FIRST PRIZE IN THE REF SCOTLAND DEVELOPING PROFESSIONALS COMPETITION

Geotechnical challenges of railway improvements on existing assets

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INTRODUCTION

The Edinburgh Glasgow Improvement Programme (EGIP) comprises a series of improvements and upgrades to key infrastructure as well as the electrification of the Scottish rail network main line between Edinburgh and Glasgow. It intendeds to reduce journey times and increase passenger capacity along this main route (Network Rail, 2014)., which are to be primarily achieved through electrification, the introduction of longer train formations (seven car formations will operate during peak periods), and the extension of intermediate station platforms to accommodate longer trains.

This paper focuses on the geotechnical design and construction of a number of key elements within EGIP, particularly bridge reconstructions which have been required to successfully achieve the scheme's goals.

DESIGN METHODOLOGY

From a suitability point of view, the design tried to, whenever possible, accommodate and re-use existing structures as opposed to rendering the existing infrastructure completely obsolete. However, given the limited records and information available on the existing structures, the design concept, in many instances, aimed to quantify the change between the existing and proposed configurations to prove that the latter would not have a detrimental effect on the structures' safety and behaviour.

The first stage of the design process was to assess the current stability based on the interpretation of the findings of the intrusive investigation and available record drawings, as well as the estimate of existing loadings. This exercise often led to the conclusion that most of the existing assets are generally not compliant with current standards (particularly existing bridges), which resulted in the design approach for the proposed works to be based on the principle that the new arrangement would not have an unacceptable detrimental effect on the existing structures. This methodology was confirmed and accepted by Network Rail as Asset Owner. As a result, the detailed design ensured no fundamental changes would occur in the foundation loading regime from that which has been applied by the existing structures or, where there is a change, it was demonstrated to be insignificant (less than 10%). Overall, all the components of the scheme referred to in this paper were categorised as Category 2 in accordance with BS EN1997-1 (2014), as no exceptional risk of failure and no exceptional ground or load conditions were identified. Finally, restrictions and limitations to construction methods and sequence, particular due to the fact that the majority of the work had to be undertaken from within train corridors and during possessions on live lines, were incorporated in the design and discussed between all parties involved.

BRIDGES RECONSTRUCTION

Six road bridges underwent/will undergo re-decking within this scheme and the analysis of their existing arrangement found them not to be compliant with current standards. The majority of the bridges appeared to be in a structurally sound condition, with no apparent signs of distress in their masonry abutments. However, upgrading the existing structures to become Eurocode compliant required profound and onerous changes.

The most cost effective and environmentally friendly way of dealing with the issue, and given that these bridges had been performing well over the last decades, and that no increase in traffic was proposed, was to accept that to reduce the environmental footprint of the works, the proposed arrangement only needed to demonstrate that they would not significantly change the stability state of the existing bridges.

To achieve this, a number of technical challenges had to be overcome as in most cases the weight of the proposed new concrete decks is significantly higher (by 50% to 100%) than the existing steel decks. This change, albeit favorable for the lateral stability of the bridges, was unfavorable with regards to their vertical stability. On the other hand, on the masonry arch bridges, the proposed new decks were slightly lighter than the existing arches, resulting in a decrease of resistance to lateral stability.

In addition to the above, the required increase in vertical clearance resulted in rises in road levels behind abutments and wingwalls in the order of 300 to 1000mm, which would lead to increases in the earth pressures behind abutments and wingwalls

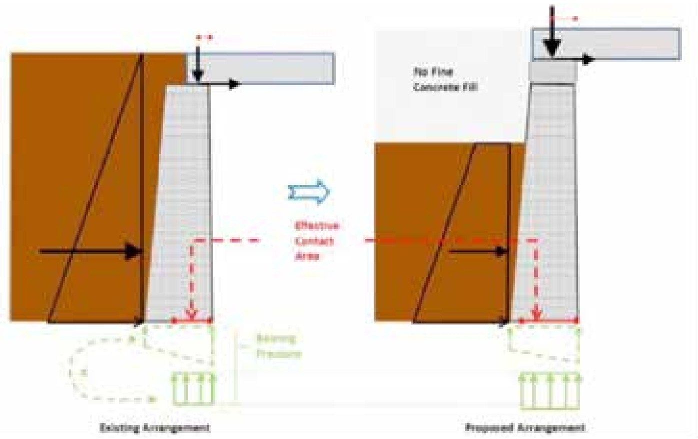

Figure 1 Proposed deck heavier than existing.

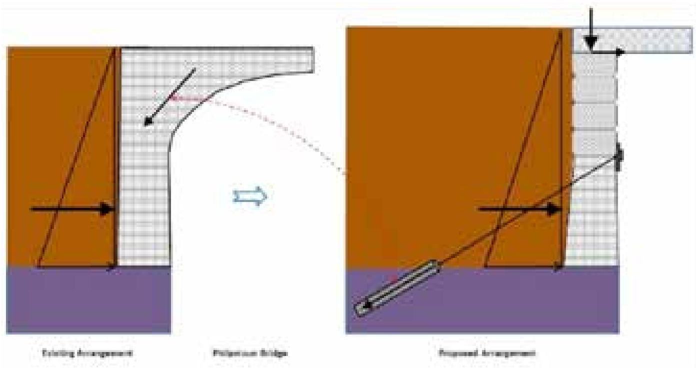

Figure 2 Philpstown bridge reconstruction.

and, ultimately, aggravate any eccentricities at formation levels.

The following subsections illustrate some of the reinforcement works designs which were adopted to provide a more sustainable solution.

3.1 Proposed deck heavier than existing

In the cases where the proposed bridge deck was heavier than the existing, the adopted solution was to limit any increase in bearing pressure to 10% of that existing. This was primarily achieved by widening the span of the new bridges (so as to increase the horizontal lever arm of the dead and live loading in relation to the toe of the abutments) and by partially replacing the abutments' backfill with no-fines concrete. Both options led to improvements in the eccentricity at the abutments' formation level, as illustrated in Figure 1 below.

In these cases, lateral stability was not an issue, with the new deck ensuring improved margins of safety.

3.2 Proposed deck lighter than existing

This scenario was found to be the case in all masonry arch bridges, which not only were fitted with lighter decks but, more importantly, lost the beneficial arch thrust effect, which helped to laterally support opposite abutments. The design of a suitable replacement for the lateral support varied from case to case. At Philsptoun Bridge, this consisted of drilled and grouted ground anchors which were installed through the abutments and terminated below rockhead (Figure 2).

In a different location, at Greenhill Bridge's south abutment, and due to constructability reasons, the simple solution found was to reduce the soil lateral pressure behind the new abutment (replacing part of its backfill with no fines concrete) and ensure that the horizontal traffic loads were accommodated by its central pier. As for the latter, in order to allow it to withstand this horizontal force the central pier was entirely rebuilt from springer level.

This was achieved by re-designing Span 1 and 2 abutments, as well as the two wingwalls in between, and converting it into one common central pier. Refer to Figures 3 and 4 for more details.

Once the lateral stability was addressed, the vertical stability was not an issue due to the reduction in weight of the decks between original and proposed.

3.3 Construction of the bridges

During construction, all of the bridges (with the exception of Greenhill Bridge) where fitted with fixed bearings on both sides so that traffic horizontal actions could be shared between abutments. This decision, not only enabled the bridges to behave similarly to their original configuration, but most importantly avoided overloading the abutments. Also, and in order to satisfy the lateral temporary stability of the abutments during construction, part of the backfill behind the abutments was removed until the new decks were installed.

The Greenhill Bridge central pier construction followed a slightly different approach to all other bridges as its central pier provides support for both spans (Figure 4). This pier was demolished down to the arch springer level and a new large gravity structure, comprising all four walls, was formed. The mass of this pier was used to resist the horizontal traffic loads from both spans.

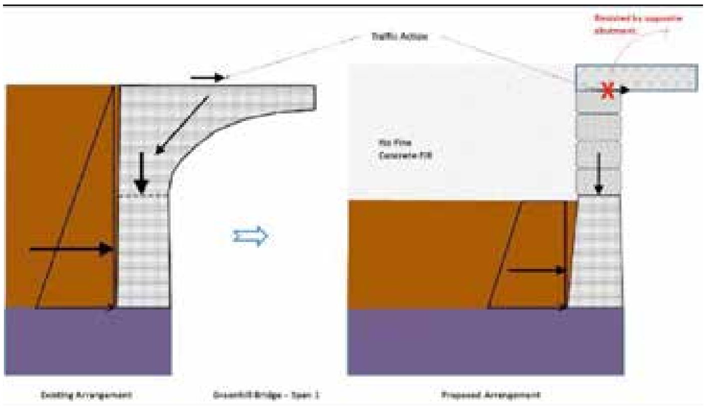

Figure 3 Greenhill bridge span 1 reconstruction.

REFERENCES

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Figure 4 Greenhill Bridge Reconstruction.