TECHNICAL MEMORANDUM

Keynsham Railway Bridge - Options Technical Note

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1.0 Introduction

This Technical Note describes feasibility bridge options considered for a new highway linkage in Keynsham connecting the A4175 (North) with the A4 Bath Road.

The note provides a summary of design considerations and site constraints affecting construction and construction issues for the bridge structures crossing the Great Western Main Line (GWML) for the three design options that have been explored.

2.0 Description of Proposed Options - 'Long List'

The 'long list' of options considered for the alignment of the route are shown in Appendix B to the Options Assessment Report (OAR)

The three route options considered for the section east of Broadmead Lane are as follows:

- Option 1 would turn southwards to cross under the railway line using a replacement structure at the location of the existing underbridge at Broadmead Lane. This would then use the existing route of Broadmead Lane to join the A4 at Broadmead Roundabout;
- Option 2 would continue eastwards beyond Broadmead Lane, staying north of the railway and using the widened alignment of an existing lane towards Pixash Lane. A new roundabout would be created at the junction with Pixash Lane; the latter would be widened with a new bridge over the railway immediately to the east of the existing Grade II Pixash Lane bridge, before tying back into the existing Pixash Lane alignment southwards. This option would require the introduction of traffic signals at the junction of Pixash Lane and the A4; and
- Option 3 would continue further eastwards approximate 350 metres beyond Pixash lane on a new road alignment, before turning south to cross over the railway on a new bridge, and then joining the A4 between Keynsham and Saltford. It has been assumed that this route proposal would join the A4 with a new roundabout between Pixash Lane and Glenavon Farm.

To the west of Broadmead Lane there are three variants of route alignment that have been considered, common to each of the Options 1 to 3:

- Variant A uses the existing Avon Mill Lane connecting to the A4175 Keynsham Road;
- Variant B uses a new alignment heading in a north westerly direction from Broadmead Lane, crossing over the River Avon to new junction with the A4175 south of Sydmead House; and

- Variant C heads in a northerly direction from Broadmead Lane, taking a longer route than Variant B, crossing over the River Avon to join the A4175 midway between Roseneath and Tudor House.

Considering the ‘Structures’ constraints for each variant:

Variant A connects with the existing access road through the paper recycling site extending east from Avon Mill Lane and requires no new structures. There is an existing bridge over the River Chew on Avon Mill Lane which B&NES confirm has adequate loading capacity. The 7.5 tonne weight restriction in force on Avon Mill Lane is not linked to any deficiency in this existing bridge structure.

Variant B includes the construction of a new bridge over the river Avon. Site constraints include difficulties the west of river crossing due to level differences, access and existing land use. This variant will not be considered further.

Variant C connects to the A4175 Keynsham Road with a proposed new roundabout. The new bridge over the River Avon would carry a carriageway with two lanes 3.65m wide, a 1.0m verge and a 3.0m shared use path on the east side. Both straight and curved horizontal alignment options will be considered further at the detail design stage. Sufficient land either side of the bridge is available to enable different bridge positions to be considered in the study.

3.0 Option 1: Replacement of Broadmead Lane Bridge (ST 665 685)

3.1 General

Views of the existing brick arch underbridge to the GWML at Broadmead Lane are shown in Figures 3.1 and 3.2 below.

Figure 3.1: Broadmead Lane Bridge viewed from the south

Figure 3.2: Broadmead Lane Bridge viewed from the north

The existing masonry arch bridge has a span of 3.65m and a headroom of 3.35m (11’ 0”) between the chord lines, which are unusually close together at 1.8m apart. Several replacement options were investigated by Tony Gee & Partners (TGP) in 2004 as part of their feasibility study into improved access to the north side of the railway line. TGP investigated multiple permutations of off line and on line widening and different widths leading to a preferred option of a partially off line or asymmetric portal supported by one thrust bored foundation and one in-situ foundation; the latter constructed within the arch opening. With deference to the previous feasibility study, the options for Broadmead Lane bridge enhancement will be re-evaluated.

3.2 Dimensions for New Opening

The assumed minimum width of the new opening will be 9.7m, comprising a single 1.8m footway, 7.3m carriageway for two lanes and 0.6m verge to the face of the wall. Typically, the span to depth ratio is 15 to 1 for portal or box type structures, so for 9.7m span a deck thickness of 0.65m may be assumed for initial design.

The headroom for new construction needs to be 5.3m above the highest point of the carriageway, footway or verge. The following figures for road and rail levels are taken from the TGP report:

- Construction depth: 0.65m deck + 0.35m ballast + 0.368m track; total approximately 1.4m;
- Rail level existing 20.4m AOD (TGP report para 9.1);
- Soffit level 20.4m AOD – 1.4m = 19.0m AOD;
- New road level 19.0 AOD – 5.3m = 13.7m; and
- Existing road level 14.4m AOD; reduction in road surface level 14.4m – 13.7m = 0.7m

The TGP report considered a wider opening of 12.8m comprising a 7.3m carriageway, 3.0m wide footway and 3.5m combined footway/cycle path. If this were to be adopted, the deck depth would increase to 0.85m and the road would have to be lowered by 0.9m below its existing level.

Any dip in the road profile has implications for drainage and vulnerability to flooding, noting that the area immediately south of the portal is already high risk and within Flood Zone 3.

3.3 Site Constraints affecting Off-Line Construction

TGP considered an option of a new opening wide enough to accommodate the carriageway only (7.3m wide) on the basis that the existing arch would be retained for foot and cycle traffic. To comply with standard TD 27/05 the opening would need to have a minimum width of 8.5m (i.e. 7.3m + 2no. 0.6m verges either side). This would imply a deck thickness of around 0.575m.

A new opening of this type would have to be set some distance away from the existing arch, so that excavation at the rear of the masonry abutment does not destabilise the arch through an imbalance of arch thrust. A separation of up to 10m may be required. Alternatively, for reduced separation, temporary ground anchors installed through the arch abutments may be required to ensure stability of the latter while the new opening is constructed alongside.

Cracking in the parapet above the north elevation and distortion in the horizontal line of the parapet is indicative of foundation failure (Figure 3.3), demonstrating the need for special care to ensure stability is not impaired further.

The bridge plan shown in Figure 2.4 below shows the constraints to deviating the road wholly to either side of the arch to create a new opening, while retaining the existing arch. To the east, the corner of Jewson warehouse would be lost, whilst to the west, part of the land at the rear of the Waitrose superstore would be taken, as well as removal of the telecommunications mast to the north. In both cases the highway horizontal alignment would need adjusting on the approaches both horizontally and vertically to comply with sighting distances. An opening installed to the west is shown skewed, causing a slight increase in length.

Figure 3.3: Broadmead Lane Bridge - Cracking in the south parapet and distortion of the horizontal alignment indicates foundation failure

Figure 3.4: Plan of Broadmead Lane Bridge showing off-line options to east and west

The road south of the railway leading westwards follows the foot of the railway embankment (Figure 3.5). This road would need to be lowered at its junction with Broadmead Lane to suit the dip of the latter needed to obtain the minimum headroom of 5.3m required for new construction. This has implication for the stability of the railway embankment, which would need to be resolved by the inclusion of a toe retaining wall.

Figure 3.5: Road westwards from Broadmead Lane follows the foot of the railway embankment.

3.4 Site Constraints affecting On-Line Construction

The ‘on-line’ option removes the arch and is wider than the off line option, as it will need to provide extra width for footways and cycle paths foregone but not retaining a separate opening. The general form for a portal construction is shown in Figure 3.6 below, this dating from 1987 for Worcester southern link road:

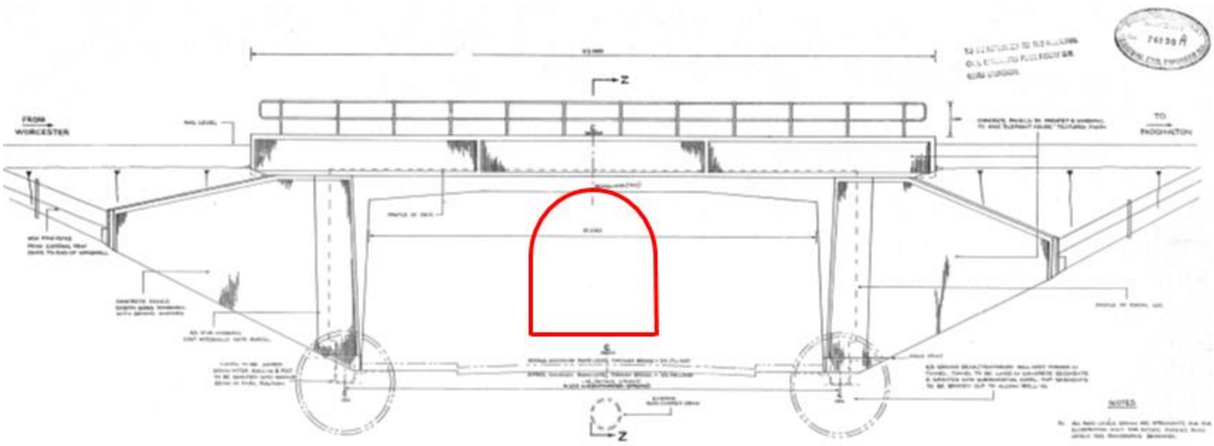

Figure 3.6: Typical portal construction with thrust bored foundations

The method of construction would involve two tunnels being thrust bored through the base of the railway embankment, each in a position such that the tunnel axis is vertically below the centreline of each wall and horizontally about 0.5m below finished road level. The tunnel boring has negligible effect upon the operation of the railway. The tunnels are then filled with concrete to half height and a slide track installed to enable a preconstructed portal to be slid into position during a three or four days possession.

The tunnels in this example had an internal diameter of 3.05m, and formed an effective spread footing about 3.3m wide. The TGP report describes a layer of clay between 12.8m and 11.9m AOD as ‘very soft’ below which firmer strata are encountered. As the new road level will be at 13.7m AOD or lower, it should be possible to ensure that the bases of the tunnels bear within the firmer stratum. If there is insufficient bearing capacity, then mini piles would need to be installed from within the tunnels.

Concentric on-line construction would enable the existing highway alignment to be retained as shown below in Figure 3.7.

Figure 3.7: Portal alignment concentric to the existing arch bridge

Asymmetric construction would allow one of the tunnels shown in Figure 3.6 to be replaced by a deep open cut excavation within the arch. In theory, this reduces cost as only one bored tunnel is required. However, it would not be without difficulties since extensive propping of the masonry abutments would be required to avoid destabilisation, caused by removal of material below and at the side of the existing footings. In short, the arch must remain fully capable of supporting all embankment and rail live load for the duration of the works in close proximity.

Figure 2.8: Portal alignment offset west of the existing arch bridge, utilising the arch for one foundation

The arrangement in Figure 3.8 shows the new opening offset to the west of the existing arch which may benefit the highway alignment and have less impact on Jewson warehouse caused by the need to reduce road levels adjacent to the property boundary. The new portal must necessarily align with the arch at zero skew, as the footing constructed within the arch is parallel to the latter.

3.5 Construction Issues

The portal can only be constructed to the north of the railway where land is available for the construction and site compound without obstructing or requiring diversion of existing roads. The railway embankment carries two tracks but is wide enough for five. We assume that Network Rail will require that the new construction maintains the existing over-wide formation width to allow for any future enhancement of the railway.

The portal length at roof level will be 23m to match the length of the existing masonry arch, whilst at the base of the embankment the corresponding length will be around 42m. The wingwalls are cast integrally with the portal.

The pre-cast concrete portal is built on slide tracks, aligned precisely with the slide tracks under the embankment defining its final position. An alternative to slide tracks is to use a multi wheel transporter as will be used in Worcester May 2018. At Broadmead Lane this would be unsuitable due to the prevailing soft ground conditions close to the surface and the longer length of possession required (5 days), to allow for the need to remove all of the fill from within the portal, not just that obstructing the portal legs and deck.

3.6 Access to Site

The need to keep the bridge open for access to the site and for other users mitigates against the asymmetric on-line method where the arch is obstructed from the outset. However, it is likely that alternative access arrangements would need to be made anyway because the arch opening is very restrictive in terms of what construction plant can pass through. The existing arch may be too restrictive to allow passage of a concrete transit mixer.

Unity Road arch located 300m west of Broadmead Lane has a more restrictive headroom of 9’ 9” (2.97m) and is unsuitable. Pixash Lane road over rail bridge 570m to the east could be used but has a width restriction and the humped vertical profile is unsuitable for delivery of construction plant on low loaders as shown in Figure 3.9 below.

Figure 3.9: Width restriction and blind summit at Pixash Lane Bridge

To facilitate suitable construction access to build Broadmead Lane Bridge, there is a need to construct the westwards link road first (Variant A), or a temporary haul road along the same alignment, in advance of the Broadmead Lane Bridge works. This is shown on drawing 204269.BC.00.28-03 (Proposed Concept Highway Alignment Option 1) in Figure 3..10.

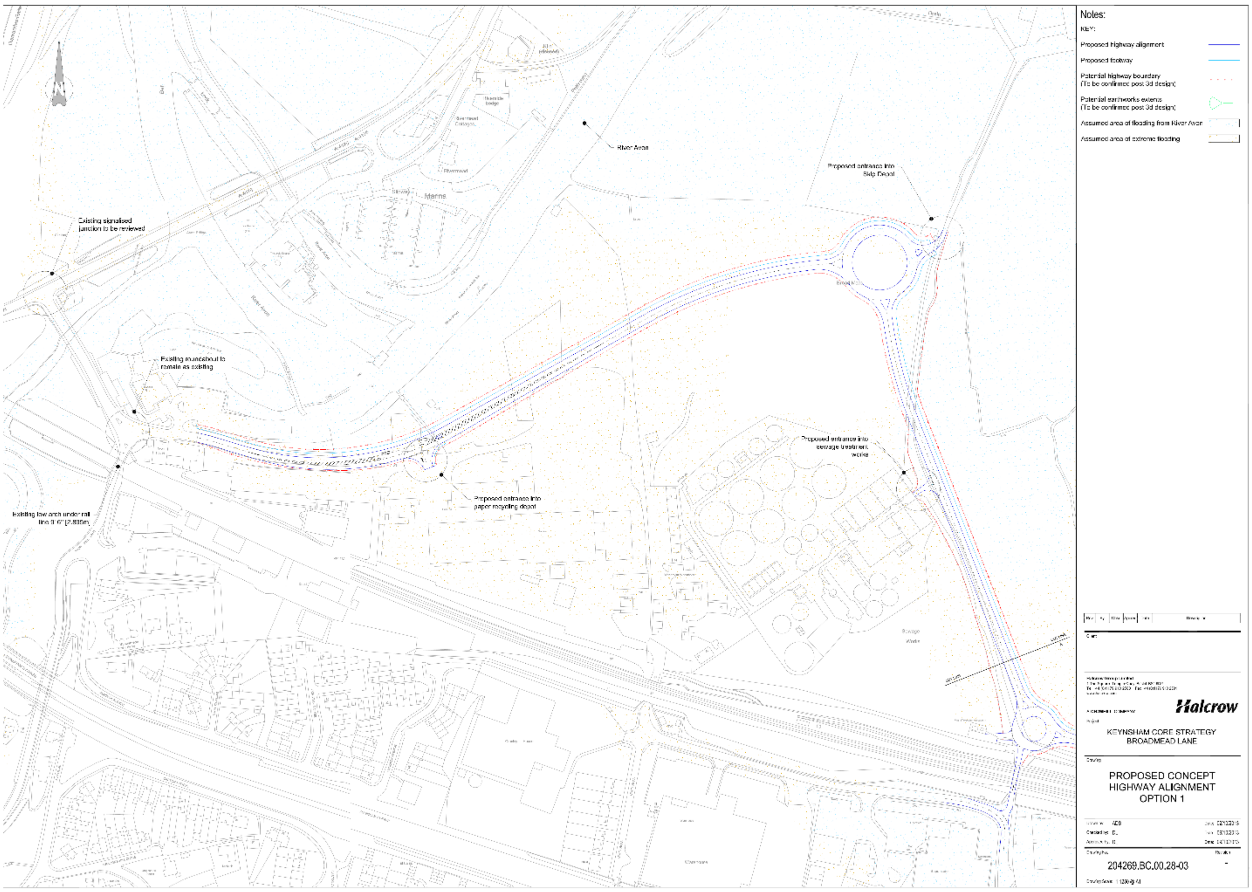

Figure 3.10: Proposed Link Road (or Haul Road) from A4175 to Broadmead Lane Bridge construction area

3.7 Programme

The construction period for a portal would typically be around nine months, and a railway possession requiring three or four days should be planned around three years in advance.

4.0 Option 2: Widening of bridge over railway at Pixash Lane (ST 671 684)

The existing bridge shown in Figure 3.9 serving Avon Valley Adventure and Wildlife Park is of single lane width and the crest vertical alignment is unsuitable for long vehicles. The widening option proposes a new bridge alongside, crossing the railway immediately to the east, with the existing bridge retained for pedestrian and cycle use.

Pixash Lane Bridge is a masonry arch of 9.144m (30') span and is Grade 2 listed, entry number: 1409197 dated 18 July 2012.

http://www.heritagegateway.org.uk/Gateway/Results_Single.aspx?uid=1409197&resourceID=5

Realignment of the road uses part of the site of the recycling centre to the south of the railway. In order to give a satisfactory vertical alignment for forward sighting distance, the approach ramps will need to be longer and higher than those for the existing bridge. There will be a minimum separation necessary between the old and the new structures governed by the need to provide a maintenance space and to ensure that the construction does not impact on the existing bridge such as vibration, or space for foundations. Figure 4.1 shows the view east from the existing bridge.

Figure 4.1: View to the east of Pixash Lane bridge where the new bridge will be located

4.1 Electrification of the Railway

For new construction, the soffit height above the railway has to be 5.1m (ref. NR/L3/TRK/2049 figure G.1.1a issue September 2017) to allow for maximum flexibility in the design and installation of overhead line equipment (OLE). The listed status for Pixash lane Bridge will probably prevent any modification to the bridge in pursuit of increased OLE clearance if any are needed, resulting in track slew or track lowering. Generally listed bridges of this type impose a constraint on the OLE, which has to dip down to a sub-optimal height under the bridge, before rising again on the other side.

The OLE has to be level under both bridges with special measures taken to restrict the upward deflection of the wire as necessary to suit the existing bridge headroom. To attain this objective of rigidity, the OLE support masts have to be spaced 13m apart in the vicinity of the bridge (ref. Furrer+ Frey design manual), which implies the need for a mast between the bridge and then 13m either side. It is important to ensure that the plan areas of foundations for the new bridge do not impede the location where future OLE foundations need to go.

If the OLE is in place in advance of bridge construction, then 3.0m electrical clearances has to be observed during construction of the abutments. Requirements for piling safety are set out in NR/L3/INI/CP0063 as below (Figure 4.2). If this cannot be achieved then piling and other works will be restricted to night time work under possession and with electrical isolation, resulting in a considerably increase in cost, project duration and noise nuisance.

It follows therefore that the clear span of bridge between abutment faces will be in the order of 15m to 16m.

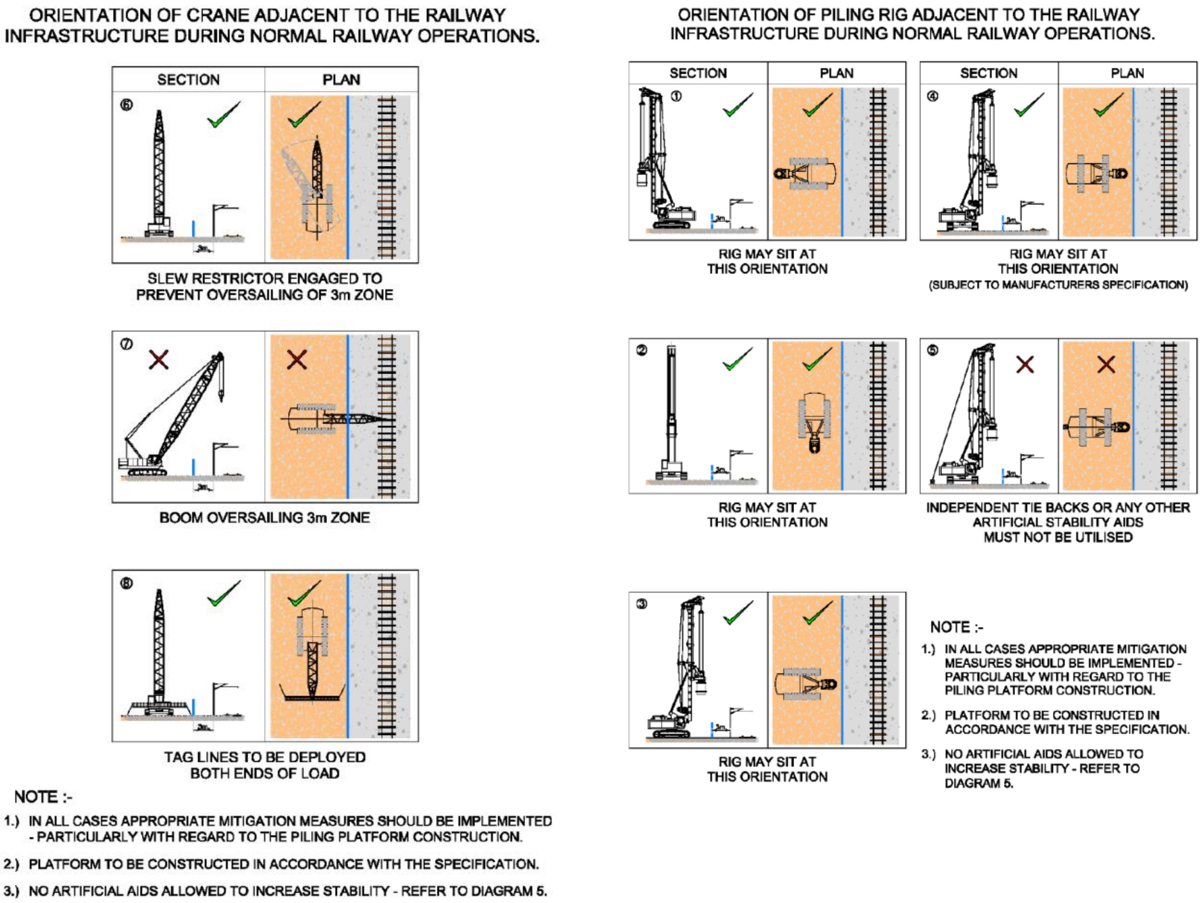

Figure 4.2: View Excerpts from NR/L3/INI/CP0063 showing orientation of piling rig and OLE clearance.

4.2 Bridge Deck Form

Pre-cast concrete bridge beams are most suited to the construction of the new bridge, with integral end moment connections to the abutments. Any of MY, T, TY or SBB (solid box beam) types are suitable, the objective being to place all of the beams and concrete edge parapets in a single overnight possession and to create a safe working platform from that moment onwards so that materials cannot drop on to the line.

By reference to the Shay Murtagh and Banagher Concrete design manuals, the following depths of construction can be inferred:

- MY4 & MYE4 450mm + 150mm topping = 600mm;
- SBB type SD3 500mm + 75mm topping = 575mm (Banagher) topping 125mm (Shay Murtagh);
- T3 535mm + 125mm topping = 660mm;
- TB4 525mm + 125mm topping = 650mm; or
- TY4 &TYE4 550mm + 150mm topping = 700mm (solid slab)

Based on a structural span of 16.0m (clear span 15.0m) and the use of the higher-grade concrete C57/70, it can be seen that type SD3 offers an advantage on construction depth. At the detail design stage, there is a need to ensure that sufficient steel for integral hogging moment continuity can be incorporated into the topping towards the deck ends. The overall construction depth from soffit to finished road level will be increased by the thickness of waterproofing and surfacing, a minimum of 0.12m at the channel, plus extra thickness required to make up vertical curvature and transverse camber. Some typical details are shown below in Figure 4.3. The parapet wall may be supplied cast together with the edge beam at the factory, depending upon lifting weights.

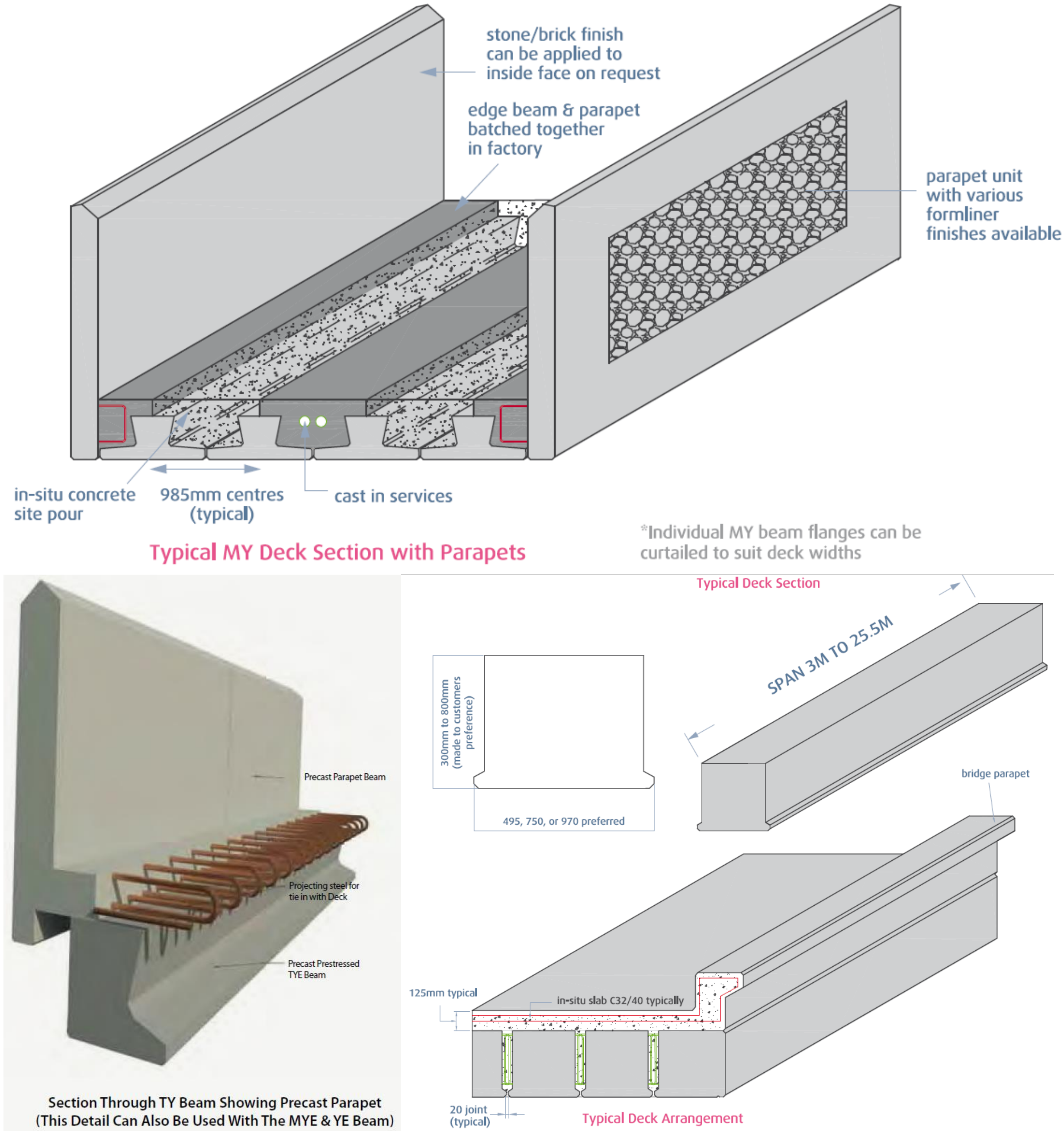

Figure 4.3: Excerpts from Shay Murtagh and Banagher bridge manuals showing typical deck details

4.3 Abutment Form

The abutment will take the form of a leaf pier mounted on either spread footings or piles. If the ground is firm with high allowable bearing pressure close to the surface, spread footings will suffice. Any excavation must not encroach within a 45° dispersal line extending downwards and away from the sleeper ends.

Wingwalls will cantilever out from the back of the abutment on a line parallel to the road, to minimise any effect of the new construction on the existing bridge or its approaches.

4.4 Site Constraints

Figure 4.4: Pixash Lane site plan

Figure 4.5: Pixash Lane Bridge aerial view from the west showing refuse depot

As for Broadmead Lane Bridge, more space exists to the north of the railway for a site compound, where the land is less developed. However, the size of plant able to reach the site is limited by the width and/or height of various existing bridges go under or over the railway. There would be a prerequisite for a haul road to the A4175 to be built in advance as previously mooted. In any event large quantities of fill material are required to bring the road approach ramp on the north side up to the level of bridge deck, and that requirement may best be met by a dedicated haul road. Note that the railway is approximately at the same level as the land either side, thus the height of the embankment will be in the order of 7m.

If the refuse depot south east of the bridge can be temporarily closed, the area released would be suitable for a site compound.

The site plan (Figure 4.4) shows a drain north of the railway directly below the footprint of the new northern approach embankment. This and any interface with the railway drainage will need diverting in advance.

4.5 Programme

The construction period for a new bridge would typically be around six months, and a railway possession requiring two or three nights should be planned around one year in advance.

5.0 Option 3: New bridge over railway east of Pixash Lane (ST 675 682)

Figure 5.1: Site for bridge in green field land to the east

At this location the railway is in a shallow cutting about 1.5m deep. The same construction constraint issues apply as for the Option 2 bridge alongside Pixash Lane. As the bridge will be at a skew angle of about 30°, the span will increase by 15% to 17.5m, requiring deeper beams. The curved alignment will require a wider bridge to ensure sighting on the inside of the bend.

Note that in the event of there being railway signal sighting issues on the inside of the bend, the span may have to be increased. Also, the soffit height of the bridge may need to be greater than 5.1m above the rail to enable greater flexibility in the design of the OLE, there being no other local constraint to height. Both of these issues to be agreed with Network Rail would conspire to increase the approach embankments height and length, adversely affecting the cost and viability of this option.