

The Construction of the Montmorency Forest GMAW-Welded Aluminium Deck on Steel Girders Bridge [†]

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Abstract

WSP was responsible for the design and detailing of Canada's first GMAW-welded aluminium deck on steel girders bridge for Université Laval. The firm developed welded aluminium panels connected by blind bolts and supported by three steel girders. The 15 m by 8 m structure was fully preassembled for quick onsite installation and designed to support both highway and forest truck loads. Amid post-pandemic procurement and welding challenges, the fabricator, designer, and owner worked closely together throughout construction. While the project experienced delays, quality was prioritised, culminating in a pioneering structure for Canada. This paper explores the construction process, including trials to optimise the 28 mm deep GMAW welds. The fabricator developed an innovative approach for positioning removable backing bars within 10-metre-long hollow extrusions. Non-destructive testing was essential due to the absence of detailed acceptance criteria in current standards. Post-welding deformation control was achieved through several iterations and the post-heating process. The bolting plate method effectively joined hollow aluminium components, and custom features were incorporated to accommodate Université Laval's research instrumentation.

Keywords: aluminum; deck; ABC; welding; GMAW; extrusion; NDT; innovation

1. Introduction

Bridge construction in Canada is shifting toward sustainable materials, notably aluminium, due to increasing traffic demands, de-icing salt exposure, and a greater focus on local resources—a trend reinforced by the COVID-19 pandemic. This paper highlights the Montmorency Forest bridge shown in Figure 1a, the first Canadian example of a GMAW-welded aluminium deck on steel girders, commissioned by Université Laval. The 15 × 8 m single-span bridge consists of three steel girders and four prefabricated aluminium panels, joined by GMAW and blind bolts. Assembled in a factory and quickly installed on-site following accelerated bridge construction (ABC) principles, the structure also incorporates steel barriers through new anchoring methods and aligns with MTDM standards for future road network integration.

Building on the 2015 Saint-Ambroise bridge [1], which used friction stir welding, this project advanced research into conventional GMAW for aluminium decks. As opposed to FSW, GMAW does not have panel size limitation and is therefore necessary to obtain large components. Supported by MTMD and SQDA funding, Université Laval's team initially



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achieved successful fabrication and testing of full-scale GAMW deck panels. The last step of this research project was to build a full-scale demonstration prototype whose design has been reported in previous publications [2,3].

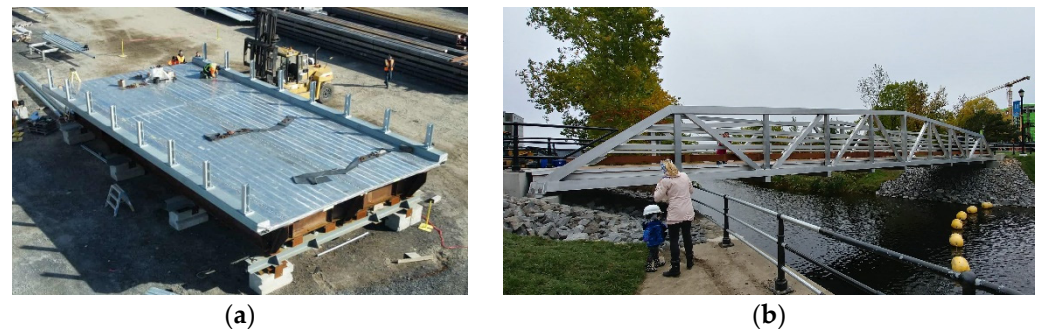


Figure 1. (a) Montmorency Forest bridge preassembly; (b) Wellington pedestrian bridges [4].

Designers and fabricators successfully delivered the Hall and Wellington aluminium pedestrian bridges in 2018 [4] presented in Figure 1b. The same organisations collaborated again throughout the fabrication activities of the Montmorency Forest bridge. While initial design specified alloy ASTM B221 6005A-T61 [5] for the deck extrusions, the extruder's proposition for EN AW-6005A-T6 [6] was retained.

This paper explores the welding procedures, non-destructive testing, post-deformation control and the anchoring of the barrier through the bolting plate method.

2. GMAW Welding Procedures

Considering the innovative nature of the project, the first months of the fabrication process were dedicated to refining the welding procedure and determining the chamfer geometry prior to ordering the aluminium extrusions. To support these iterations, ULaval provided extrusions similar to those intended for the project. The extrusions featured a 28 mm top skin and an 8 mm bottom skin, both initially prepared with a 30° chamfer. The main initial challenge for the fabricator was achieving full penetration root welds without the use of permanent backing bars on extrusions measuring up to 10 m in length. Since copper backings are not permitted in the CSA standards, stainless steel, ceramic and anodized aluminium were the three materials considered for the temporary welding backings. Following preliminary testing, anodized aluminium proved to be the most effective option.

However, the manufacturer still had to find a method to allow the installation and removal of backing bars inside 10 m long hollow extrusions. The fabricator addressed this challenge by developing a temporary backing system consisting of a pressurised hose placed between two bent aluminium plates, as shown in Figure 2a. The grooved anodized aluminium round bar and flat bar were welded on the bent plates. After inserting the assembly inside the extrusions, compressed air was introduced into the hose, which forced the backings firmly against the roots of the joints. This system allowed consistent full penetration root welds to be achieved while still enabling easy removal of the backing system after welding.

Regarding the GMAW parameters and chamfer geometry, the main challenge was achieving consistent full penetration welds on the 28 mm thick top skin of the extrusions. Initial trials were conducted using a 1.2 mm ER5356 filler wire with 100% argon shielding gas on a 60° V-groove joint. Considering the length of the extrusions, the welding operation was mechanised, as shown on Figure 2b.

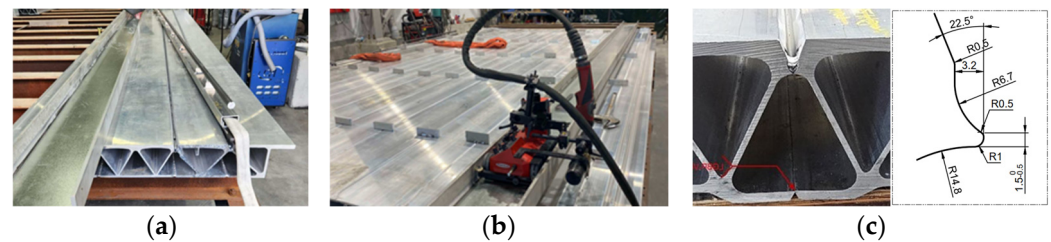


Figure 2. (a) Removable backing bar; (b) Mechanised GMAW; (c) 45° “J” chamfer geometry.

These initial parameters produced satisfactory root passes; however, between 16 and 18 weld passes were required to fill the 28 mm joint. In comparison, only three passes were required to complete the 8 mm joint on the opposite skin. This large difference in heat input generated significant distortion between the two skins of the extrusion.

To address this issue, both the chamfer geometry and the welding parameters were revised. The chamfer angle was reduced to 45° and modified to a J-groove configuration, as shown in Figure 2c, in order to decrease the number of weld passes required for the 28 mm joint. In addition, except for the root pass, the welding parameters were adjusted to better meet the quality requirements of the project.

While the reduced chamfer opening helped decrease the total number of weld passes, it created difficulties during the second and third passes. Due to the restricted access within the joint, these welds had to be deposited in a nearly vertical orientation, which resulted in a lack of fusion along the weld sidewalls. To resolve this issue, the filler wire diameter was increased to 1.6 mm ER5356 and the shielding gas was changed from 100% argon to a mixture of 50% argon and 50% helium. The addition of helium increased the arc energy and heat input, improving weld penetration and sidewall fusion within the constrained joint geometry. These modifications eliminated the lack of fusion observed during the second and third passes.

With the revised welding parameters and joint configuration, only seven weld passes were required to fill the 28 mm joint, compared with the initial 16–18 passes. Finally, no major difficulties were encountered when welding the 8 mm thick joint located on the bottom skin of the extrusions. According to the fabricator, this weld was relatively straightforward due to the reduced thickness of the joint.

3. Ultrasound Non-Destructive Testing

The design specifications required ultrasonic testing (UT) on 100% of the welds subjected to high stress variations and on 50% of the remaining welds. The GMAW welds on the 8 mm thick flat bottom skin presented a geometry that was favourable for UT inspection. However, the 28 mm deep groove welds located in the top skin presented several inspection challenges.

Due to the curved geometry of the extrusion beneath the root of the top skin welds, the interpretation of ultrasonic echoes near the bottom of the weld was difficult. During preliminary inspections performed on extrusion samples, the inspection team repeatedly observed a characteristic echo appearing near the weld root. After further investigation, this echo was identified as being generated by the internal geometry of the extrusion close to the welding root.

As illustrated in Figure 3a, discontinuities located at depths below approximately 20 mm appeared on the ultrasonic testing device before the geometry-related echo. In addition, because of the relatively low density of aluminium, significant discontinuities such as lack of fusion or cracks produced strong signal reflections, often exceeding 0 dB on the UT device.

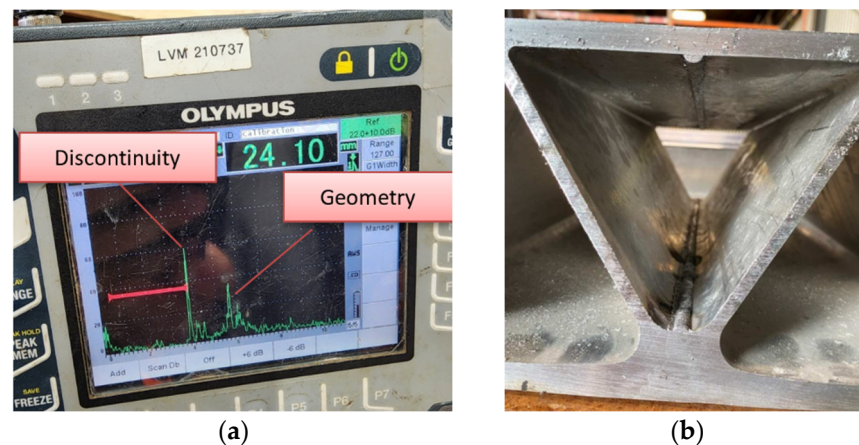


Figure 3. (a) UT device screen; (b) proper root penetration achieved.

The inspection of the weld root in the 28 mm deep groove welds was particularly challenging. The non-flat geometry of the extrusions made it very difficult, if not impossible, to clearly interpret the signal amplitude associated with potential discontinuities in this region. Consequently, UT was not used to assess the root penetration of these welds. Instead, after removal of the temporary backing bars, a camera was inserted inside the extrusion sections to visually inspect the weld root. Proper root penetration was identified by the presence of a continuous weld bead along the joint, as shown in Figure 3b.

Finally, due to the limited guidance provided in CSA W59.2—Welded Aluminium Construction [7]—which is the Canadian standard for welded aluminium structures, a specific ultrasonic testing procedure had to be developed for this project. Unlike its counterpart for steel structures, CSA W59—Welded Steel Construction [8]—CSA W59.2 does not provide rejection criteria based on reference signal levels expressed in decibels. Instead, the aluminium standard refers to CSA W59 for the classification of discontinuities according to the decibel values measured by the UT device.

Considering the significant difference in density and acoustic properties between steel and aluminium, the direct application of steel-based criteria can be restrictive for the inspection of aluminium welds. Therefore, in collaboration with UT specialists, project-specific rejection criteria were established. These criteria were validated by correlating UT indications with visual inspections performed after applying chemical agents to reveal welds aspect, as shown on Figure 4a. The calibration process of the UT device is shown in Figure 4b.

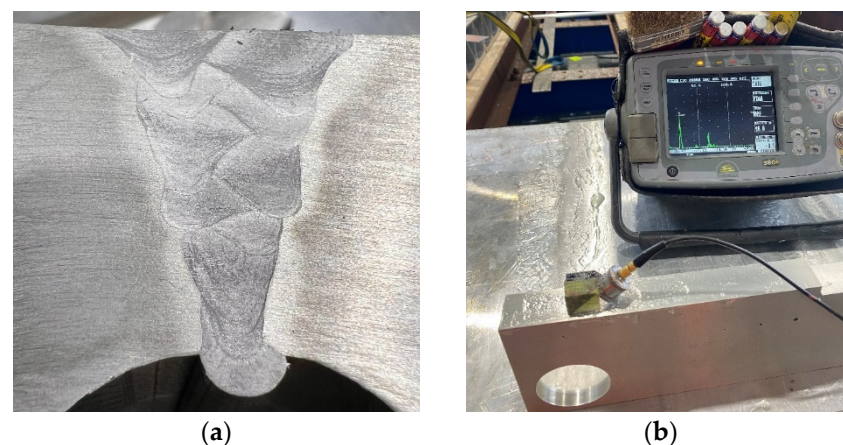


Figure 4. (a) Visual aspect of welds; (b) UT calibration process.

4. Post-Welding Deformation Control

Another challenging aspect of this project was the control of post-welding deformation resulting from the heat input during the welding process. The significant difference in thickness between the top and bottom skins of the extrusions resulted in higher heat input in the top skin. This imbalance generated both transverse and longitudinal deformation, as illustrated in Figure 5a. This phenomenon was studied during the experimental phase of the project in order to predict and control the post-welding deformation of the extrusion deck panels. Based on the results obtained during these trials, a restraining system using hydraulic jacks was developed by the fabricator to limit transverse deformation during welding, as shown in Figure 5b.

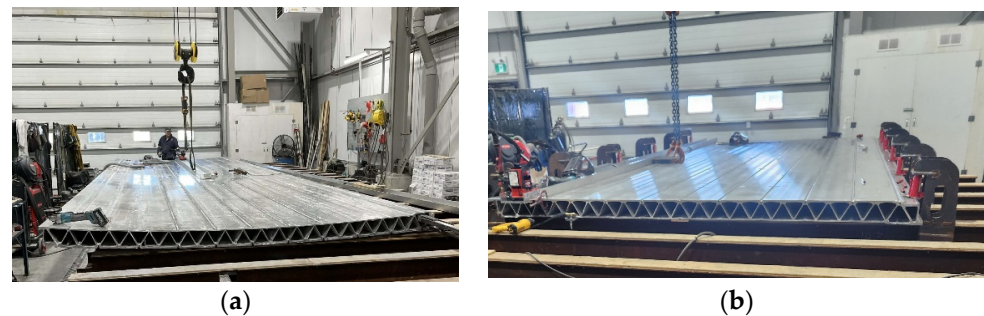


Figure 5. (a) Transverse deformation of extrusions panel; (b) restraining system.

In addition, the bottom skins of the extrusions were intentionally ordered shorter than the top skins to create a slight camber once the extrusions were assembled. However, during production, the new extrusions behaved differently from those used during the experimental phase. The heat input generated less deformation than initially anticipated, which required the manufacturer to adjust the geometry of the extrusions to achieve the desired final alignment.

When the welding of the deck panels was completed and the welds had been inspected, both transverse and longitudinal deformations were measured using an automatic level, as shown in Figure 6. The collected measurements were compiled and compared with the project tolerances. When necessary, controlled post-heating was applied in the heat-affected zones (HAZs) of the extrusions to correct the deformation and meet the specified tolerances. Throughout the project, transverse deformation of up to 10 mm and longitudinal deformation of up to 20 mm were observed on the 10 m-long deck panels.



Figure 6. Deformation measurement method.

5. Bolting Plate Method

Aluminium decks are mostly composed of hollow extrusions that can be up to 10–15 m in length. Connecting secondary elements such as barriers with bolts to these extrusions triggers an issue since there is no access to hold the nut in place while tightening. Previous publications [2,3,9] reported the bolting plate method as a promising solution which was tested in the current project.

Figure 7a shows how the long bolting plate constraining the galvanised steel nuts and washers is inserted into the aluminium extrusion. With recent developments, the washers are simply glued and ultimately bear on the top skin bottom surface after tightening. Figure 7b presents prequalification tests that were requested in the structural specification. The fabricator successfully demonstrated its capability to achieve the code-compliant turn-of-the-nut method with the bolting plates. It was also confirmed that reducing the plates thickness from 24 to 19 mm was acceptable and did not impact the behaviour.

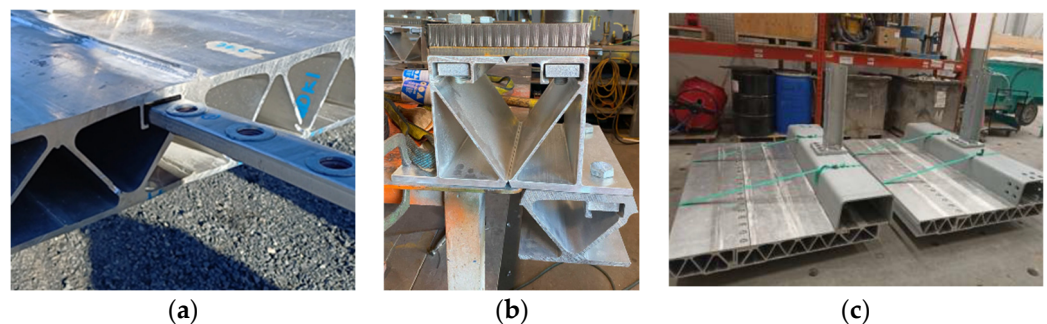


Figure 7. (a) Bolting plate insertion; (b) assembly tests; (c) barrier modules ready for load trials.

Demonstrations modules shown in Figure 7c were fabricated in the early phases while finalising the welding procedures. They replicated the deck geometry including the bolted details. The anchoring block, the curb and the barrier's post were assembled successfully using the bolting plate method and delivered to Laval University for load tests. There is now significant proof that the bolting plate method is an appropriate solution to achieve turn-of-the-nut compliant bolted connections in aluminium structures.

6. Conclusions

This paper documented the construction of Canada's first GMAW-welded aluminium deck on steel girders and demonstrated the feasibility of this approach for traffic-loaded bridges. The project confirmed that GMAW enables large, prefabricated aluminium decks but requires carefully optimised joint geometry, welding parameters, and innovative removable backing systems to achieve reliable full-penetration welds in thick extrusions. It also highlighted limitations in current CSA aluminium welding standards, particularly for ultrasonic testing of deep and complex welds, requiring project-specific inspection procedures. Post-welding deformation proved to be a governing challenge and necessitated active restraint, geometric pre-camber, and controlled post-heating. Overall, the fabrication and quality control strategies developed provide valuable guidance for future aluminium bridge projects.

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Conflicts of Interest: The authors declare being employees of WSP and Proco. The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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