110 mm ($4^{3}/_{8}$ inch) section for the main truss and 76 mm (3 inch) section for the lateral truss, is very strong in tension. The top chord members, which will always be in compression, are at risk of buckling if the length exceeds the critical length. This particular truss, probably a Mark III, has no lateral members between the trusses, but relies on the outrigger members to restrain the top chords from buckling.


Figure 9: Detail of top chord joint on Inglis Bridge 2014

The pipe members are connected with pin connections at cast iron rosette shaped nodes (Figure 9). The design of the main trusses avoids fiddly nuts and bolts, a characteristic shared by Bailey bridges. Instead, a 40 mm ($1^{1}/_{2}$ inch) pin fastens the ends of the chord into the rosette. This makes for quick assembly, and also minimises the number of small parts which can easily be lost.

The use of cast iron for the nodes is a reflection of the age of its invention. Cast iron is weak in tension, but strong in compression. The rosette allows up to six members to be connected without eccentricity. The member loads are maintained as pure tension or compression, without the bending moments often introduced in conventional truss structures. The cast rosettes would have been relatively heavy to carry by hand, but they are robust and interchangeable. The top chord rosettes have six available sockets and the bottom chord rosettes have four, with the base of the rosette bolted to the transom girders.

The crenellated collars on the ends of the pipe members are threaded connections of the hollow pipe onto the shaft that receives the pin. The collars would probably have remained attached to the chords during transport.

As shown in Figure 9, the two brackets below the collars allow the connection of the outrigger members. These appear to be fabricated out of heavy steel plate.

It is heartening to discover such a venerable example of military engineering still carrying vehicles in 2014. Its durability is testament to the versatile design by Charles Inglis, allowing repeated dismantling and erection using very simple techniques. The fact that the components probably lay in a Council yard for up to five decades, but were able to be quickly put into use, demonstrates the simplicity and longevity of the concept.

8. Conclusion

The Inglis Bridge was an important portable bridge design used in WW1. Charles Inglis, the designer, had a distinguished academic and military engineering career. Only a handful of examples of Inglis bridges are known to remain, in England, Wales, Canada, Germany, and Pakistan. The Simpson Reserve Bridge is one of the last to remain in vehicular use.

9. Acknowledgements

Much of the background history of Inglis and his portable bridges comes from three key websites on this topic: Wikipedia, the British Imperial War Museum, and Think Defence.

Jim Mestyanek, Senior Project Engineer of Manawatu District Council, assisted with the history of the road bridge at Vinegar Hill.

Richard Nester, of the Department of Conservation, was the first to identify that the Simpsons bridge had a heritage interest.

10. References

Simpsons Scenic Reserve, Department of Lands file, G04-316.

Wikipedia, "Charles Inglis (engineer)." Accessed 3 September 2014. URL: http://en.wikipedia.org/wiki/Charles_Inglis.

Think Defence, "The Inglis Bridge." Accessed 3 September 2014. URL: http://www.thinkdefence.co.uk/2014/inglis-bridge/.

Bay of Plenty Beacon, 23 February 1943, 3. Available from URL: www.paperspast.natlib.govt.nz.

Scally, Mrs. Jack. *Mrs Jack Scally's Hunterville & District: Where the Friendly Neighbour Cares*. Hunterville: Mrs Jack Scally, 1980.

Hopkins, H.J. *A Span of Bridges, An Illustrated History.* Newton Abbot, UK: David & Charles, 1970.