The Design of a Steel Truss Footbridge on a Heavily Constrained Site

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1 Introduction

Cock Lane Footbridge is a 50m single-span steel warren truss structure in Peterborough which will be constructed in 2019. It is a replacement of the existing U-type steel footbridge and forms part of the Werrington Grade Separation scheme (Werrington GS).

Figure 1 – Top - Proposed Cock Lane Footbridge. Bottom – Existing Cock Lane Footbridge

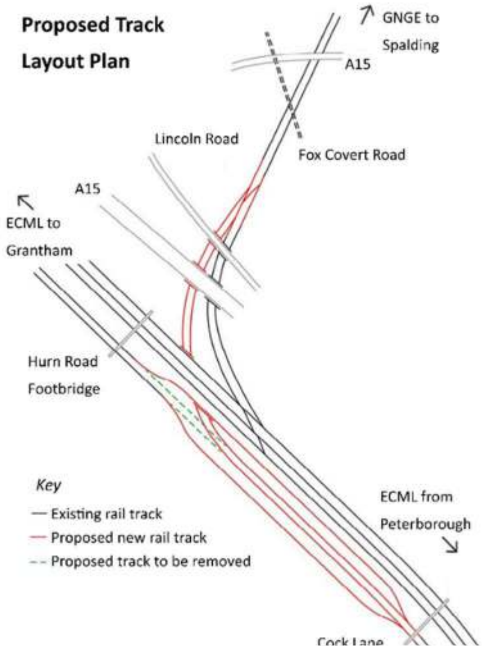

Figure 2 - Proposed Track Layout Plan of Scheme (Network Rail, 2016)

Werrington GS will separate slower traffic from currently crossing the East Coast Mainline (ECML) at grade. The grade separated junction will be achieved by the construction of a dive under structure and the construction of 3 km of two new lines (Network Rail, 2018).

The scheme forms part of a programme of eleven projects under the Connectivity Fund, a £247 million investment programme aimed to reduce journey times and increase rail capacity. The Benefit Cost Ratio (BCR) for the projects under the Connectivity Fund was determined collectively to be 3.8 with a Net Present Value of £2.5 billion (Network Rail, 2017), by increasing train capacity by 33% and reducing journey times among other operational benefits.

Cock Lane FB
Clear Span: 49.9m
Effective Span: 50.3m
Main Span Weight: 45t
Design Completion: 2018
Construction: 2019-2020
Capital Cost: Approx. £2m
Client: Network Rail
Contractor: Morgan Sindall
Designer: Mott MacDonald

2 Threading the Eye of a Needle

Cock Lane FB is located at a critical and heavily constrained part of the scheme. As part of the sequencing of the construction, the bridge must be constructed early in the programme of works. Furthermore, it is adjacent to two key culverts, meanwhile crossing the dive-under, slewed tracks, ECML, and railway and overhead electrification.

2.1 132 kV Cables

Early in the design development phase it was identified that the proposed footbridge was in close proximity to 132kV overhead cables, which run parallel to the tracks. Unfortunately, as a result of the location of the existing footpaths, the location of the main span coincided with the point of lowest sag of the cables.

A safe solution requires the structure to be a minimum 3.6m from the deck of the structure to the sway profile of the cables at maximum conductor temperature hanging vertically or swaying up to 45 degrees (Energy Networks Association, 2016). This was modelled as a 3D shape to determine the change in profile with varying sag along the length of the cable. It was found that the structure in its initial situation would be foul of this requirement, so it had to be repositioned.

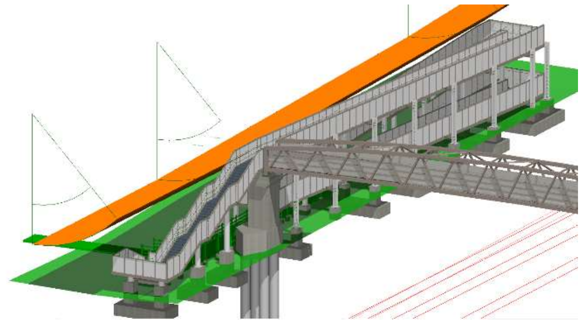

Figure 3 - Clearance of structure in final location to 3.6m cable sway clearance profile demonstrating no clashes with the deck

2.2 Hazard Zone

All new structures should be constructed outside the hazard zone, a 4.5m corridor from the nearest running edge in accordance with NR/L3/CIV/020, in the case this is not achievable, then certain train impact mitigation measures need to be undertaken.

2.3 Chosen Location

An investigation into the feasible locations of the structure complying with the constraints identified that the western pier would either need to be:

Option A (rejected): Translated 100m north. This would be foul of the planning requirements as part of the planning submission and would increase crossing times.

Option B (adopted): Shift the bridge to be within the hazard zone.

3 Structural Form

The main span is a full-through bowed warren truss. The mid-span has a permanent camber of 500mm to aid drainage and maximise clearance over the railway.

To improve the efficiency of the design I proposed a change in the truss form from Pratt to Warren, and the number of truss portals reduced from 26 to 15. This not only improved the aesthetics of the structure but also resulted in a 10% reduction in steel and a 41% reduction in the number of welded joints. The compressive loads in the web elements is concentrated near the supports, therefore the bowing of the top chord reduces the web elements' effective length at these locations, increasing buckling capacity.

One key aspect of the design was to verify the global buckling resistance of the truss. Top chord bracing was added to remove this as a limiting factor in the form of a modified warren in plan. This intervention greatly increased the efficiency of the structure and improved its resistance to transverse wind loading.

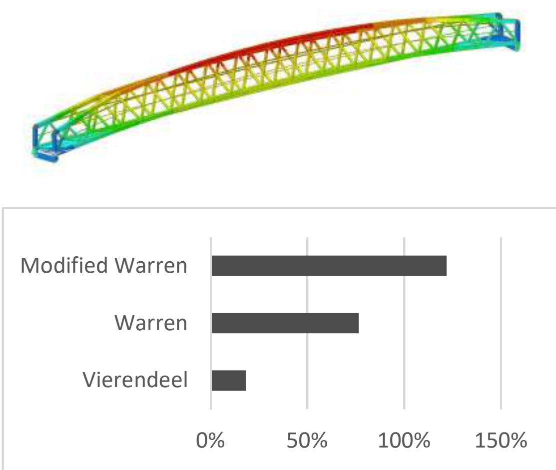

Figure 4 - Top – 1st Buckling Mode of Structure with Modified Warren Top Chord Bracing. Bottom - Increase in buckling capacity of main trusses with top chord bracing.

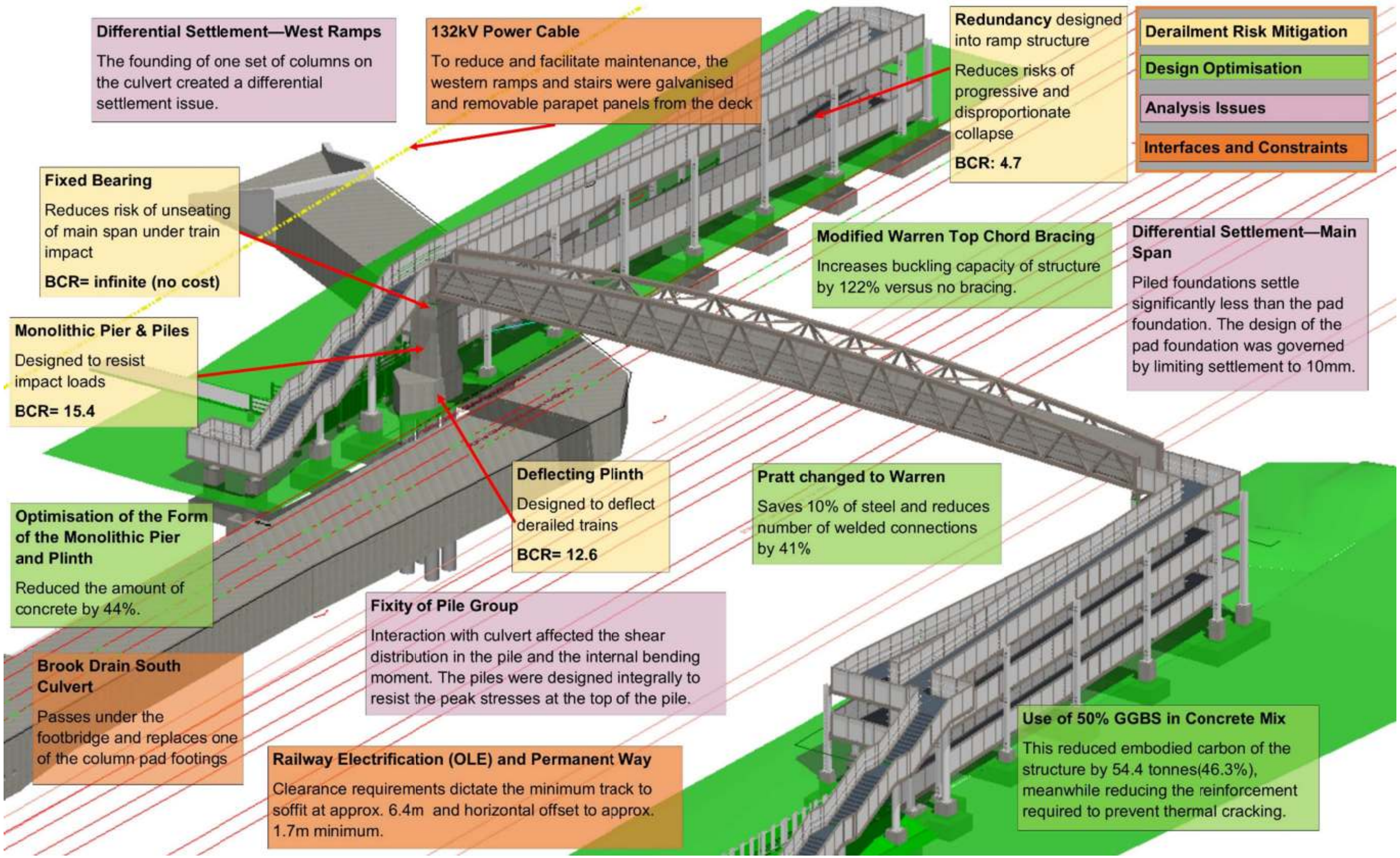

Figure 5 - Design Interventions (aerial view from east)

4 Assessing Train Impact

The western ramps and pier located within the hazard zone necessitated a risk assessment in accordance with UIC 777-2R.

This determined that the mitigation measures shown in Figure 5 should be adopted. The format of this risk assessment results in a monetary value for the reduction in risk of fatality versus the capital cost to determine the BCR for each intervention, utilising the estimated cost of a fatality of £1.897 million (RSSB, 2018).

5 Erection

The construction methodology was developed in collaboration with Morgan Sindall, the main contractor. Transportation of the structure to site is limited to 25m sections, therefore it had to be split into at least two sections and assembled on site. Site welding was removed from the outset as an option due to the health and safety risks combined with the difficulty in achieving factory quality welds, hence bolted splice connections were specified. To prevent these from being subjected to the highest axial forces at mid-span, the structure was split into three.

Once assembled, the main span is to be lifted in with a single crane from the east side, this will maintain the crane collapse radius away from the 132kV cables. It will be lifted at truss nodes located approximately 10m from either end of the span.

6 Critique

The stand-out issues for this bridge were the constraints and maintainability. The spatial constraints were complex, varying along the length of the railway. Without 3D modelling of the structures and constraints, it would have proven challenging to find a feasible and safe position for the bridge.

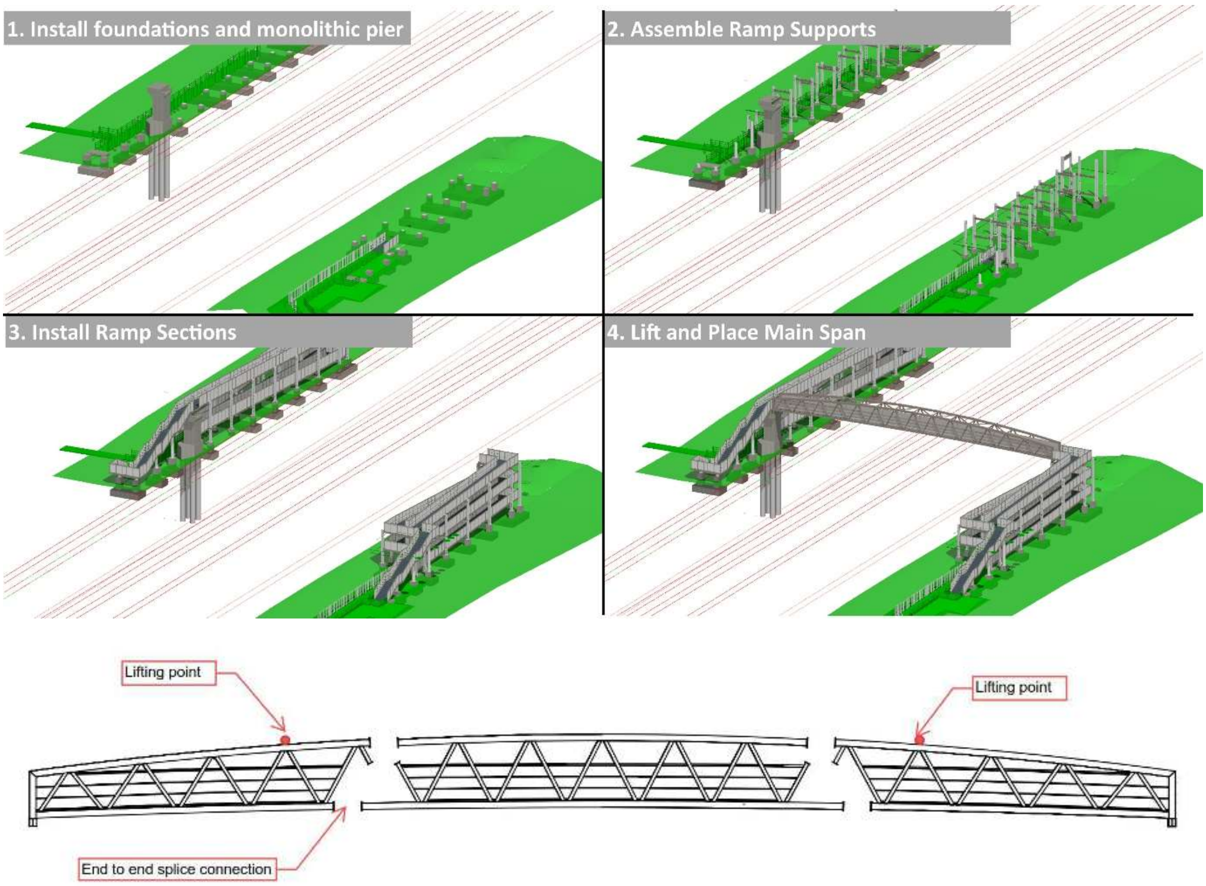

Figure 6 – Top - Construction Sequence. Bottom – Pre-assembly sections

It was very satisfying to determine a feasible location for the bridge considering the severe constraints it was subject to, leaving approximately 0.4m to spare between the structure, the absolute minimum clearance to the tracks and the 3.6m clearance to the 132kV cables.

Moreover, measures were put in place to facilitate and reduce the frequency of maintenance due to difficult access. However, use of another material such as weathering steel could have reduced the need for maintenance even further.

The spatial challenges were further compounded by the design of the footbridge being on an accelerated programme compared with the rest of the scheme. This meant that early design iterations to other parts of the project impacted on the detailed design of the footbridge. An example of this is the realignment of Brook Drain South, a 6m wide, 2m high culvert passing under the western ramps. The impacts of this design change were mitigated by collaborating with the drainage design team, using 3D modelling to optimise its alignment. This interface resulted in three columns bearing onto the culvert, impacting on differential settlement across the structure. However, due to redundancies built into the west ramps, this had only a negligible impact on the design.

7 Conclusion

Cock Lane Footbridge is situated in a highly complex, heavily constrained site. This design highlights the importance of understanding constraints to ensure a successful project and the benefits of modelling constraints in 3D. Collaboration and effective communication between design team and the contractor have enabled the development of a safe, efficient design.

8 References

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9 Acknowledgements

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