Aluminium: Flexible and Light

Towards Sustainable Cities

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Chapter 5 *Light and Strong* includes a brief history of the use of aluminium in the assembly of road, rail and pedestrian footbridges. Although this parallels the use of aluminium in architecture, uptake is later and arguably more variable. However there are many more aluminium bridges than suggested by numerous contemporary commentators and academics, as demonstrated in this chapter. The first aluminium bridge deck was installed on Smithfield Street Bridge in Pittsburgh, USA in 1933, almost 40 years later the first use of aluminium in architecture – the ceiling of Church of St Edmund, King and Martyr, Fenny Bentley, Ashbourne, Derbyshire, England in 1895. The earliest extant all-aluminium bridge is the Arvida road bridge, 1950, spanning the Saguenay River at Saguenay–Lac-Saint-Jean in Québec with primary arch spanning 88.4m. Chapter 5 *Light and Strong* includes many examples of more recent and contemporary applications of aluminium alloys in the assembly of bridges from the elegance of the Bridge of Aspiration by WilkinsonEyre, 2003, to the design and fabrication of a rapidly deployable bridge for the Canadian Army by MAADI Group in 2016. The first decades of the twenty-first century reveals a renaissance in all-aluminium

Fig 1.12 Arvida Bridge spanning the Saguenay River at Saguenay–Lac-Saint-Jean in Québec, 1950

Fig 1.13 Bridge of Aspiration, Covent Garden, London, England, architect WilkinsonEyre, 2003

Fig 1.14 Deployable Military Bridge, Canada, designed and fabricated by MAADI Group, 2016

Fig 2.3 The Boeing 247D is regarded as the first 2000 series aluminium alloy semi-monocoque airliner, 1933

Copper is the primary element added to 2000 series alloys, but typically not more than 5 per cent. 2000 series alloys can be strengthened by heat-treating, which is discussed below. This alloy series provides toughness and high strength, however the presence of copper limits its corrosion resistance and therefore components should either be protected by a coating system or cladding with a high purity aluminium alloy. 2024 alloy with 3.8–4.9 per cent copper is often used in aircraft assemblies. The first aircraft built from this series of aluminium alloys was the Boeing 247D, introduced in 1933.[7]

Manganese is the primary element added to 3000 series alloys, with typically between 0.3 and 1.5 per cent, and magnesium is also used between 0.2 to 8 per cent, depending on the specific alloy. 3000 series alloys offer reasonable strength and are readily worked. The body of an aluminium drinks can is typically formed from 3004 alloy and the ends are made from 5182 alloy. Incidentally, Coca-Cola was first produced in 1886, the same year that Hall–Héroult process was effectively simultaneously invented in the USA by Charles Martin Hall and in France by Paul Héroult.

Silicon is the primary element added In 4000 series alloys, which lowers the melting point of the aluminium. In 4043 alloy, between 4.5 and 6 per cent silicone is used. Typically produced as a wire 4043 is used for welding 6000 series components in automotive and structural applications.

Fig 2.4 An aluminium Coke can, with 3004 aluminium alloy deep drawn body and 5182 alloy cap

Fig 2.5 Audi's welded aluminium space frame of the Audi A8

Fig 2.6 Welded aluminium pedestrian bridge by MAADI Group

Yanchep Bridge, Australia: Designer and Fabricator, Peter Maier Leichtbau GmbH, 2009

In the western Australian city of Wanneroo, the all aluminium Yanchep pedestrian bridge has been installed to protect the biodiversity of the beach dunes in an area of rapid urbanisation north of Perth. This bridge is 143m long and 2.5m wide, the aluminium is finished with silver anodising. It was fabricated by Peter Maier Leichtbau in Singen, Germany and installed by Landmark Products of Deception Bay, Queensland, Australia. Aluminium was primarily selected on the basis it would be maintenance free even in a costal environment and that the total cost of ownership would prove beneficial to the owner, the local authority, as is confirmed by the Canadian research cited on pages 438–439. However, the height of the bridge above the dunes has proved controversial with the residents of Wanneroo. In 2012, the State of Western Australia Administrative Tribunal ruled the City should lower the boardwalk from 5.5m at its highest point to 2.1m above the natural ground level. This work to lower and realign this bridge was carried out by R.W.E Robinson and Sons during 2014.[7] Yanchep Bridge is now a long term environmental and community asset on the coastline of Western Australia.

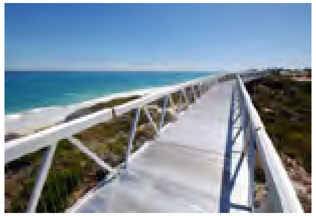

Fig 5.95 Aluminium deck of Yanchep Bridge, designed and fabricated by Peter Maier Leichtbau

Fig 5.96 All aluminium Yanchep Bridge, designed and fabricated by Peter Maier Leichtbau

Equestrian Park Bridge, Blainville, Québec: Designer and Fabricator, MAADI Group, 2012

This bridge was designed for use by pedestrians, horses and riders. It is an 18m single span all aluminium bridge with a clear width of 3m and a self-weight of almost 7 tonnes or 380 kg/m. It was fully prefabricated in Boucherville, Québec, by MAADI Group. It is an open truss with a gently curved profile fabricated from MIG welded square hollow section (SHS) aluminium extrusions in two sizes, 125mm and 150mm. This mill finished single span aluminium bridge rests on simple concrete abutments. It has an Ipe hardwood deck and kick plates with aluminium guardrails. The hardwood Ipe is often described as Brazilian Walnut.

Fig 5.97 Equestrian Park Bridge, an aluminium bridge with a hardwood deck, designed and fabricated by MAADI Group

Fig 5.98 Equestrian Park Bridge, Blainville, Québec

Oil Rig Pedestrian Bridge: Designer and Fabricator, MAADI Group, 2014

This all aluminium pedestrian bridge was designed and fabricated by MAADI Group. It spans 46.3m between two platforms and is a walk through box truss with a clear width of 1.2m. It has an aluminium grip span® deck, aluminium kick plates and guardrails. The self-weight of the bridge is only 13.7tonnes or 296 kg/m. The bridge is fabricated from welded 150mm and 200mm SHS aluminium extrusions, using a combination 5083-H321 and 6061-T6 alloys, all left mill finish. It will require very little maintenance, even in an exposed maritime location. Both MIG and TIG welding was used to fabricate this bridge. It was fully prefabricated in Boucherville, Québec, shipped to site in five 12.2m (40') shipping containers and installed as a single span element. MAADI Group produce a diversity of aluminium pedestrian bridges, typically based on welded fabrication. However, it has also developed weld free prefabricated aluminium bridges.

Fig 5.100 [right] 46.3m Oil Rig Pedestrian Bridge being craned into position, published with permission of the oil extraction company

Fig 5.99 46.3m Oil Rig Pedestrian Bridge linking two offshore platforms, published with permission of the oil extraction company

Deployable Military Bridge, Canada: Designer and Fabricator, MAADI Group, 2016

This prototype of a rapidly deployable military bridge for the Canadian armed forces has been designed and fabricated by MAADI Group.[8] Designed for pedestrian and light vehicles to over come obstacles in the battlefield, such as rivers and ravines. This bridge has an overall length of 18.3m to be able to span a maximum 16m, with a clear width of 1.5m. Eight to ten people can deploy the bridge in 80 minutes. The quick fit prefabricated assembly of aluminium components is locked off with stainless steel bolts, with reusable stainless steel split pins on stainless steel wire tethers. This military bridge is a development of MAADI Group's patented weld free civic pedestrian bridge range Make-A-Bridge®. It has a capability of being crossed by 127 soldiers if their weight is well distributed. The vertical frequency of this bridge is 5.8Hz, significantly greater than 3Hz required by AASHTO LRFD Code for the Design of Pedestrian Bridges (US 2009). The guidance to this code issued by Association of State Highway and Transport officials refers to the problems on the Millennium Bridge in London and states that the lateral frequency needs to be above 1.3Hz.[9] The bridge can also carry small vehicles, such as snowmobiles and quad bikes up to 500kg.[10]

Fig 5.101 A prototype of a rapidly deployable military bridge with a maximum span of 16m

The bridge is built up from modular aluminium components and the key detail of the trusses are cast aluminium tripods. The trusses are preassembled into four sections and then bolted together. The aluminium deck panels pivots on one tubular cross beam and clips onto the next one, the deck panels also interlock to help secure the complete bridge deck. Once the bridge has been assembled, typically it is launched into position from one bank. As soon as it is correctly located, each end of the bridge is jacked up and bearings are fixed in place. With training, all this can be achieved in 80 minutes, less time than a feature film. The bridge is operational and the obstacle has been overcome. The military version of MAADI Group Make-A-Bridge® is an exemplar of Design for Assembly (DfA) and Design for Disassembly (DfD) as discussed in *Aluminium Recyclability and Recycling*.[11] It is also an

Fig 5.102 Rapidly deployable military bridge on test by the Canadian Army

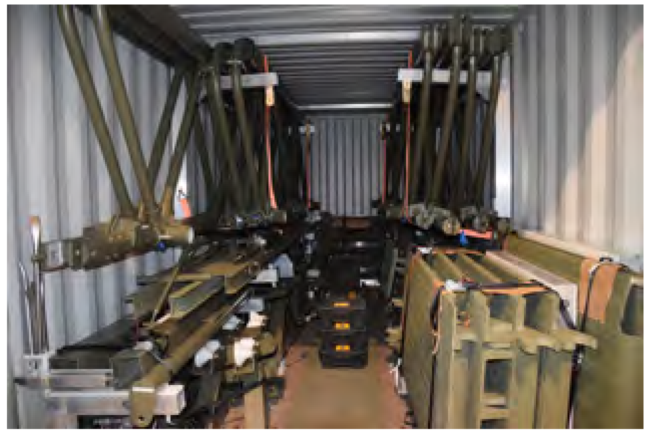

Fig 5.103 Inside a 6.1m container all the components of the prototype bridge

excellent example of the versatility of aluminium extrusions and casting, providing flexibility in design and realisation Alexandre de la Chevrotière, CEO of MAADI Group, considers that 'this product would not be possible without capability of aluminium extrusions'.[12]

The aluminium extrusions of the prototype rapidly deployable military bridge were fabricated from 6005A-T6 and 6061-T6 alloys, with the nodes cast in AA357-T6 alloy. The stainless steel bolts are coated Xylan® 1424 a fluroployemer that contains PTFE, providing corrosion protection and friction resistance. The bridge is polyester powder coated in Canadian Army Dark Oliver Green. The complete bridge only weighs 1970 kg or 69.9 kg/m^2, a direct equivalent to the average weight of a Canadian citizen per m^2, and at least half the dead weight of an equivalent steel bridge.[13]

Fig 5.105 Military personel using a rapidly deployable military bridge

Fig 5.104 A rapidly deployable bridge can carry small vehicles, such as snowmobiles and quad bikes up to 500kg

While this book is being produced, the 5e Combat Engineer Regiment of the Canadian Army is testing the prototype for sixth months including airlifting the bridge into remote locations by helicopter. This testing started on 18 January 2016. Prior to this, the prototype bridge was load and vibration tested by the Engineering Faculty of the University of Waterloo. This prototype is part of a research project led by MAADI Group, *Make-A-Bridge®*, funded by Centre québécois de recherche et de développement de l'aluminium (CQRDA), Qubec Aluminium Research Center, with the *Programme d'Innovation Construire au Canada* (PICC), *the Build in Canada Innovation Program* (BCIP) and *Programme d'aide à la recherche industrielle* (PARI), *Industrial Research Assistance Program* (IRAP).[14]

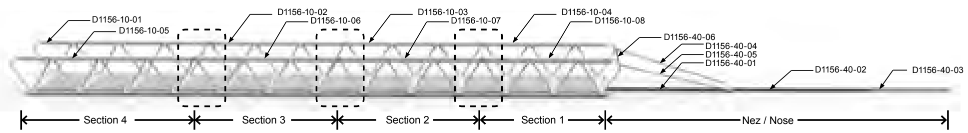

Fig 5.106 Elevation of the Deployable Military Bridge indicating sectional compnents

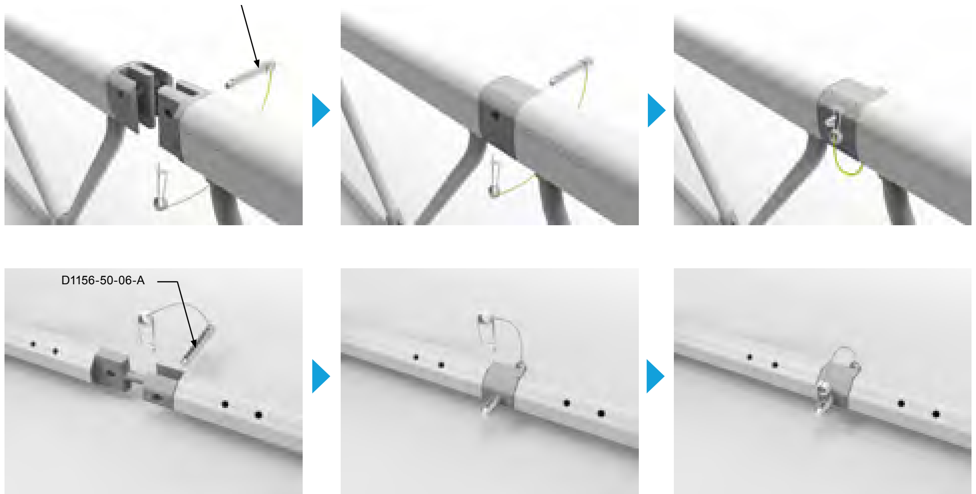

Fig 5.107 Section assembly of the Deployable Military Bridge

MAADI Group's Deployable Military Bridge is a development of its kit of parts approach to weld free civic footbridges, as demonstrated by its patented Make-A-Bridge® range. A silver anodised pedestrian footbridge from this range will be installed in Calgary, Alberta, Canada, during the spring of 2016.[15]

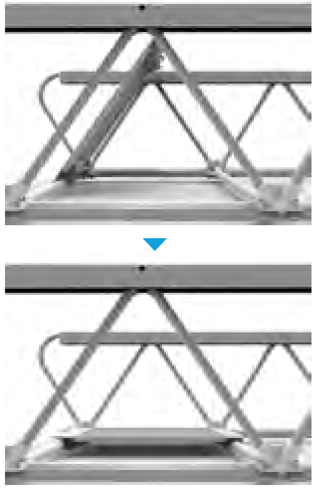

Fig 5.108 Decking assembly of the Deployable Military Bridge

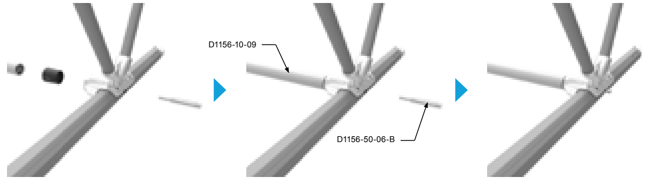

Fig 5.109 Truss assembly of the Deployable Military Bridge

Fig 5.110 A silver anodised Make-A-Bridge™ pedestrian footbridge at MAADI Groups factory awaiting installation in Calgary, Alberta

Aluminium Staircase in Parc de la Rivière-Beauport, Québec, Canada: Designer and Fabricator, MAADI Group, 2015

Descending 15m (50′) from the street into the park, this staircase, with its welded aluminium structure and timber deck was designed and fabricated by MAADI Group for the local government, Ville de Québec, who are the custodians of Parc de la Rivière-Beauport. This park is located around the river Beauport, which became a focus for the development of industry in Québec city in the eighteenth century. Traces of this early industry can still be found in the otherwise beautiful urban park. Aluminium was selected for the new staircase primarily for its durability and the minimal maintenance required beyond annual inspections. A combination of alloys were used in the assembly of this staircase 6061-T6, 3003-H14. A range of extruded sections were deployed including 50, 75 and 100mm SHS, 40 × 100 RHS and 40 × 40 L-sections, combined with 3mm plate and expanded mesh for the balustrade. All mill finish aluminium. Connections were predominately MIG welded.

Fig 5.183 Aluminium Staircase descending 15m into Parc de la Rivière-Beauport

Fig 5.184 Timber treads and landing of the Aluminium Staircase in Parc de la Rivière-Beauport

Fig 5.185 A safe low maintenance route through the trees of Parc de la Rivière-Beauport

Aluminium Bridges

The primary advantages of using aluminium in the construction of bridges are, it is:

- Lightweight, with a high strength to weight ratio, this is particularly important in opening bridges and the refurbishment of existing bridges.
- Durable, offering long-life with low maintenance, subject to appropriate alloy selection, detailing and finishing.
- Flexible in fabrication from the extrusion of large sections and highly developed welding techniques including friction stir welding.
- Rapidly installed, using large prefabricated components that can be readily transported and lifted in to place.

Furthermore, the total cost of ownership of all aluminium bridges can be beneficial. The case studies set out above evidence the benefits of specifying aluminium bridges in many parts of the world, with extant examples dating back over 65 years.









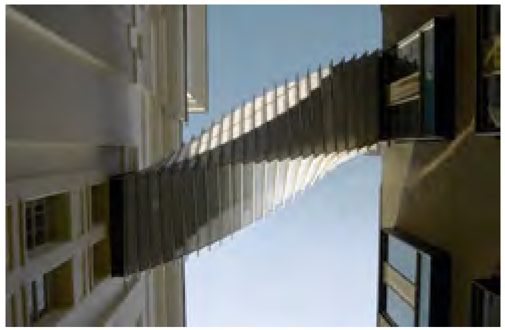


Fig 5.198 Aluminium Bridges from Arvida, 1950, via the Millennium, in London to 2016