Auckland Rail Electrification and its Effect on Existing Overbridges

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Abstract

Overhead electrification of the Auckland railway network requires assessment of the vertical clearance at overbridges to ensure adequate physical and electrical clearances.

A study was undertaken to identify overbridges where clearances fail to meet the requirements of electrification and to evaluate options for improving the clearance. Options include lifting existing bridge decks, replacing existing bridge decks and replacing the entire bridge structures. Site measurements indicate that 42 bridges on the network require attention.

1 Introduction

The Auckland rail network is an essential element in the transportation system of New Zealand’s largest city. Electrification of the commuter routes is a significant component in a package of upgrades which will increase the frequency and reliability of services.

The switch from diesel to electric powered rail vehicles requires increased vertical clearance to accommodate pantographs, electrical safety clearance and contact wire infrastructure. The network includes 57 road overbridges, 26 footbridges, three tunnels and one through-truss underbridge where existing clearances require confirmation and comparison with the dimensions needed for electrification.

Nine of the footbridges, two of the tunnels and the truss underbridge have insufficient headroom for electrification. While these structures present their own design challenges, the focus of this paper is on road overbridges and the other structure types will not be discussed further.

A review of existing clearance data indicated that more detailed investigation was required at 42 overbridges. AECOM carried out data gathering which included site measurements and advised the network operator ONTRACK on the most efficient and cost effective solutions. The options considered were (in order of impact on the structure):

- Do nothing
- Maintain the current track alignment but utilise reduced electrification tolerances
- Lower the track
- Raise the existing deck
- Replace the deck
- Replace the entire bridge
- Close the road and remove the bridge

Significant factors requiring consideration included the need to accommodate services, the effects on adjacent stations and level crossings and the effects on the local road network.

This paper outlines the issues encountered in AECOM's investigation into increasing the clearances at overbridges for electrification of the Auckland rail network and discusses the recommended solutions at three typical bridges.

2 Problem Definition

2.1 Vertical Clearance

The existing diesel train system requires a minimum 250 mm vertical clearance between the train roof and overhead structures. Overhead electrification of the network requires sufficient space between the rail vehicle and the overbridge to accommodate a pantograph, contact wire and its support elements, as well as minimum electrical safety clearance.

Current standards for electrified track require the vertical clearance at new structures to be a minimum of 5.50 m; at existing structures the preferred clearance is 5.20 m, which may be reduced to 4.775 m where the track is maintained to reduced tolerances. These values are increased when a level crossing is close to the bridge as the contact wire height is increased to protect crossing user safety.

Site measurements indicated that 42 overbridges have insufficient vertical clearance to meet the preferred minimum, and that 22 do not meet the absolute minimum clearance.

2.2 Bridge Construction Records

Many of the bridges with inadequate clearance predate current design codes. These structures typically were designed by the New Zealand Railways head office in Wellington with spread footing foundation depth to be determined by the local bridge engineer; however no records of these local site decisions are available. In general the head office records show mass concrete abutments with the underside of the foundation at track formation (subgrade) level.

Good records exist for bridges constructed after 1960 however and these typically have more robust piled foundations.

The data gathering exercise excluded site investigation works and therefore many of the as-built foundation details could not be verified. Consequently for the older bridges this qualifies many of the conclusions drawn.
2.3 Services

Services are present at most of the bridge sites. Some of these services pre-date rail and bridge construction and are of regional importance. Services identified include conventional and fibre-optic telecommunications cables, medium and low voltage electric power, high and medium pressure gas, water supply and wastewater.

In most cases, due to the absence of legal agreements at time of installation, the cost of temporary or permanent relocation must be borne by the electrification project rather than the service owner. This can represent a significant cost restraint.

2.4 Disruption to Road and Rail Traffic

Alterations to road bridges invariably affect the rail and road traffic using the bridge. The volume of traffic is a major consideration for the final solution; it may require the consideration of alternatives such as using half and half reconstruction to keep the road partially open during works. Temporary bridge solutions have also been considered and recommended where it is impossible to keep at least one lane of traffic open and where available land makes this solution viable.

The Auckland Rail Network relies heavily on its main lines. For example, there is only one line North from Newmarket. The closure of any line, such as resulting from track lowering, is likely to cause major disruptions to the overall rail service and needs to be carefully considered.

2.5 Bridge Ownership and Regulatory Issues

Of the bridges included in the study only one is owned by ONTRACK. The others are owned by either one of the four local transport authorities or the New Zealand Transport Agency. This diverse ownership itself represents a complication as each bridge owner has differing criteria in permitting outside parties to affect its assets.

Similarly it is anticipated that Building Consents will be required for all structural modification works. Each territorial authority has different consenting processes and requirements which will further complicate and possibly lengthen the time required to obtain works approval under the Building Act. AECOM identified the need to involve each of the territorial authorities early in the design process in order to minimise the associated risks.

3 Site investigation

The existing vertical clearance data was verified using a hand held laser distance meter. The overall condition of the bridge was recorded and the accuracy of the record drawings verified. The condition of the track was noted and lateral clearances to the abutments and piers recorded.

At this stage no other site investigations, such as detailed topography and soils investigations, have been undertaken however these are anticipated as being critical to subsequent stages of the identification of the optimal bridge solution.
4 Options Considered

4.1 Do Nothing

Only two of the 42 structures investigated meet the 'do nothing' clearance criterion of 5.20 m.

4.2 Maintain Track to Reduced Tolerances

Clearances at 13 of the 42 structures are between the absolute minimum of 4.775 m and the preferred value of 5.20 m. At these structures it is possible to maintain the future track and electrification infrastructure to closer tolerances, removing the need for physical bridge alteration works. This is obviously a desirable outcome, as electrification works costs are consequently minimised.

4.3 Lower Track

Lowering the track allows the clearance to be increased with little or no disruption to road traffic. Although it is permissible to increase the clearance to the absolute minimum of 4.775 m and maintain the track to reduced tolerances, in practice ONTRACK prudently elected to target a 5.20 m clearance and use regular tolerances for this solution.

The main structural issue associated with track lowering is maintaining the vertical and horizontal stability of the abutments, especially where shallow spread footing foundations are involved.

The principal concern with respect to the overbridges is the effect of lowering the ground level in front of the abutments. This is a major source of risk to the project given the uncertainty on the detail of the foundations of older bridges (see section 2.2 above). It can also affect more modern structures with abutments constructed in mechanically stabilised, reinforced earth.

The weak and compressible soils commonly found in Auckland typically require temporary track excavations and backfill to 1.2 m below the final track level to ensure long term track stability. Consequently this undercut case governs the electrification track lowering scheme.

Compared with shallow abutment foundation works, underpinning of bridge intermediate piers on shallow foundations is relatively simple. Whilst vertical loads are similar to abutments, lateral loads are generally much less as no retained soil pressures are involved. Whilst this simplifies the solution working within a restricted working area still poses complications.

4.4 Raise Existing Deck

Raising the existing deck clearly requires an increase in the road level carried by the bridge deck. The vertical alignment of the road at many bridges does not comply with current standards for sight distance. Further reductions in sight distance are unacceptable and therefore proposed roadworks may extend over a significant length of the bridge approaches. Changes in road levels may also affect road intersections and private entrances close to the bridge. As a result, alteration of the road level...
increases the overall cost of bridge works and can lead to significant disruption to road traffic and inconvenience to adjacent landowners.

A variety of bridge deck types are found on the network. The decks of more than half of the bridges, constructed in the early 20th century, have steel I sections fully encased in concrete and an integral deck slab (see Figure 4-1). These decks are monolithic with the mass concrete abutments however there is no continuity reinforcement tying the two elements together.

Precast pre-tensioned bridge beams became common during the 1970s. This type of beam deck is generally designed as simply supported, with linkage bars transferring transverse and longitudinal forces to the abutments. Transverse post tensioning and cast in situ longitudinal shear keys provide transverse load distribution. These decks are also relatively simple to raise but need to be lifted as one single deck unit due to the transverse continuity details, precluding lane by lane raising.

In all the cases considered however the cost of the associated roadworks was greater than the cost of the structural modifications. This cost made the deck raising option less attractive than any of the other alternatives.

4.5 Replace Existing Deck

The early 20th century bridge decks, shown in Figure 4-1 above, typically have span to depth ratios in the order of 1:10. Modern construction materials, utilising for example prestressed concrete bridge beams, allow ratios of between 1:20 and 1:30. Consequently replacement of the deck using modern components may provide the necessary clearance increase without altering the finished road level on the bridge. This avoids the drawbacks noted above for lifting the existing decks.

Deck replacements can thus provide the advantage that existing road levels can be maintained with the smaller construction depth providing the extra clearance necessary for electrification.
Existing stringer beams vary from 760 mm to 1060 mm deep including concrete deck slabs. The spans are typically less than 10 m (the width of a double tracked railway line) so a 450 mm deep standard prestressed concrete Double Hollow Core bridge beam, with transverse prestressing instead of a concrete topping slab provides a much thinner alternative.

These modern bridge beam replacement decks would probably be simply supported on elastomeric bearing pads eliminating the need to replicate the existing semi-integral bridge arrangement, which can be difficult to reliably replicate especially where existing abutments are constructed using mass concrete. Naturally detailed analysis will need to be undertaken to investigate the new abutment arrangement where the new deck no longer props the two abutments under lateral earth pressures, as in the original configuration. Ground anchors or similar lateral strengthening of the original abutment walls is therefore likely to be necessary.

4.6 Replace Bridge

An entirely new bridge may be the required solution if the existing bridge has insufficient structural capacity and cannot be strengthened or retrofitted to achieve the new clearance levels.

In other situations the bridge may be in very poor condition or the increase in clearance is such that the existing substructure and foundations are overstressed and cannot be economically strengthened. This is discussed more in the St Marks Road Bridge case study below.

4.7 Remove Bridge

Demolishing the bridge removes the overhead structure and hence the electrification clearance problem. This concept is not as asinine as it at first sounds. Most bridges when constructed carried major traffic routes however since construction a number of these of routes have been by-passed and the major routes cross the railway via more recently constructed road bridges with adequate clearances. Consequently some of the bridges now only carry routes of minor or local significance.

Initial discussions with local authorities has indicated a reluctance to remove even minor route bridges from their road network. This is in spite of suitable alternative diversion routes and the removal of long term bridge and road maintenance liabilities. As a consequence this option is likely to involve protracted discussions and negotiations with the bridge owners and hence, despite its simplicity, it carries a high programme risk to the timely delivery of the electrification project.

5 Case Studies

5.1 Sandringham Road Overbridge

Sandringham Road overbridge is a two span semi-integral bridge with a total length of 10.6 m. The deck is a 760 mm deep solid concrete slab reinforced with rolled steel I sections at approximately 800 mm centres; the record drawing shows no details of transverse reinforcement or any ties between the deck and substructure.
The abutments are mass concrete and the pier is assumed to be reinforced concrete. The record drawing shows pad foundations at varying levels determined by the original ground profile; the top of the foundation at one abutment has been exposed by previous track lowering. Trial pits adjacent to the south abutment, carried out for an associated rail project, showed the foundation soil to be weak clay.

The bridge carries three lanes of traffic giving an overall width of 10 m. The vertical alignment of the road includes a sharp crest curve at the north abutment. The 7-day average traffic flow is 21 000 vehicles per day (vpd) and the bridge is adjacent to a major intersection with a flow of 16 985 vpd in the opposing direction. The nearest potential alternative railway crossing points are level crossings, which experience significant road traffic delays due to the frequency of train services, especially at peak times.

Figure 5-1 Sandringham Rd Overbridge

The existing clearances are 4.685 m on the up main and 4.235 m on the down main (on the left and right respectively of Figure 5-1 above). The required increases in clearance, to achieve a value of 5.00 m intermediate between the absolute and preferred values, are 315 mm and 765 mm respectively.

Lifting the existing deck would require alteration to the vertical alignment of the road. The resulting effects on the adjacent intersection and nearby businesses, plus significant disruption to road traffic in both directions through the intersection, led to the rejection of this option.

Previous lowering of the up main, which was carried out without foundation works, has exposed the top of the foundations in that span. This was judged to represent the maximum possible lowering without requiring foundation works. Given the poor ground conditions found by the trial pits, it was considered likely that the cost of underpinning required for further lowering of the up main would be prohibitive.
Lowering of the down main to the same level as the up main was considered to be feasible and economic, although a further 315 mm clearance increase would still be required.

Replacement of the deck with 450 mm deep precast prestressed double hollow core beams, using transverse post-tensioning rather than an in-situ topping slab to minimise structure depth, offers a clearance increase of 310 mm. Thus a new deck would still require a 455 mm increase in road level, with the attendant problems noted above.

However, a combination of lowering the down main with a new deck offers the possibility of achieving the desired clearance with an increase of only 5 mm in road level. This requires no significant alteration to the vertical alignment. The deck form also allows the new deck to be constructed in stages, reducing the disruption to traffic using the bridge. This option is considered to offer the best combination of disruption to road and rail traffic, cost and construction risk.

### 5.2 St Marks Road Overbridge

St Marks Road overbridge has a single 9 m span. The deck consists of 610 mm deep steel I sections with transversely spanning mass concrete jack arches on corrugated steel permanent formwork (see Figure 5-2 below). The abutments are mass concrete and the site inspection showed them to be in a poor condition with areas of soft and spalling concrete. The record drawing shows pad foundations approximately 1 m below track formation (subgrade) level.

The bridge carries three lanes of traffic giving an overall width of 8 m. The vertical alignment of the road includes no sharp vertical curves. The 7-day average traffic flow is 7280 vpd and a motorway on-ramp is immediately east of the east abutment.

![Figure 5-2 St Marks Rd Bridge deck as-built](image)
The existing clearance is 4.0 m on both tracks, giving a required increase of 1.0 m to achieve 5.00 m. The existing track gradient is very steep at 1:33 and this cannot be increased without a significant impact on train performance. Lowering the track was ruled out as the vertical curves required to tie in to the existing alignment would increase the gradient.

The existing deck is considered to be insufficiently robust to tolerate lifting to a higher level, and the resulting increase in road level at the bridge will require roadworks over a significant length. Given the required 25% increase in retained height, the condition of the abutments is also considered to be a significant risk to the project.

Replacement of the deck with 450 mm deep precast prestressed double hollow core beams, using transverse post-tensioning rather than an in-situ topping slab to minimise structure depth, offers a clearance increase of 160 mm. Therefore the road level would increase by 840 mm to provide the required clearance.

Replacement of the entire bridge allows the work to be staged, minimising delays to road traffic. It also reduces the risk resulting from uncertainty over the accuracy of the record drawings. This option has been recommended for further study, including site investigations.

5.3 Railway Lane Overbridge

Railway Lane overbridge is a five span bridge with a total length of 41 m. The deck consists of 610UB longitudinal beams with a composite reinforced concrete deck slab. The beams are simply supported on 1200 mm deep girders which span transversely between 310UC columns, which are founded on H section steel piles. The abutments are of reinforced concrete on reinforced concrete bored piles.

![Figure 5-3 Railway Lane Overbridge](image-url)
The bridge carries a single lane of traffic on a private road over two main lines and three sidings. The road traffic volume is low but the bridge provides the only access to a major transport company’s regional distribution centre. The road alignment is level on the bridge with sharp changes in grade at the abutments and steep approaches. The rail traffic volume is high and there is no alternative route for freight and passenger traffic travelling between Auckland and stations to the south.

The existing clearance is 4.156 m on both main lines; the sidings will not be electrified and therefore no increase in clearance is required. A raise of 844 mm is required to achieve 5.0 m clearance.

Track lowering is not a feasible solution as the disruption to rail traffic is operationally unacceptable. Replacement of the existing deck with a thinner precast prestressed concrete solution would significantly increase the dead load, requiring reconstruction of the piers and their foundations and strengthening of the abutments.

The recommended option is to raise the deck to provide the required clearance over the two main lines, with the remaining spans raised by smaller amounts so than the change in road level at the abutments is kept to a minimum. The anticipated construction sequence is:

1. Carry out preparatory work for bridge lift (including overnight track blocks as required for scaffolding, lift frames, etc.)
2. Block track, lift and secure bridge, reopen track
3. Complete bridge works and remove scaffolding, lift frames etc.
4. Extend abutment and wing walls to suit new deck and road levels (or construct retaining walls at edge of roadway)
5. Raise services in approaches, construct new road pavement & kerbs
6. Construct new road surfacing and road markings

6 Conclusion

Electrification of the Auckland railway network requires the vertical clearance to be increased at a large number of existing overbridges. Each site requires consideration of a range of issues. By working closely with ONTRACK technical and electrification managers, AECOM has identified the key issues at each bridge site and recommended the optimum solution depending on the prevailing conditions, cost and risk.

7 References

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