Design for Manufacture

by Hazel Needham, Expedition Engineering

The construction industry has a reputation for being slow to adopt new technologies. The AVA Footbridge challenges this perception by utilising manufacturing technology not previously used in the sector. State-of-the-art modelling software and production equipment are being used to create a bridge that is manufactured in a similar way to a car on a production line with the aim of reducing cost, carbon and programme.

Network Rail recognised that meeting the targets set out in the UK Government Construction 2025 strategy would require a change that could only be achieved by innovating. Our brief was to combine a collaborative design process with high-tech manufacturing and precision engineering to create an adaptable footbridge that meets Network Rail's Access for All requirements. The project, which is partly funded by Innovate UK, will revolutionise the way Network Rail procure footbridges.

As Principal Designer, Expedition have been at the forefront of the project working alongside Hawkins\Brown, X-Treme Systems, Walker Construction and Network Rail as a collaborative consortium. As the Senior Engineer for Expedition, I participated in the development of the concept as well as leading elements of the technical design. I was also pivotal in linking the technical and code-based requirements with the manufacturing constraints.

Lower costs

33%

reduction in the initial cost of construction and the whole life cost of built assets

Faster delivery

50%

reduction in the overall time, from inception to completion, for newbuild and refurbished assets

Lower emissions

50%

reduction in greenhouse gas emissions in the built environment

Improvement in exports

50%

reduction in the trade gap between total exports and total imports for construction products and materials

Targets set out in the UK Government Construction 2025 Report

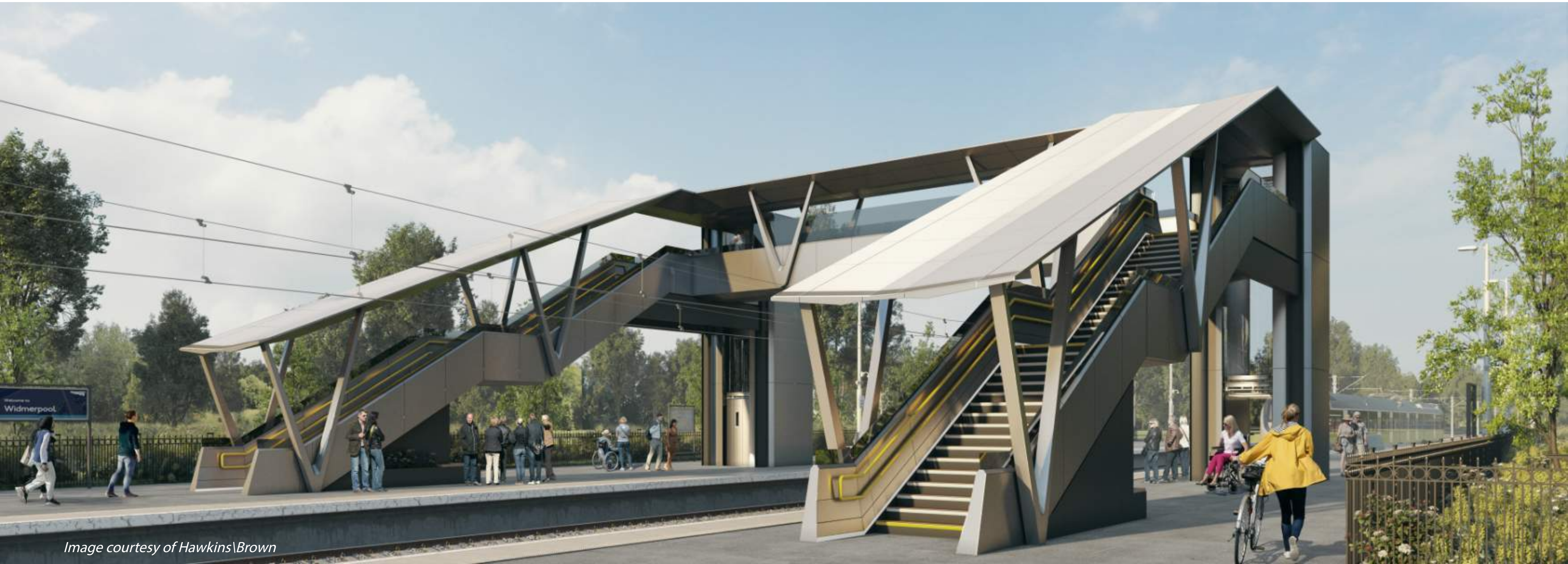


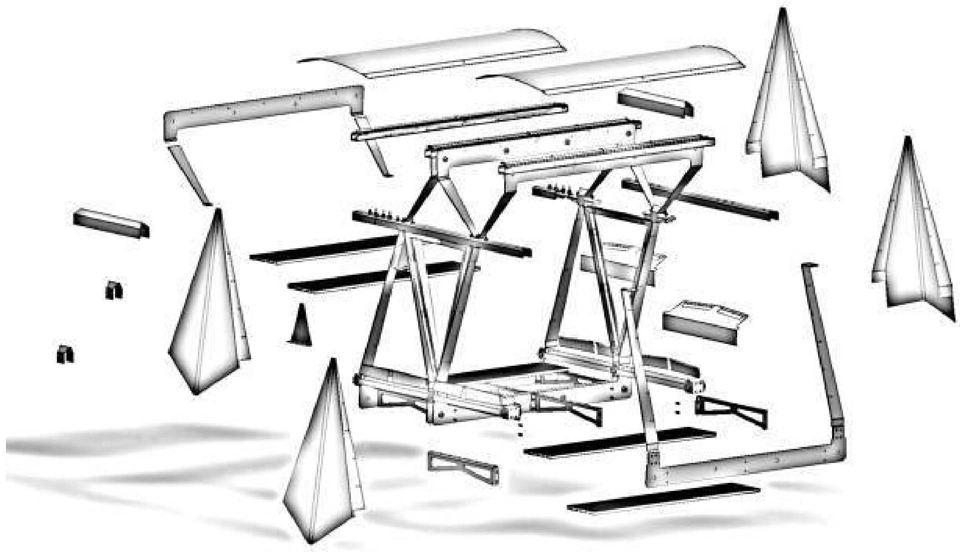
Image courtesy of Hawkins\Brown

Understanding the Constraints and Opportunities

The appointed manufacturer specialises in the production of bespoke storage solutions made from precision-folded sheets of stainless steel and had no previous experience in the construction industry. Understanding the technology was vital to the success of the project. COVID added an extra challenge to this, as site visits and in-person collaboration was limited.

The manufacturing process has several advantages to fabrication. The first is the use of fully integrated 3D models that include every nut, bolt and plate as well as the services. Having a detailed 3D model improves coordination, enabling a smooth manufacturing phase. The 3D model exports directly to the laser cutting machines, which have incredible accuracy and speed. Lack-of-fit concerns and programme are reduced, and nesting tools reduce waste. Any shape can be cut, allowing design optimisation as bespoke sections can be made.

Laser Cut Elements Produced by X-Treme Systems. Image courtesy of X-Treme Systems



Exploded view of Solidworks Model. Image courtesy of X-Treme Systems

The project doesn't use any standard sections; instead, all elements are folded from plate. I-sections and hollow-sections were not economical to form meaning that the most practical sections were channels, flats, and angles. We explored the use of composite sections created by bolting plates together with preloaded bolts to form elements with thicker flanges. This created more efficient sections reducing the weight of the structure.

To enable offsite construction and flexibility the project utilises a modular approach. The steel is procured in 1.5x3m sheets which dictated the module length. Incorporating this requirement into the project early was critical as it had a significant impact on the architecture and structural system. The plate thickness was limited to 12mm which encouraged optimisation as detailed design calculations were completed early.

The next constraint to be understood related to bend radii. As the sheets are cold formed from lean Duplex, the bend radii is typically 2-2.5 times the plate thickness. This not only affected the section properties but also impacted bolt positions. This pushed us to consider the connection details early in the design process. Having the manufacturer onboard during the design phase was important as we could discuss options and develop details to suit the production process.

The Value of Prototyping

Following the design principals above, the team and I developed two solutions – the first a full-height truss with dual-function cladding panels that stabilise the truss members and the second a shallow beam that uses composite plate action to provide the required capacity. Prototype modules of these options were manufactured giving the team a better appreciation of the manufacturing methods.

The prototypes demonstrated that the manufacturer, who had no previous bridge building experience, had the skills required to construct a high-quality product. Seeing the speed of the cutting and assembly processes and the strengths of a manufactured product come to fruition was inspiring. The prototypes created excitement which is critical on innovation projects where there are inevitably setbacks. It was noticeable during this period that the team was more motivated and that new solutions were developed which are used in the final design.

The prototype was also useful as a communication tool and for engaging the client with the project. The client was able to walk across the prototype and provide critical feedback and the images of the prototype have been shared widely generating publicity. As with many innovation projects, investment in the AVA Footbridge was made with the understanding that there is demonstratable return. The prototype gave confidence to Network Rail and Innovate UK that the project has real potential.

Client Visit to the Prototype

Images courtesy of X-Treme Systems

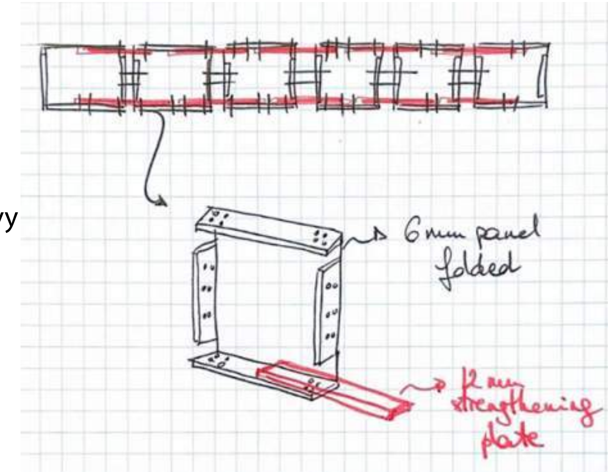
Final Design

The scheme is being taken forward as a full-scale demonstrator project to be built at a Network Rail Test Track before moving to a permanent home on a live railway. The design therefore meets all the Network Rail standards.

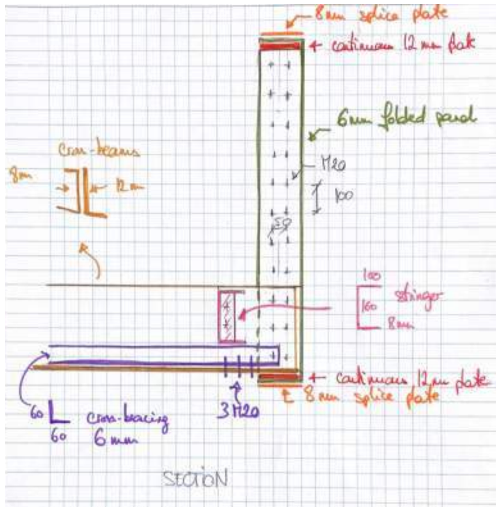
As a result of building the prototype, we refined the following structural and architectural aspects of the design:

- Allowed a continuous glass window which significantly improved the user experience
- Removed any elements that may have allowed the structure to be climbed
- Eliminated the need for machined/cast parts
  - These elements are expensive, have long lead times and are very heavy
- Avoided bending the plate wherever possible
  - Plate bends at connection points induced minor axis moments significantly impacting the plate capacity

The primary structure is formed of two longitudinal girders, concealed within the parapet linked by crossbeams. The main girders are made of 1.2m long panels folded to make a C, with the flanges strengthened by additional plates. All panels are spliced together to ensure continuous behaviour. The additional plates are also regularly bolted to the C-panel with preloaded bolts to achieve composite behaviour between the two plates. The vertical folds are connected to the crossbeams to provide a U-frame action and transverse stability.



Sketch of Primary Beam C-Girder



Section through half of U-Frame

Image courtesy of Hawkins\Brown

What’s Next?

The manufacturer is currently in the process of modelling the bridge with cutting due to begin this winter. Once the bridge is built it will remain in place for 3 months for a period of monitoring and evaluation. The demonstrator bridge will be a fully-functioning bridge, but it is still a prototype, and we anticipate that further improvements will be identified during this trialling period which will feed into a continuous improvement loop.

Reflection

Completing an innovation project during a global pandemic has been challenging. Workshops were completed online and there were long periods of isolation. Once the team were able to meet in person there was a noticeable increase in creativity and solutions were reached more quickly. Reflecting, I wonder whether some of the challenges we faced during the early stages of the project could have been overcome more easily had in-person collaboration been possible.

Although the project was primarily an innovation project, an added challenge was the requirement to move the bridge to a permanent site. Having a permanent home for the prototype has numerous benefits and supports circular economy principles. However, it also meant that failure – a degree of which is expected in innovation - was not an option. Step change was therefore difficult to achieve and, had the project remained purely a prototype, even more innovative ideas could have been tested.

Working on the AVA Footbridge and exploring the world of manufacturing has been fascinating. The key to success has been working closely with the manufacturer from the start. Getting feedback on details early and having prototypes to test ideas allowed the team to develop a solution that is tailored to the manufacturing system. The project demonstrates that using a manufacturing approach and off-site construction methodologies reduces programme, cost and carbon. To meet the Construction 2025 targets, this type of technology needs to be used more widely and hopefully the AVA project will inspire others.

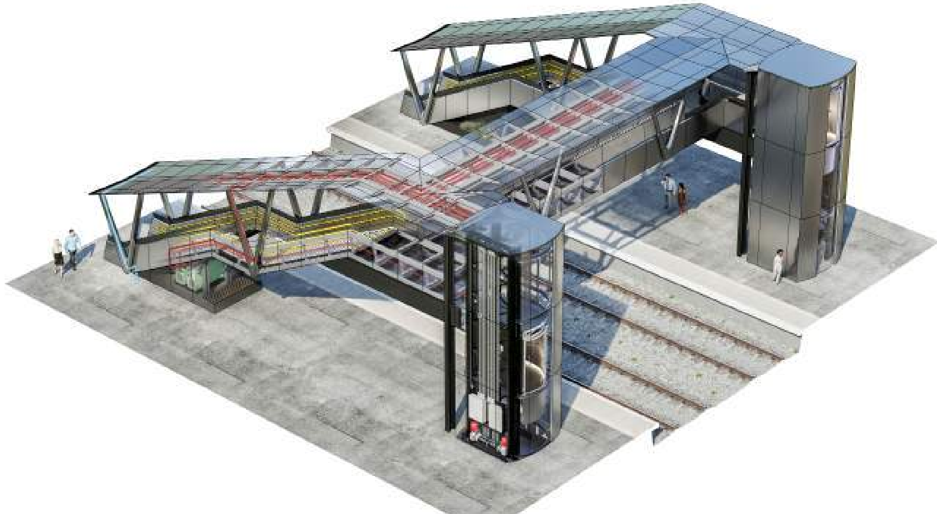


Image courtesy of Hawkins\Brown

Image courtesy of Hawkins\Brown