Birse
Rail Consultancy

Network Rail

Network Rail (London North West Territory)

Support for Listed Building Consent

Structure Name:	*Bridge 42*	Structure Number:	*42*
ELR:	*BEJ*	Mileage:	*10m 0462yds*
Structure Type:	*Underbridge*	OS Ref:	*SP 105 775*
Location:	*Whaley Bridge, Derbyshire*		
Report Ref:	*R2200-P7F98-LBC-04*		*Revision: -*

Western Elevation of Underbridge 42

Author:	Birse Rail Consultancy	L Robb (Designer)	Date 3/02/09
Checked:	Birse Rail Consultancy	J Stiles (CRE)	Date 3/2/09
Approved:	Birse Rail Consultancy	S Moon (CEM)	Date 3.3.9

SUPPORT FOR LISTED BUILDING CONSENT

Contents:

Appendices

IDENTIFICATION OF STRUCTURE

Fig 1 : East Elevation

Fig 2 : West Elevation

Building Name: Railway Bridge	**LBS Number:** 469325
Parish: Whaley Bridge	**Listing Grade:** II
District: High Peak	**Date Listed:** 19/06/1998
County: Derbyshire	**Date of last amendment:** 19/06/1998
Postcode: SK23 7HT	**NGR:** SK 01148 81154
Road Name: Market Street (A5004)	**Structure Type:** Rail over Road (Underbridge)
Railway Structure Number: 42	**Engineers Line Reference:** Buxton to Edgeley Junction (BEJ)
Railway Mileage: 10miles 0462yards	

EXECUTIVE SUMMARY

This report has been written in support of Network Rail's proposal to reconstruct Bridge 42, spanning Buxton Road in Whaley Bridge, Derbyshire.

The Grade II listed bridge carries rail traffic over the 'BEJ' route from Buxton to Stockport. This route has a line-speed of 50mph and is capable of accommodating RA10 traffic (heavy freight), except for Bridge 42, which does not meet the necessary loading capacity. Essentially, this restriction imparts a speed restriction over the bridge of 10mph, together with a limiting effect on the amount of freight traffic permitted on the route.

This report examines the importance of the BEJ route in context with the rail network as a whole, and seeks to provide a full narrative explaining the drivers behind the proposed reconstruction.

PPG15 requires that any proposal for the demolition of a listed structure must (not exhaustively) demonstrate:

> *"clear and convincing evidence that all reasonable efforts have been made to sustain existing uses of find viable alternative uses, and these efforts have failed; and that preservation is some form of charitable ownership is not possible or suitable, or that redevelopment would produce substantial benefits for the community which would decisively outweigh the loss resulting from demolition."*

Clearly, alterative uses or preservation would not be viable options given that the structure is an integral part of the operational railway, therefore, the thrust of the evidence in this report focuses on the "substantial benefits" that would outweigh the loss of the bridge, and importantly, why the bridge cannot be repaired or strengthened to achieve the expectations of a modern railway.

In considering available options to overcome the constraints related to the bridge, the following factors have been taken into consideration:

1. Line-speed

The BEJ route is capable of accommodating rail traffic at 50mph. However, there is a 10mph speed restriction imposed on the bridge due to the risk associated with its limited capacity and defects. Effectively, a train travelling at 10mph exerts little more stress on a structure than a train standing still.

2. Line capacity

Directly linked to line speed, capacity is limited on the BEJ route because of the risk associated with heavy freight trains, therefore freight is restricted to limited weekend movements only. The speed restriction does not allow for freight to be interspersed with passenger trains without significantly impacting on travelling times.

3. Economic drivers

Most minerals mined from the three Peak quarries (Dowlow, Tunstead and Peak Forrest) are carried by rail freight on the Chinley to Buxton (CNB) line via Dove Holes Tunnel. The tunnel is suffering from significant drainage problems which will need to be remedied in the near future. This will result in a lengthy closure of the tunnel, during which time the freight will not be able to use this route. The only alternative is BEJ, however without sufficient capacity over Bridge 42, freight would have to be carried by road.

There are inherent problems associated with this such as weight restrictions on the highway network, and limits on the amount of lorry movements, which could ultimately have a severe impact on the export of quarried materials.

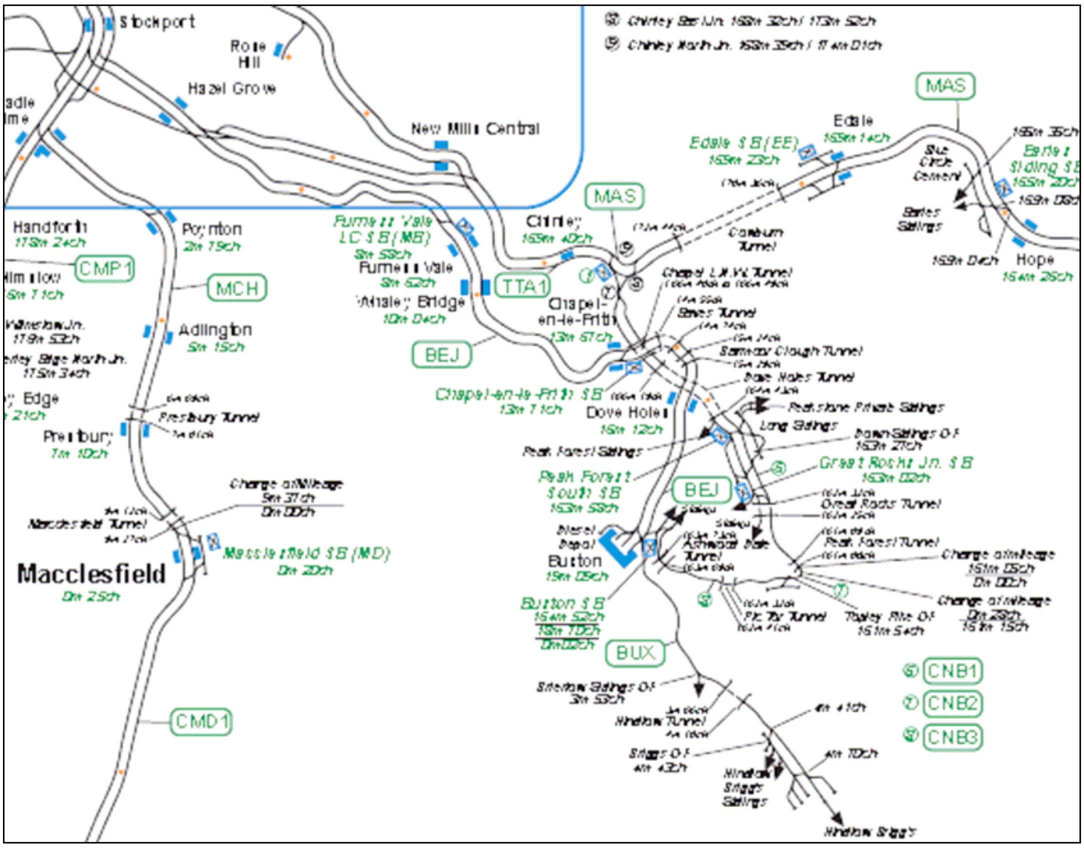
4. Diversionary route

The BEJ line could provide a diversionary route as an alternative to the CNB line to allow for trains to be re-routed during planned works (such as those mentioned at Dove Holes tunnel). Network Rail's freight customers EWS and Freightliner Heavy Haul and their end-customers such as Lafarge, Cemex, RMC Roadstone, ICI Chemicals and Polymers Group, ICI Lime Division, Tarmac and Peakstone (Beswick Lime Quarry) have indicated that in order to safeguard their businesses, it is essential to retain the flexibility of routing trains via both the BEJ and CNB routes. The restrictions imparted by Bridge 42 are therefore unacceptable to rail users.

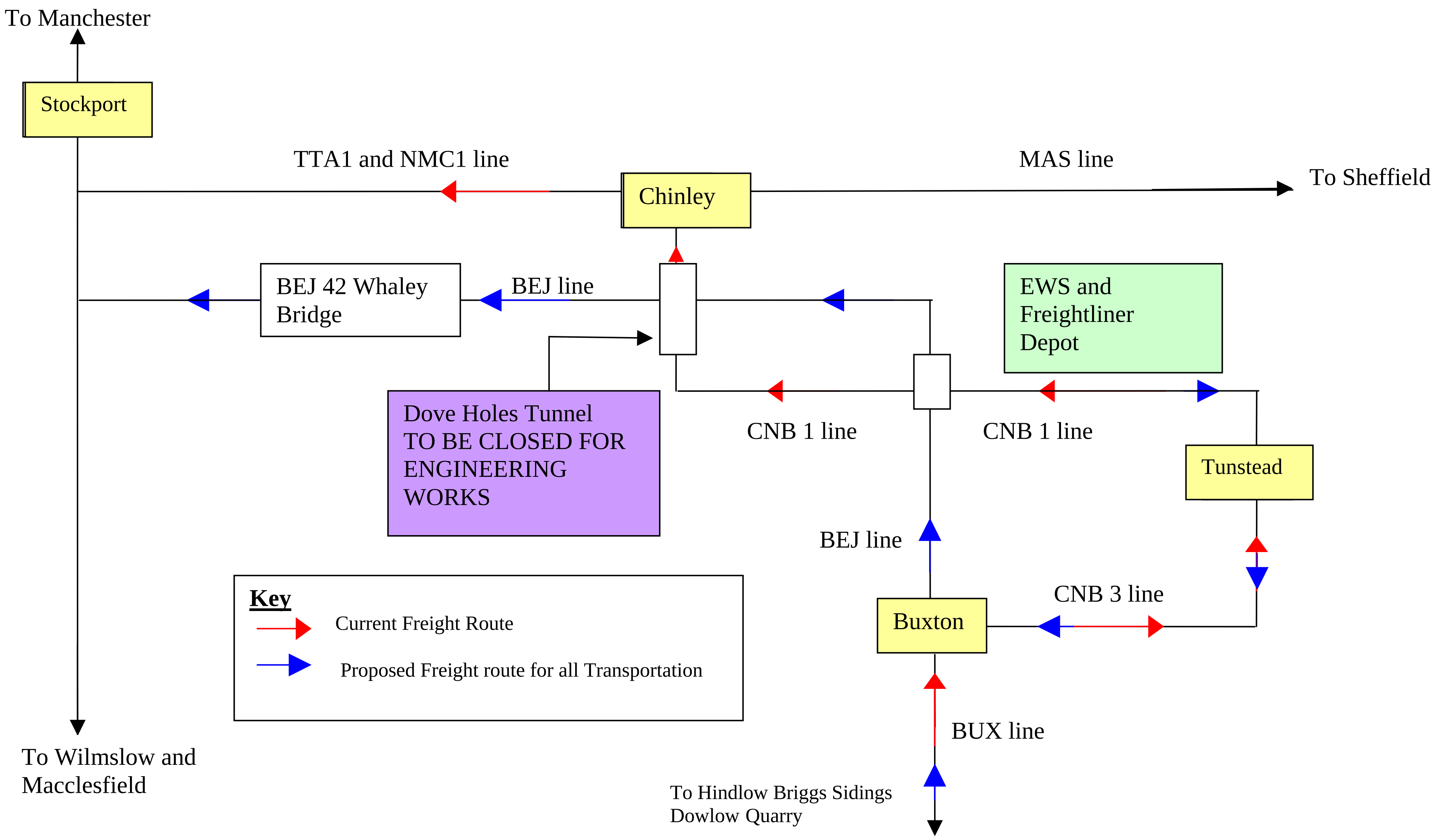
In conjunction with the Department of Transport and the three northern Regional Development Agencies (One North East, Northwest Regional Development Agency and Yorkshire Forward), Network Rail is currently looking at the feasibility of creating a 'Manchester Hub' to provide better links with key rail services across the north of England. The resolution of capacity issues around Manchester are considered vital for the economy of the north of England.

Although the line between Buxton and Stockport is not specifically mentioned in the debates to date the route between Sheffield and Stockport (The Hope Valley Line), which is currently at capacity, is referred to as a constraint to growth. By relieving Freight trains from this route and diverting them via the Buxton to Stockport route, capacity will be released for other services and therefore allow for growth in rail services.

The map below identifies the bridge in context with the network, whilst the route diagram on the opposite page illustrates the pathing opportunities that could be achieved without the restrictions over Bridge 42.



LINE DIAGRAM TO DEMONSTRATE PATHING OPPORTUNITY FOR FRIEGHT OPERATING COMPANIES AND STAKEHOLDERS



5. Bridge defects

A number of fractures have been identified in the cast iron elements of the bridge, with historic repairs in situ. Further intrusive investigations requiring the removal of the existing deck concrete have not been carried out as there is a high likelihood that additional defects will be uncovered (or indeed inadvertently caused by the breaking out of the concrete). Should further defects be found, this would reduce the current limited capacity of the bridge, and with no guaranteed repair and strengthening techniques, would lead to road and rail closures for an unknown period of time.

Not withstanding the presence of defects in the cast iron, the structure itself is not designed to be capable of carrying the expected loading of the rest of the BEJ route. This is due to the stresses applied by passing trains and the resulting rotational forces exerted on the bridge, exacerbated by the skewed alignment of the structure.

6. Road clearance (and potential 'bridge bash')

The clearance (distance from the road level to the bridge spans) is below that of modern highway standards, and as a result there is a risk of the bridge being "bashed" by a high vehicle passing underneath. Given the nature of cast iron, a collision could potentially cause a catastrophic failure of the entire structure, or cause damage to hidden areas of the bridge making an assessment of the damage difficult (if not impossible) to quantify.

Cast iron is also susceptible to sudden brittle failure and is unlikely to exhibit defects that would alert Network Rail to such a bridge bash, unlike other metals that would show bends or tears, prompting intervention.

Options to mitigate this problem could potentially involve the introduction traffic calming measures to create single file traffic in the centre of the road where the clearance is greatest, or lowering the road to increase the height. Whist both of these options are feasible, they would not be desirable due to the impact on traffic in Whaley Bridge, and the presence of buried services in the road, and potential flooding issues.

These options have not been explored in great detail as they would only serve to improve one of the constraints associated with the bridge, and would not increase the line speed or capacity, which is the ultimate aim of Network Rail.

In essence, the following options are examined within the report:

- Repair

This would consist of repair to the existing structure, with very little intervention. This option has been ruled out because it doesn't allow the speed restriction to be lifted, nor does it allow for increased freight capacity, together with the fact that it doesn't negate the risks associated with the over-stressed elements. The techniques available for repairing cast iron cannot be guaranteed for load-bearing elements because of the specific effects imparted on them in this location.

- Strengthening

All strengthening options must consider the geometrical and loading constraints that are to be met. Only the most feasible strengthening options are covered in the report, and not options such as "lowering the road", or "raising the bridge" as these are deemed unacceptable from the outset.

In addition, strengthening of the structure will necessitate compliance with legislation and modern standards that will not be accommodated by the cast iron elements. Ultimately, it would not be possible to strengthen the bridge given the constraints described in detail in the technical report; the addition of new elements would need to provide significant or full support to the railway above, leaving the original cast iron structure effectively redundant in its capacity as a bridge. This would bring into question the validity of retaining a structure that is not doing the job it was designed for along with the associated risks of the arch retention.

- Reconstruction

Reconstruction would allow for the line-speed to be increased to match that of the BEJ line, and would permit access to additional freight movements. A new bridge structure would also allow the line to be used as an effective diversionary route at times when the CNB line is closed.

The clearance height from road level of any new bridge would be above that required by the current highways legislation, thus mitigating any potential bridge bash occurrences. In addition, new bridges are designed to resist the impact of most collisions from highway vehicles without the potential failure associated with cast iron.

This would also be the quickest solution in terms of disruption to both road and rail traffic.

It is important to highlight that there are a number of options available for any new bridge including a curved span alluding to the form of the existing bridge, or a modern architecturally designed bespoke structure. A design would be agreed in consultation with the Local Planning Authority.

Benefit Analysis of Reconstruction

Reconstruction Benefits	Reconstruction Dis-benefits
Reinstates route capacity	Loss of a listed structure
Safeguards future freight traffic	
Meets our customer's expectations	
Improved bridge strike mitigation	
Reduces highway and rail closures required for maintenance purposes.	

Conclusion

Network Rail, as custodians of over 2000 listed buildings and structures, takes a responsible and active role in maintaining and enhancing the historic environment, whilst operating the core business of providing a modern and efficient railway network. It is rare that these two objectives conflict in such a way as that experienced in respect of Bridge 42. Indeed, the bridges listed below are of similar form and continue to work effectively as part of the rail network:

- DSE UB 146 Spans 58 & 59. New Bailey St, Salford - Refurbished in 2007 (not an arch);
- COL UB 62A Gloucester St, Manchester - Refurbished in 2008;
- COL UB 94A Castle Street, Manchester - Refurbished in 2008;
- COL UB 93A Chester Road, Manchester – Planned refurbishment in 2009;
- COL UB 92B Knott Mill, Manchester – Planned refurbishment in 2009;
- BBB UB 2 Croal Viaduct – Draft plans to refurbish in the next 5 years.

Whilst every avenue to repair and strengthen the structure to meet the expectations of our rail customers has been explored, the report demonstrates that neither of these options would achieve any real long-term benefit, as replacement would be anticipated within a five year period. In conclusion, the report supports the proposed reconstruction of the bridge.

1.0 INTRODUCTION – DESCRIPTION AND HISTORY OF THE STRUCTURE

The current structural arrangement comprises three pairs of cast iron arches spanning between the masonry abutments. Spanning between the arch pairs are wrought iron cross girders with curved wrought iron floor plates. A concrete slab is present over the entire deck that encases the tops of the hidden arch elements. The slab has then been waterproofed with a bituminous material.

The structure carries two live railway lines over the A5004 (Market Street). The structure is highly skewed at 45 degrees and spans 20m over the busy road.

The original construction of Bridge 42 was undertaken in 1863. Relatively quickly after the construction, the entire original cast iron floor sections that spanned between the arches were removed and replaced in their entirety with Wrought Iron beams and a concrete slab circa 1896. It is this arrangement that is still present today.

It is not recorded as to why the cast iron elements were replaced, however the changes did not reduce weight, or provide an obvious betterment in terms of reduced floor thickness, or wider deck for example. It is envisaged that the cast iron cross girders may have been showing signs of distress from dynamic loading. Alternatively the works may have been undertaken in response to a number of Cast iron railway bridge collapses starting with the 'Dee Bridge Disaster' in 1847 through to the Norwood Junction collapse of 1891.

Figure 1: View of Bridge Soffit

During the replacement of the floor in 1896 the archive drawings record the necessity to repair a crack in one of the cast iron arches. During the removal and replacement of the new deck elements, the opportunity was undertaken to repair the crack as depicted in Figure 5. It is important to note that it was necessary to remove the deck in the location of the defect to undertake the repair.

A number of the original cast iron bracing elements have also been replaced with Wrought Iron angle sections also depicted in figure 6.

As a result of the deck replacement in 1896, only the cast iron arches, parapets and some bracing elements remain as part of the original 1863 structure, which has been subject to railway traffic operation for over 145 years.

2.0 CURRENT CONDITION AND CAPACITY OF THE STRUCTURE

2.1 Superstructure

The following elements of the structure are showing signs of distress and are in poor condition:

1. Crack to cast iron arch connection at mid span;
2. Crack to cast iron arch member at springing point;
3. Cracks to cast iron parapets and displacement;
4. Cracks to 2 No. cast iron bracing elements;
5. 2No. Tie bars missing;
6. Corrosion of floor plates at deck ends over abutments;
7. Waterproofing failure – signs of water egress through soffit.

There are a number of key elements to the structure that are hidden and their current condition is unknown.

The remaining elements of the superstructure are in 'fair' condition. This can be attributed to the quality of the workmanship combined with suitable maintenance over the 140 years working life.

2.2 Substructure

Generally, the condition of the substructure is in 'good' condition. The substructure is showing no signs of distress and no significant defects have been noted, however, the following defects are present:

1. Vegetation growth and staining of abutments and wingwalls; in some areas;
2. Minor masonry defects (mortar loss, spalling and minor cracking etc).

2.3 Capacity of the Structure

In 1997 Network Rail (Formerly Railtrack) commissioned a structural assessment of Bridge 42 by an independent consultant. The purpose was to assess the capacity of both the superstructure and substructure against the current loading from railway traffic. The results of the assessment indicated that a number of elements were being overstressed as follows:

- Cast iron arch ribs overstressed at the mid point connection (6 No. locations);
- Cast iron arch ribs overstressed at every connection with internal cross girders (102 No. locations);
- All cross girders overstressed in bending (51 No.)

Based on the results of this assessment, the train speeds on the structure were reduced so as not to overstress the above elements as follows:

- 50mph for light locomotives;
- 25mph for class 60, 66, 67, 73, 37, 47, 55, 56, 58, 59, 8, 20, 31, & 33 locomotives;
- 10mph for Heavy Axle Weight Vehicles & Freight.

Since this time, the structure has been regularly inspected to ensure that the above speed restrictions were sufficient to reduce the loading to acceptable levels and limit the propagation of the defects outlined above.

As a minimum Network Rail must address the above defects whilst ensuring that economic and operational requirements of the railway are reinstated to the required capacity with consideration for realistic anticipated growth. These requirements are detailed in the following section.

3.0 RAILWAY ECONOMIC AND OPERATIONAL REQUIREMENTS

The strategic requirements for the railway in the area are key on developing the BEJ line as an alternative route to the currently highly utilised Manchester to Sheffield line (MAS). The MAS line is currently near full utilisation and cannot support the freight growth anticipated. The only structure on the BEJ line that does not meet the proposed increase in traffic volume, freight speed and freight axle weight is Underbridge 42. The necessity and consequences of these increases are described in more detail below as follows:

3.1 Increase In Traffic Volume

Growth at the quarries at Dowlow, Tunstead and Peak Forest has increased in recent years, which has resulted in congestion on the Hope Valley rail route (part of the MAS line). To relieve the freight frequency on this line, the only alternative is to use the BEJ route. This would have the effect of increasing the rail freight traffic on the BEJ line.

- This will have a significant increase in fatigue cycles generated in the structural elements.

3.2 Increase in Freight Vehicle Speeds

The heavy axle speed restrictions currently imposed on the BEJ line prevent the opportunity for the FOC's to operate trains between the regular passenger services operated by 'Northern Trains'. This is due to the difficulties in timetabling speed restricted freight trains efficiently between passenger trains.

- The proposed speed increase for freight vehicles (10mph – 50mph) would amplify the vertical dynamic loading factor by up to 40%. In addition, the increase in horizontal centrifugal loading from the same speed increase would be in the order of 1700% (17 times greater).

3.3 Increase in Freight Axle Weight

In addition to the above heavy axle speed restrictions, the heaviest axles are restricted from using the BEJ line. It is proposed to increase the maximum freight axle weight from 23t to 25.5t. This proposed increase in axle weights is to ensure that the alternative BEJ route can be used as a direct alternative to the congested MAS lines.

- This would represent an additional 10% increase in vertical and horizontal live loading.

In addition to the above long term strategic demands on the BEJ line, there is also an immediate requirement for a temporary increase in utilisation of the line, to facilitate required closures of adjacent parts of the network for major maintenance and renewals, as follows:

3.4 Dove Holes Tunnel Major Maintenance

Dove Holes tunnel is a long tunnel on the Chinley to Buxton (CNB) route and requires major refurbishment works to improve track drainage and water management. To undertake the works, a number of long tunnel closures are required and a suitable diversionary route needs to be in place. Network Rail have undertaken a review of the potential diversionary routes and have determined that the only suitable option is to utilise the BEJ line from the Tunstead terminals to Stockport Manchester. However, the current operating restrictions over Underbridge 42 would mean that passenger services would be significantly disrupted if the restrictions cannot be lifted.

Increasing the capacity over Underbridge 42 is a 'critical path' operation in the wider strategy of improvements to the local rail network.

3.5 Improvements in Passenger Services

The ability to reduce freight traffic on the adjacent lines will benefit passenger based 'train operating companies' (TOCS) as current congested routes leave little potential for an improved passenger train service.

Without the ability to implement these drivers, the strategic rail growth plans for the area will be severely affected.

4.0 ENGINEERING REQUIREMENTS

In addition to the above economic and operating improvements required on the BEJ line, Network Rail wish to address the associated engineering aspects when considering addressing Underbridge 42:

4.1 Impact Risk from Highway Vehicles

Currently, the structure is unsigned with minimum headroom of 4585mm (15ft) and is spanning the busy A5004 road named Market Street.

The material, form and condition of Underbridge 42 is such that it is vulnerable to severe consequences from bridge strikes. The bridge form is such that the main structural cast iron elements are exposed to direct impact and could lead to unpredictable or perhaps sudden local or global collapse.

A recent bridge strike in 2007 caused damage to two of the bracing elements such that one was partially dislodged and the other was hanging over the footway. The bridge strike report indicated that vehicles parked adjacent to the bridge may have forced the high vehicle to take a revised line under the structure to avoid on-coming traffic passing around parked vehicles. This shows that drivers of large vehicles do need to negotiate the arch soffit to avoid a bridge strike.

Network Rail have experienced first hand the consequence of a bridge strike to cast iron arches when in 1975 Underbridge 34 (on the BEJ line) had to undergo emergency reconstruction after an impact event. The structural form of the cast iron arches on Underbridge 34 were identical to those at Underbridge 42.

It is Network Rail's aspiration is to eliminate this risk during any works.

4.2 Repairs and Maintenance

The existing structure is in requirement of the following works:

1. Grit blast and renew protective treatment;
2. Deck waterproofing and deck end drainage;
3. Repair / brace around cracked cast iron central arch joint;
4. Repair cracked cast iron spandrel up-stand;
5. Repair cracked cast iron bracing;
6. Replace 2 No. missing tie bars;
7. Repair cracked cast iron parapet sections.

It is Network Rail's aspiration to tackle these points when developing the preferred option.

4.3 Confidence in Long-term Performance and Structural Adequacy

Items 3, 4, 5 & 7 above, are defects that are non-maintenance related and are either due to structural overstress, fatigue or casting defects in the original cast iron. In the short, medium and long term, Network Rail wishes to have confidence in, and ensure the adequacy of, the entire structure. It is of great significance for Network Rail that unforeseen maintenance and repairs that will disrupt the operational railway are guarded against, especially considering the required increase in traffic volume, freight speed and freight axle weight outlined in Section 1.0 above. The following points discuss the particular areas of Network Rail's concerns in more detail as follows:

- The route between Buxton and Edgeley Park is limited by U/b 42. The route is a strategic option for increasing rail freight in future;

- There is an aspiration for NR to restore the line speed over the bridge to improve the frequency of services. There is currently a long-term speed restriction on the line because of the structure's condition.

5.0 TECHNICAL REPORT

The above sections have outlined the case for improvements at Whaley Bridge to be implemented, the following elements of the report detail the justification for the proposed option to meet the requirements and they also respond to the specific requirements of Tim Allen, English Heritage Officer for East Midlands Area (provided to Network Rail via email on 20th November 2008) with regards to Network Rail's proposals to address the shortcomings of the current bridge asset. The requirements are as follows:

"We have examined the proposals from Network Rail and our view is that insufficient efforts have been made by the applicant to explore the scope for repair and strengthening of the present bridge structure so it can continue in use.

The applicant does not sufficiently explore the feasibility of removing the existing concrete fill to the bridge deck so as to access the cast iron work for repair and the introduction of addition structural elements.

The applicant has failed to explore solutions in which realistic loadings might be accommodated through repair and strengthening of the existing fabric. Replacing the bridge deck with an entirely new element in order to carry aspirational loadings much higher than those likely to be required in the foreseeable future should not be the solution. This issue should be explored with reference to the likely load requirements laid out in the Rail User Strategy as opposed to the much higher figure in new deck design brief from Network Rail.

The cast iron arches of Bridge 42 make an important contribution to the local historic environment and we do not feel they should be lost without the exploration of more sophisticated solutions than that proposed."

Each comment in turn has a response in the subsequent sections of the report. In each case, full justification for the response is provided.

In conjunction, the report and appendices demonstrate that repair and/or strengthening options are not feasible because they are contingent on risks to the safe operation of the railway, which cannot be practicably mitigated. Likewise, the statutory engineering requirements for strengthening introduces U/b 42 to structural design conditions that will make compliance unachievable.

English Heritage comment:
"We have examined the proposals from Network Rail and our view is that insufficient efforts have been made by the applicant to explore the scope for repair and strengthening of the present bridge structure so it can continue in use."

U6.0 RULING OUT REPAIRS & STRENGTHENING

6.1 REPAIRS

Birse Rail Consultancy have undertaken 3D modelling of the deck to analyse the arch behaviour to determine the potential overstress from the combined tension(s), prying force(s) and shear. The results of the analysis have shown the following:

i) That the current loading restrictions on the structure would appear to reduce the stress levels to within acceptable limits (assuming the section was un-cracked) and that any attempt to reinstate the line speed would increase the stress to levels that are unacceptable for the safe and continued use of cast iron;

ii) The flanged bolted connection would increase any tension affects further via prying force;

iii) That determining the capacity of the cracked section of the arch would only result in reducing the assessed capacity even further.

iv) In the areas identified as 'overstressed' through analysis, two fractures are evident within the cast iron and a third crack is intimated in the archive drawings for the structure.

v) The causes of such defects in the cast iron are attributed to the loading regime overstressing the elements combined with fatigue over the 145 year life of the structure.

vi) The cross girders do not meet the assessment criteria based on their original geometrical properties and can only be strengthened to meet the required capacity.

A detailed summary of the analysis and results are included in Appendix C.

As a result of the above findings Network Rail have considered the following repair and strengthening options:

6.1.1 Option 1 – Keep Existing Line Speed and Monitor Defect

The 3D assessment shows that at the current line restrictions, the stress could be managed to within acceptable limits, however, this assumes an 'uncracked' section. The actual capacity of the cracked sections would be significantly reduced and as a result:

- Network Rail are not willing to leave the cracks insitu in their current state;
- The cross girders cannot be repaired and require strengthening;
- Network Rail are not willing to keep the current line restrictions in place;

As a result this option has been discounted.

6.1.2 Option 2 – Keep Existing Line Speed and Undertake Repair

Network Rail have investigated repair techniques and have concluded the following:

- The cast iron elements cannot be welded insitu, due to the number of variables that need to be controlled;
- Any welding would be a stress raising and fatigue detail that cannot be relied upon;
- Taking the arch down, taking it away to a workshop, repairing and reinstating has been ruled out as this would necessitate closing the railway and road for a significant time and is also not physically practicable;
- Metaloc crack stitching is not a structural repair that can tolerate repeated cyclic loading and tension to be resisted at the repair location.;
- Consultation with contractors specialising in repair of CI structures concluded that the performance of any repair will not be guaranteed due to the uncertainty with other key factors, such as load, environmental effects and vibration. This offers NR no assurance to the lasting function of the structure, particularly with regard to robustness against (collision) loading;
- The cross girders cannot be repaired and require strengthening;

As a result this option has been discounted.

6.1.3 Option 3 – Reinstatement of Original Existing Line Speed and Monitor Defect

- The results of the above assessment combined with the presence of a crack at the locations identified as overstressed in the assessments of the structural capacity are not deemed a 'coincidence'. As a result, it is not possible for NR to remove the operating restrictions on the line without addressing the defects.
- The cross girders cannot be repaired and require strengthening;

As a result this option has been discounted.

61.4 Option 4 – Reinstatement of Original Line Speed and Undertake Repair

Based on the fact that even in undamaged / original condition the arch structure would be overstressed by the removal of the operating restrictions, it is not possible to repair the structure and remove the restrictions.

As a result this option has been discounted.

Based on the outcome of the above assessment it is clear that strengthening must be undertaken to reinstate the operational capacity of the line meet the demands on the railway.

English Heritage Comment:
"The applicant has failed to explore solutions in which realistic loadings might be accommodated through repair and strengthening of the existing fabric."

6.2 STRENGTHENING

Particular strengthening options are discussed in Section 5.4. Adopting a strengthening and repair route will necessitate full use of current design standards, codes of practice and other relevant industry publications.

Given that NR do not consider that any repairs as stated above would actually provide any tangible benefit to the status quo, any strengthening works would need to be designed such that they were sufficient for all design loads to bridge the overstressed areas. The requirements for this loading are as follows:

6.2.1 Strengthening Loads

Strengthening works will make use of the mandatory applied load cases that originate from the British Standards Institution (BSI). These are in excess of loads that have been used by NR for the assessment of structure in its current state (it has been assessed as 'under capacity'). Similarly, the relevant BSI standards require consideration of what are termed the 'secondary effects' of loading. These will introduce additional loads into the CI arches not accounted for in the current assessment.

A more detailed commentary on the technical approach affected by the statutory requirements for carrying out strengthening is contained within Appendix C.

6.2.2 Discussion on Particular Strengthening Proposals

Strengthening proposals will be considered feasible when a satisfactory balance is achieved between the constraining factors at the site (for example headroom) and the statutory design requirements (such as the loads/forces used in design). By this logic, it is also clear that not achieving such a balance results in a proposal being impractical.

Summary of Constraints - The following list expands on key physical constraints at site:

i. Existing Bridge Form of Construction
The lateral steel/concrete floor, which spans between nibs of the CI arches, is at the same level as the arch top web/flange and thereby occupies the construction space available – refer to Figure 2 below.

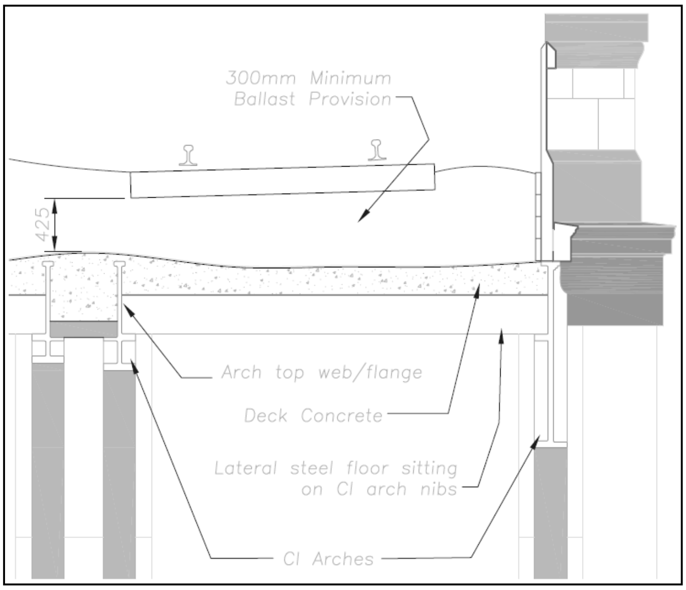


Figure 2 – Cross section through existing deck Illustration of how construction space for new structural members is limited

The current track alignment can accommodate only increases of structural depth of approximately 125mm, with a strengthening solution to the top of the deck. Achieving capacity through strengthening in this available space is therefore considered to be impractical, without vertical realignment of the track.

Figure 3 – Arrangement of Arches and Deck Soffit

Figure 4 – Detail of steel floor supported on CI nib

6.3 Discussion on Particular Strengthening Proposals - continued

ii. Railway vertical alignment
The current railway alignment over the bridge is 1:150. Refer to Figure 5 (overleaf).
Increasing the depth of bridge construction by strengthening measures to the top of the bridge deck results in:

a. The gradient becomes more severe on the approach to Whaley Bridge Station (375 yards to the north of the bridge) – reducing to 1:140 approximately, assuming 400mm increased construction depth;
b. Affecting the platform layout at the station will include re-setting platform copings and potentially repositioning of station structures and signage. HMRI require that gradients through stations should not be steeper than 1:500;
c. Braking distances will need to increase with potential changes to the signalling design layout;
d. Greater tractive effort from vehicles heading up the gradient, affecting journey times and reducing train headways;
e. The approach railway embankments are steep and exhibit signs of some local slippage. Increasing the alignment of the track will require further material to be added to the top of the embankment, which will further reduce its stability without remedial works.
f. Similarly there are retaining walls in the track formation to the south of the bridge – these will be overtopped with track formation materials if the track alignment is increased. Extra weight of material will also be imparted on the railway-supporting structures between Bridge 42 and the station.

iii. Headroom
There is a bridge-bash risk to the structure and a recent known strike from a vehicle caused structural damage. The DoT highway envelope requires minimum clearance for 5.030m and currently the carriageway fouls this in both directions (4.610m at highway channel level).

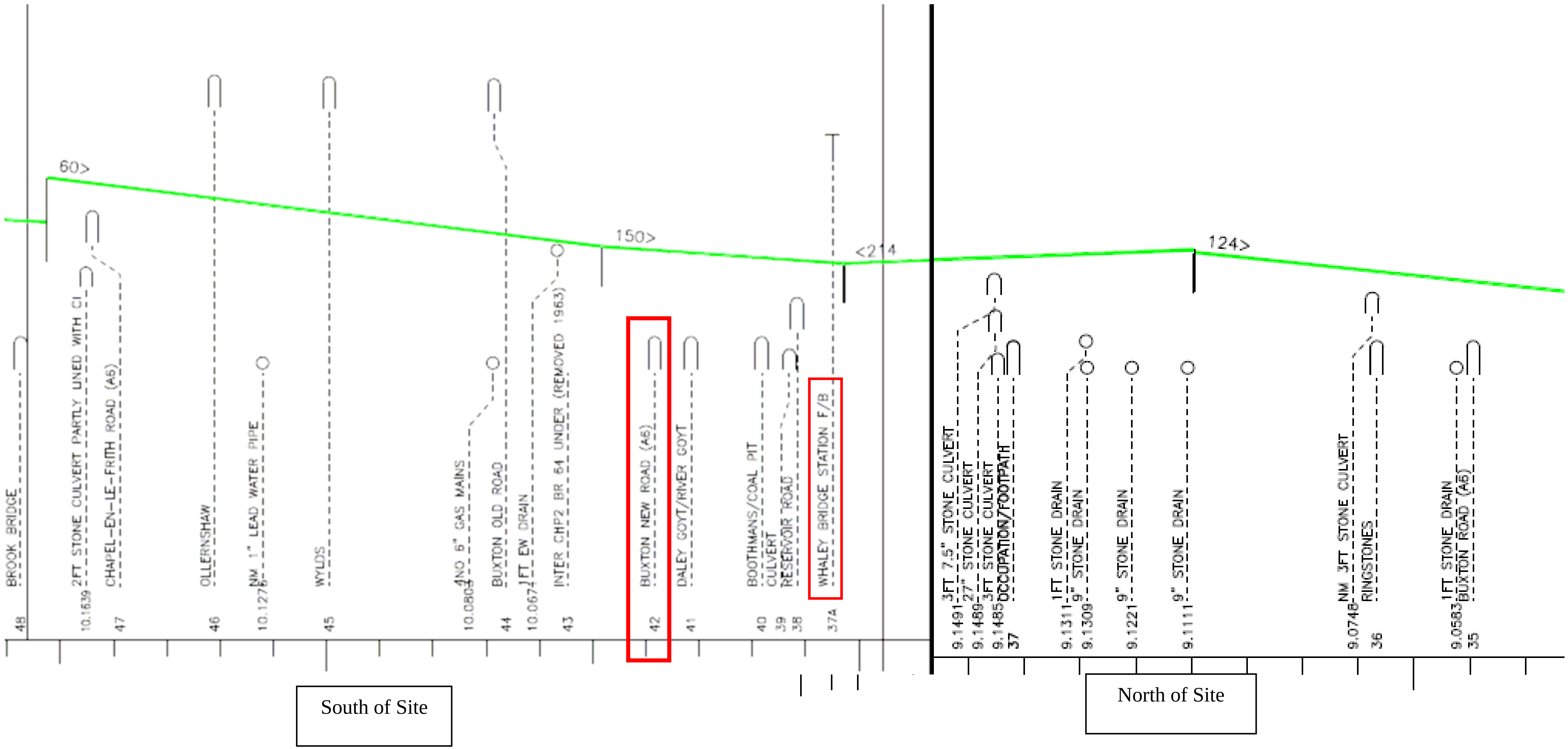
iv. Superstructure Materials Condition
The primary members of the bridge are cast iron (CI) and a proportion have known fractures through their full thickness. CI structural members are typically brittle and offer relatively poor tensile strength.

v. Highway Width & Patronage
The bridge spans across Buxton New Road (A5004) which is well-trafficked, including double-decker buses and HGVs. The current single carriageway width is 8.5m kerb to kerb.

Observations from site attendance identified that larger vehicles tend to pass below the structure by veering towards the centre of the highway. This is accentuated by cars frequently parking on the side of the road below the bridge.

The local highways department has confirmed that the road is not subjected to a sensitivity order despite it being the primary arterial route through Whaley Bridge.

Figure 5 – Schematic of Track Vertical Alignment in Whaley Bridge Area (source: NR Five Mile Plans)



6.4 Strengthening Proposals – the Impact of Constraints

This section assesses the outline proposals made by contributors and reviewers of the planning application and summarises how they are affected by the constraints discussed previously.

1. Over-Slabbing Existing Deck with New Structural Elements Proposal

Features

i. Temporary removal of track and ballast;
ii. Installation of new reinforced concrete slab to span above arch top flanges;
iii. Aims to strengthens the lateral steel/concrete floor which is currently overstressed;
iv. Connection to existing arches helps to tie all of them together.

Comments

i. The 'constraints' section of the report identifies that a minimum depth of ballast must be retained after strengthening. This leaves a limited area available for the new slab, which would be a maximum of 125mm deep;
ii. Connecting new slab to existing deck would require excavation and removal of existing materials;
iii. The slim depth of slab would only share some applied load laterally;
iv. Strengthening will introduce design loads that will overstress the cast iron arches. Global stability will also be affected as secondary effects have to be considered. [These are discussed in more detail in Section 7 and Appendix C];
v. The risks of highway collision and further progressive deterioration of the superstructure will be retained.

2. Complete Removal of Lateral Steel Deck & Replacement Proposal

Features

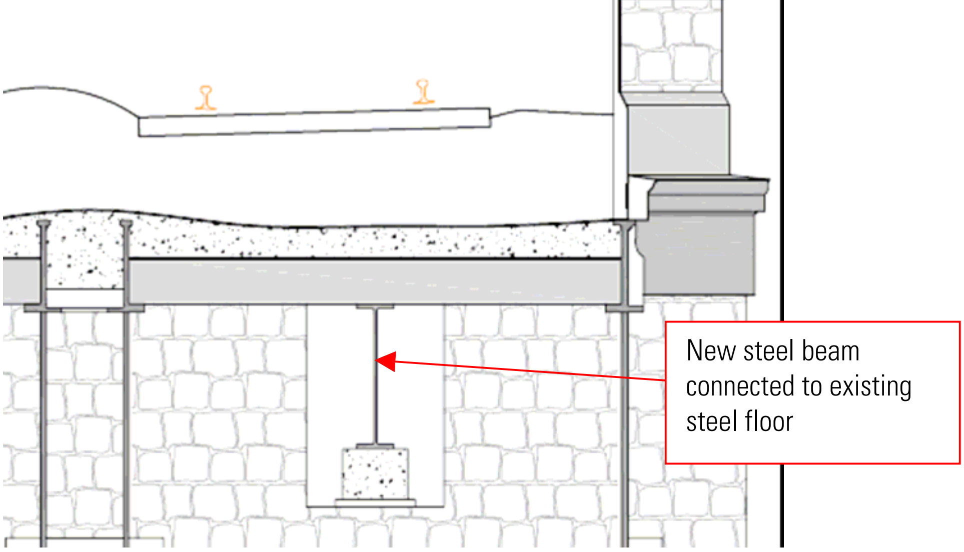
i. Temporary removal of track and ballast;
ii. Permanent removal of existing deck members supported by the arches;
iii. Replacement with new steel/concrete deck units in a like-for-like location.

Comments

i. The new deck will carry design loading although without mechanical connection into the CI arches. The new deck will also still be supported by the CI arch nibs. An assessment of the nibs' capacity to carry 'new' design loads show overstress in the nibs.
ii. Removal of the existing floor introduces risk of:
    - Instability during construction activities – arches are slender and the majority of the self-weight of the bridge is above them;
    - The risk of locked-in forces within the arches being released when the decks are removed, leading to further fractures developing;
    - Worsening of the verticality of the arches as a result of the above – this will significantly increases stresses in the arches when load is applied.
iii. The risks of highway collision and further progressive deterioration of the superstructure will be retained.
iv. Strengthening will introduce design loads that will overstress the cast iron arches. Global stability will also be affected as secondary effects have to be considered.

3. Installing new supporting steelwork below the existing deck structures and retaining existing bridge elements.
Features i. No works required to the top of the existing bridge deck; ii. New supporting steelwork to be installed below the existing arches only to relieve the overstressed lateral steel floor, which is retained; iii. Loads are shared between new steelwork and existing CI arches

Figure 6 – Section through Deck with New Supporting Steelwork



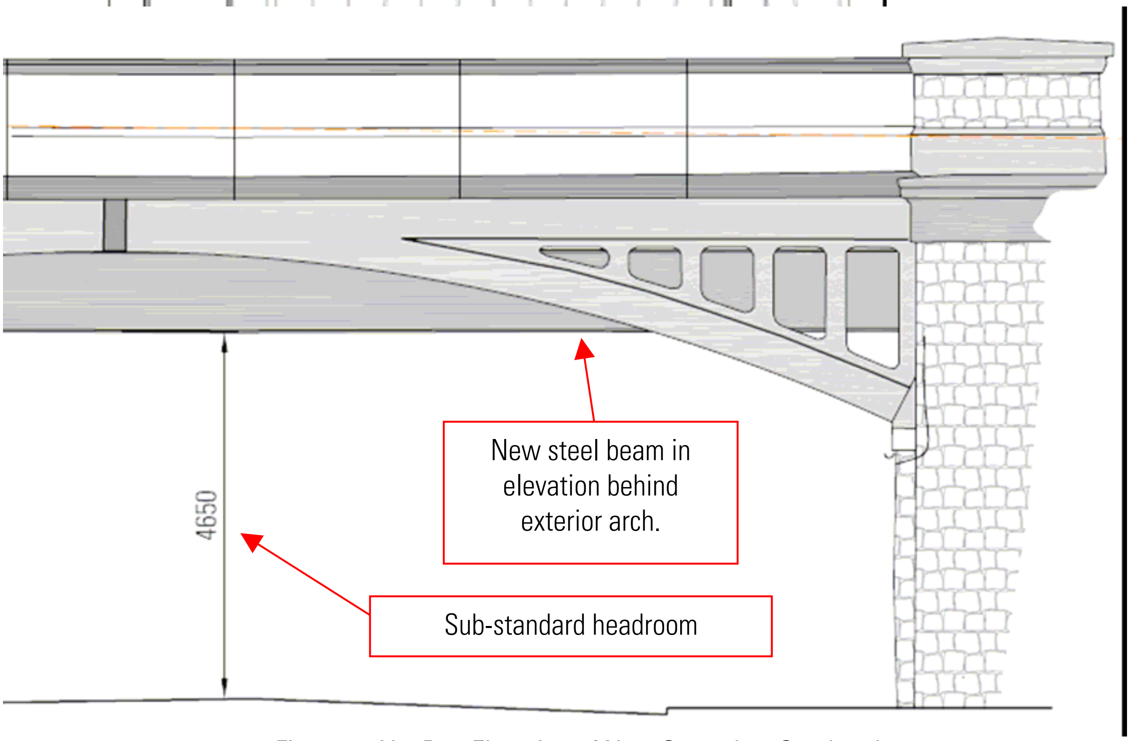


Figure 4.0X – Part Elevation of New Secondary Steelwork

Installing new supporting steelwork below the existing deck structures and retaining existing bridge elements (continued).
Comments i. The amount of the total load the new structural members can take is limited; the CI arches won't be redundant and therefore are still required to support the railway. ii. New bracing systems will be required between the new steelwork and adjacent arch members. This is complicated by not being able to drill/fix new steelwork directly to existing CI. iii. Outline design of this arrangement demonstrates that the depth of the new steelwork protrudes further into the headroom clearance envelope. Consideration has also been given to arching the new additional steelwork to mimic the profile of the existing arches. This is considered unfeasible because: i. The depth of the new steelwork will mean that it will protrude below the level of the bottom of the existing arches. This is because the existing lateral steel decks fit within the depths of the arch sections and so any new steelwork would therefore have to be positioned below the current arches profiles. ii. Slimming-down the arches at their midspan position to reduce this effect cuts the capacity of the new sections beyond acceptable limits. iii. The skew of the bridge and shallow profile of the arches means that effective bracing systems cannot be accommodated.

6.5 Technical Approval

Providing the extent of repairs, coupled with the likely nature of the strengthening works to meet statutory requirements is unprecedented within Network Rail. It is probable that the procedure for gaining internal technical approval will be prolonged and may not be accepted.

Increasing duration between proposing work and executing gives rise to prolonged exposure to risk of progressive deterioration, the risk of further vehicle strikes are extended and a prolonged period of speed restriction over the structure.

English Heritage Comment:
"The applicant does not sufficiently explore the feasibility of removing the existing concrete fill to the bridge deck so as to access the cast iron work for repair and the introduction of addition structural elements.

6.6 Deck Investigation

Removal of the existing deck concrete would be necessary to expose secondary members for investigation. The concrete on the deck is structural and its removal poses a number of risks with corresponding temporary works for loss of arch stability. Investigations would enable a tactile survey of the buried arch elements to be carried out and also permit necessary strengthening measures (currently the deck members are below capacity for current railway use).

There is a risk of identifying further defects during investigations. Any more defects will only go to reducing the current bridge capacity further and may result in immediate closures of rail and road whilst corrective actions are carried out. The uncertainties voiced by the specialist repair contractor regarding remedial works would prompt introduction of an appropriate monitoring regime, which is impracticable if repair locations are embedded within the deck (i.e. the railway could not be operational during investigations).

It is important to note that the investigations can be undertaken, however, it will require the following works:

- Closure of the Railway;
- Closure of the road;
- Sleeper slide;
- Excavation of ballast;
- Removal of concrete;
- Inspection;
- Examination;
- MPI testing;
- Replacement of concrete;
- Replacement of ballast;
- Reinstatement of sleepers;
- Tamping of railway;
- Opening of the line.

It is envisaged that the above process would require intensive work over a 2-day railway closure and a 2-day road closure working 24hr shifts.

Even if this work was undertaken and no further defects were present, the analysis proves that strengthening is required and the strengthening options highlighted previously would be required and hence ruled out as discussed in the previous sections.

English Heritage Comment:
Replacing the bridge deck with an entirely new element in order to carry aspirational loadings much higher than those likely to be required in the foreseeable future should not be the solution. This issue should be explored with reference to the likely load requirements laid out in the Rail User Strategy as opposed to the much higher figure in new deck design brief from Network Rail.

7.0 STRENGTHENING LOADS – 'ULTIMATE' CONDITION

The relevant load cases to this 'ultimate' condition are mandated by the code of practice. They apply to all structures and aren't the same loads referred to in the comments above.

As the current assessment identifies that the bridge is under-capacity, accommodating any increased load will increase the current 'ultimate limit state' overstress and result in other elements becoming stressed or unstable, principally:

i. The bridge construction has insufficient strength to resist the lateral loads. New bracing systems will be required – complex fabrication and construction – and changes the path of load;
ii. The longitudinal and lateral effects on the arches coupled with the effects of their relative skew, introduces twisting (torsion) effects. This will increase stresses on mid-span connections which already exhibit signs of overstress;
iii. Additional 'shear' forces within the vertical spandrel posts in the arches will be introduced.

In combination these loads would further overstress susceptible cast iron structural elements.

7.1 Strengthening Loads – Other Conditions

7.1.1 Fatigue Design

The strengthened structure will require the new elements to provide a minimum fatigue life in excess of the retained elements of the structure. The frequency and intensity of axle loads referred to in the English Heritage comments "*failed to explore solutions in which realistic loadings might be accommodated through repair and strengthening*", relate to this load case only, and they are correct to suggest that a realistic loading could be considered for this situation alone. However this will not obviate the requirement for other conditions to be satisfied and will be an increase to the existing limited condition.

7.1.2 Serviceability Design

'Serviceability' (limits on deflections and the like) performance of the retained elements will vary following the strengthening works, as arches will be braced in pairs and loads will be higher than existing.

Lateral deflections of the superstructure will be governed by the efficiency of new bracing and the stiffness of the strengthened deck. From initial inspection, the magnitude of loads in the braces that connect into the CI arches will be significant, given the slenderness of the CI arches. In other words, the arches are unlikely to be structurally capable of carrying the load effects presented by the new bracing systems. Deflections will be outside of code limits in this case.

7.1.3 Track/Structure Interaction

Track/bridge interaction is affected by the deformation of the bridge under loading. Excessive deflections in the bridge are manifested within the alignment of the track when trains pass. Limits are imposed by the codes of practice to reduce the risk of 'twist' in the track; an effect accentuated by the high skew of the bridge. Excessive twist leads to a higher probability of derailment, particularly so on a curved track alignment. This condition can only be 'designed-out' by strengthening works – making the bridge more rigid.

All of the above conditions are relevant to the repair and strengthening of the bridge and demonstrate the issues associated with each case.

8.0 STAKEHOLDER CONSIDERATIONS

Any investigation, repair and strengthening measures must be programmed around a sequence of road, footway and railway closures to accommodate the works and protect the interests of other stakeholders. Such closures will be significant to account for the complexity of the works.

A bridge replacement option will cause significant disruption over a short specific timeframe. In such instances, alternative arrangements are made to ensure that disruption to users of road and rail services is minimised. Further disruption following the bridge replacement will be minimal, with all elements detailed to be low maintenance. The likelihood of unplanned repairs in future is significantly reduced with a bridge replacement, and with it the associated disruption.

Repair and strengthening measures will increase the life of bridge but won't reduce the risk of further closures to carry out unplanned repairs to events, such as bridge strikes. In such instances, the period of notice is short and inconvenient to the community and service users. Similarly the requirement for ongoing maintenance throughout its remaining life will still necessitate disruptive periods of closure and diversion. In addition the structure has been subject to fatigue loading for over 145 years and a significant increase in anticipated life of the cast iron can only be extended by a strengthening scheme that makes the structural elements a façade.

9.0 SUMMARY

i. The report has responded to English Heritage's comments and identified factors that demonstrate how NR are unable to repair or strengthen U/b 42 and meet their obligation to fulfil statutory requirements.

ii. Carrying-out repair work to the bridge is an essential measure; strengthening or replacement works will be needed at some stage in the short term.

iii. Restoring line speed is a short term objective for NR, and increasing freight a longer term aspiration. Both will increase loading on the bridge.

iv. Deterioration of the bridge will continue until strengthening or repair is carried out, with a retained risk of strikes from highway vehicles.

In summary, it is demonstrable that providing strengthening and repair works won't give Network Rail certainty that U/b 42 can support the applied loading that are statutory requirements. These measures also retain significant risk and only defer an inevitable future bridge replacement scheme.

10.0 CLOSING REMARKS

A final comment from English Heritage made note of the "*important contribution to the local historic environment and we do not feel they should be lost without the exploration of more sophisticated solutions than that proposed.*"

The aesthetic contribution of the structure is acknowledged by Network Rail. On this basis, they are amenable to developing their own alternatives to improve the appearance of the current preferred reconstruction option.

End.

Report Produced by:

Birse Rail Ltd Consultancy
Lyndon House
58-62 Hagley Road
Edgbaston
Birmingham
B16 8PE

Tel: 0121 456 4200

Report Produced for:

Network Rail
3rd Floor
Square One
4 Travis Street
Piccadilly
Manchester
M1 2NF
Tel: 0161 880 3000

Appendix A

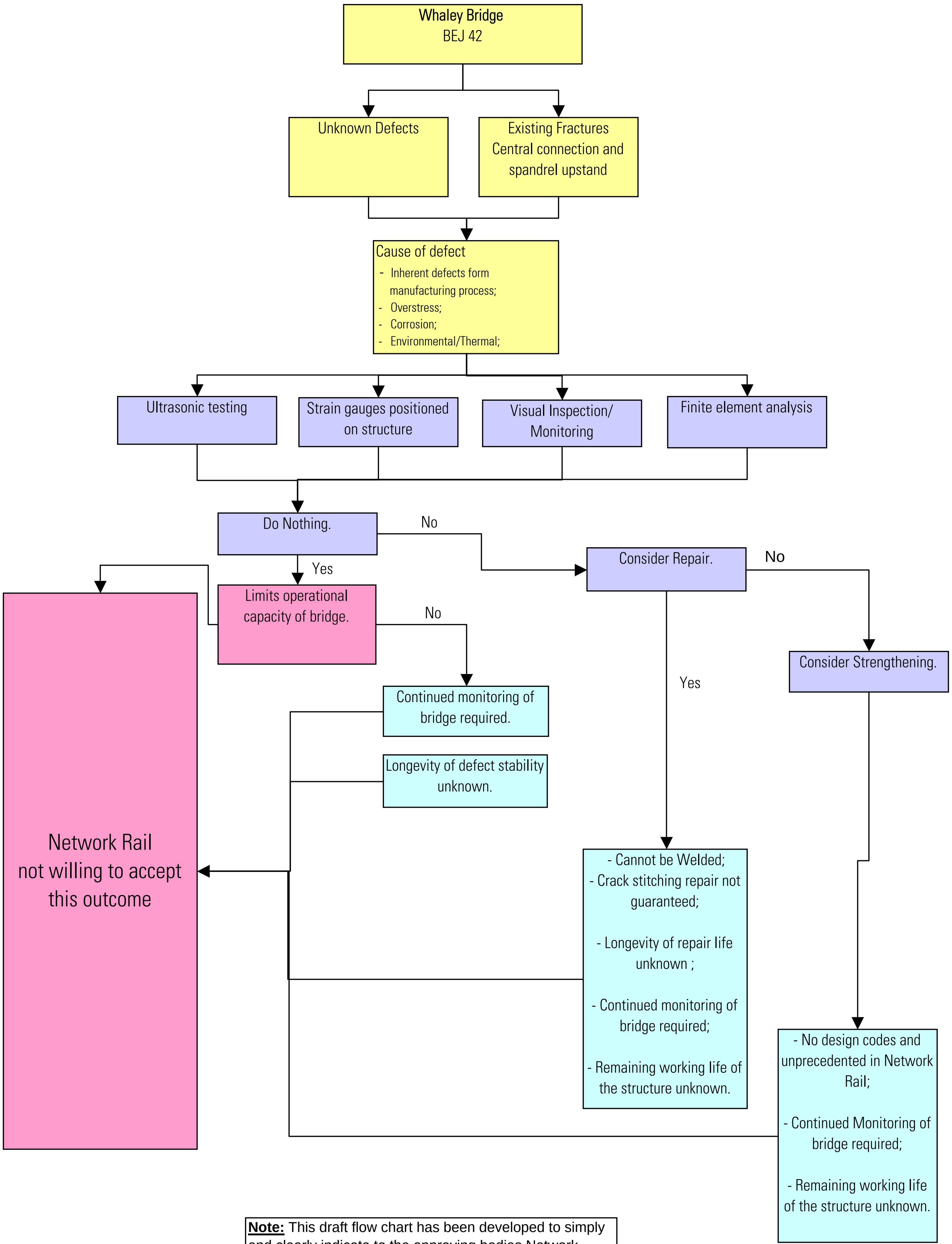
Options Matrix

Option Ref:	Description	Ability to Meet the Remit Requirements	Affect on Structural Element							Highway Clearances (h)	Road Closures (i)	Rail Closures (j)	Construction Risks (k)	Summary & Matrix Score
			Abutments (a)	Pilasters (b)	Parapet (c)	Cast Iron (d)	Wing-walls (e)	Underside of Deck (f)	Rail Tracks (g)					
1. Repair	**Repair Only** ▪ Repair cast iron crack; ▪ Repair parapets; ▪ Clean and paint; ▪ Minor masonry repairs to substructure.	**<u>Design Life = 0 / Not Guaranteed</u>** ▪ High risk of future cracks developing; ▪ Specialist repair contractor cannot guarantee strength. **<u>Maintenance = Not Guaranteed</u>** ▪ Condition of existing waterproofing cannot guarantee a 25-year maintenance free life even if re-painted. **<u>Resistance to Impact = Poor</u>** ▪ Impact to cast Iron elements could be catastrophic and cause global collapse of deck sections. **<u>Load Carrying Capacity = Sub-standard</u>** ▪ Cast Iron: Repair does not increase the 'under-strength' cast iron, which is currently overstressed; ▪ Cross Girders: Are inherently under capacity for modern trains and require strengthening;	Minor masonry works No visual impact.	Minor masonry repairs only - No visual impact.	Clean and paint repair or replace any damaged sections in steel to match existing.	Existing Cast Iron retained Repainted	Minor masonry repairs only - No visual impact.	Features retained and repainted.	None.	No improvement in highway clearances	Majority of works can be undertaken from lane closures, however a short duration road closure will be required for works to mid span elements.	It is envisaged that all works could be undertaken within planned ROR possessions.	Undertaking repairs and cleaning and painting leads to the detection of more cracks / unplanned repairs. Further crack detection could render this option unviable.	**Not a Viable Option** ▪ No Guaranteed Design Life; ▪ Reliance on existing cast iron elements; ▪ Global collapse from impact risk high; ▪ No provision for future railway loading increases.
	<u>Option 1 – Rank = N/A</u>	*0*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*2*	*3*	*5*	*3*	**<u>Total = 0</u>**
3. Box girder deck reconstruction with modified replica steel arches	**<u>Reconstruction</u>** ▪ Box girder reconstruction ▪ New revised arches ▪ Improvement to highway clearances ▪ All structural elements higher than 5.1m. ▪ Track slue	**<u>Design Life = 120 year Design Life</u>** • Box girder reconstruction can be designed to 120yr design life **<u>Maintenance = Max 25 yrs free</u>** ▪ New waterproofing system with full painting of metallic elements 25yr design life; ▪ Maintenance issues regarding access to parapet. **<u>Resistance to Impact = Very good</u>** ▪ Headroom improved and the outer elevation beams would be designed against impact **<u>Load Carrying Capacity = Future Requirements</u>** ▪ New deck would be designed to meet future loading requirements.	Will require significant work to tie into existing abutment, however suitable Cladding / rebuild will hide works Recess from removal of internal arches will require cladding	Minor masonry repairs only - No visual impact	New parapet to be constructed to mimic existing	Outer elevations to mimic existing . Internal Cast Iron Arches removed	Minor masonry repairs only - No visual impact.	Features cannot be retained as concrete requires break out and cross girders will be removed to facilitate new box-girder deck	Slue required to facilitate lateral clearance between box girder and outer arch. Works to ballast retaining wall required	Improvement to highway clearances	Majority of works within a road closure with additional lane closures as required	It is envisaged that the main works could be undertaken within planned a 72hr OROR possession	Risk of damage to Cast Iron to due brittle properties during demolition	▪ 120yr design life; ▪ Reduced maintenance; ▪ Elevations improved clearance; ▪ Slight improvement in headroom; ▪ Designed to cater or future railway loading
	<u>Option 14 – Rank = 6 of 8</u>	*4.5*	*3*	*3*	*1*	*0*	*5*	*0*	*1*	*4*	*2*	*4*	*5*	**<u>Total=10.6</u>**
4. Box girder deck reconstruction	**<u>Reconstruction</u>** • Box Girder reconstruction • No replication of arches	**<u>Design Life = 120 year Design Life</u>** • Box girder reconstruction can be designed to 120yr design life **<u>Maintenance = Max 25 yrs free</u>** ▪ New waterproofing system with full painting of metallic elements 25yr design life; ▪ Maintenance issues regarding access to parapet. **<u>Resistance to Impact = Excellent</u>** ▪ Headroom does not require any impact protection. **<u>Load Carrying Capacity = Future Requirements</u>** ▪ New deck would be designed to meet future loading requirements.	Will require significant work to tie into existing abutment, however suitable Cladding / rebuild will hide works Recess from removal of internal arches will require cladding	Minor masonry repairs only - No visual impact	No retention	No retention	Minor masonry repairs only - No visual impact	Features would not be retained	Track removal and reinstatement along existing alignment.	Highway clearance does not require impact protection	Majority of works within a road closure with additional lane closures as required	It is envisaged that the main works could be undertaken within planned a 72hr OROR possession	Risk of damage to Cast Iron to due brittle properties during demolition	▪ 120yr design life; ▪ Reduced maintenance; ▪ No impact protection required; ▪ Significant improvement in headroom; ▪ Designed to cater or future railway loading.
	<u>Option 15 – Rank = 1 of 8</u>	*5*	*3*	*5*	*0*	*0*	*5*	*0*	*3*	*5*	*3*	*4*	*5*	**<u>Total =14.1</u>**

Please note that this table is an extract from Report 1, and as a result the referencing should not be used. However, the content of the table remains current and has been included to simply highlight key points from alternative options. The full 'Options Matrix' should be referred to by the reader if required.

Appendix B

Bridge 42 – Flowchart of Key Factors



Note: This draft flow chart has been developed to simply and clearly indicate to the approving bodies Network Rail's position with regards to options other than reconstructions.

It shows that no matter what the outcome from any further detailed investigations / analysis that 'do nothing', 'repair' and strengthening are not satisfactory options for this particular case. It is hoped that this be developed further with feedback from Network Rail to strengthen the outcome that no matter how much time and resource are input into the options they are not acceptable.

It is also important to note that this flow chart does not include for any cost or programme concerns.

Appendix C

Technical Commentary

Technical Commentary

This appendix provides supporting information to the statements made in Section 5.0 of this report.

C.1 Relevant Codes of Practice that must be considered for strengthening and repair:

To design for strengthening and repair, the following standards apply:

- Preventing collapse from overloading – covered by 'Ultimate Limit State' design referred to within BSI code of practice 'BS5400' parts 1,2,3 & 6);
- Preventing excessive deflections/movement in service – 'Serviceability Limit State' design (BS5400 parts 1,2,3 & 6);
- Preventing failure from long-term effects of loading – 'Fatigue' design (BS5400 part 10);
- Ensuring that track/structure interactions are acceptable for railway safety – covered by Union International Chemin (UIC) Codes (UIC 776-3R).

The effects of collision from highway vehicles are covered by BD60/04, but the magnitudes of the loading, by inspection, would not be resisted by the superstructure. (It is noted that this code of practice is more appropriate for new works).

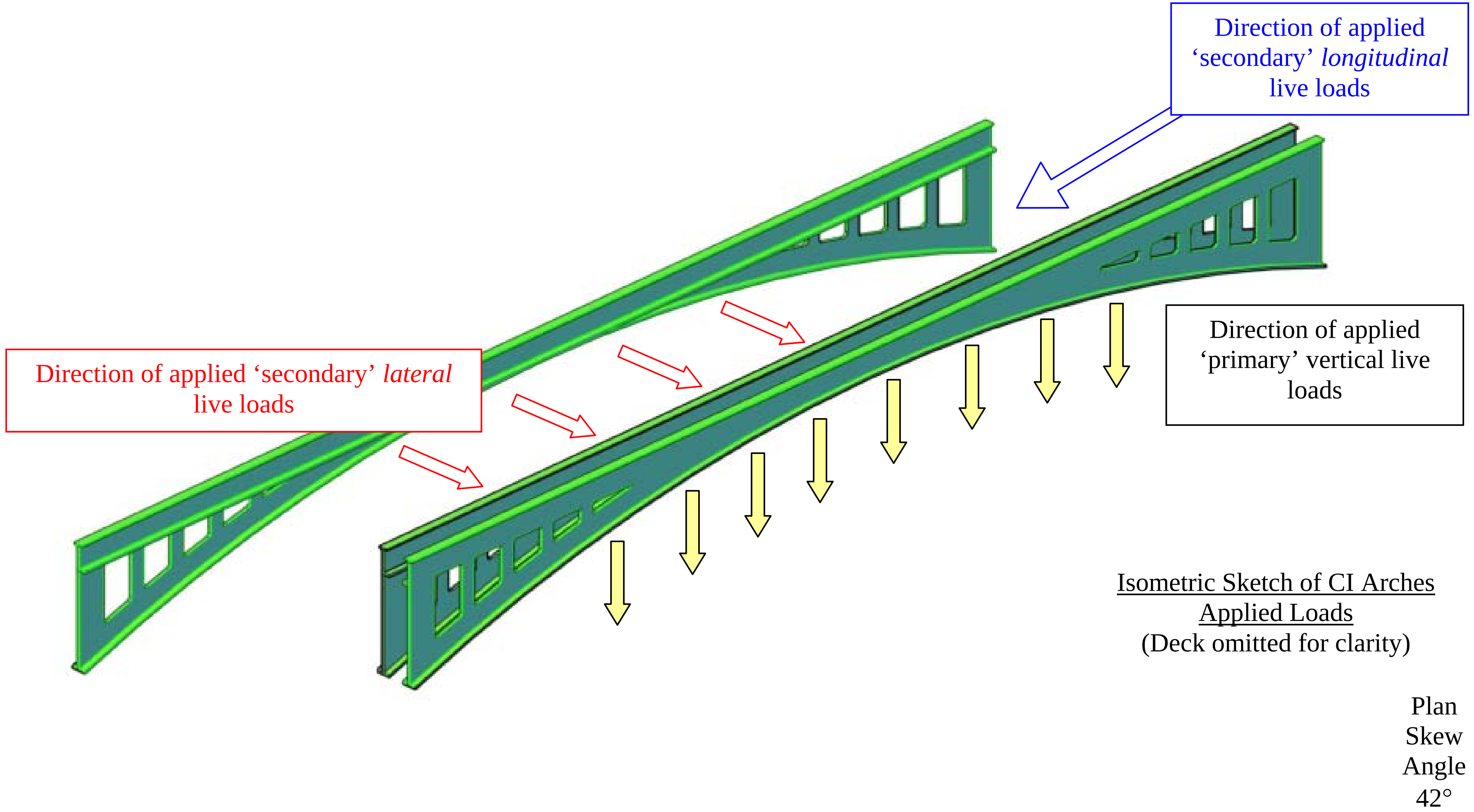
C.2 Secondary Live Loads

BS5400 part 2 outlines the requirements of secondary live loading. Strengthening and repair to the structure will require consideration of these loads and this introduces further concern about the immediate capacity of the bridge (i.e. can it be demonstrated that it carries the load) and the longer-term effects (i.e. changing the relative stiffness of bridge members will change the load path and the effects of this on existing elements). This is of particular concern to members already exhibiting defects.

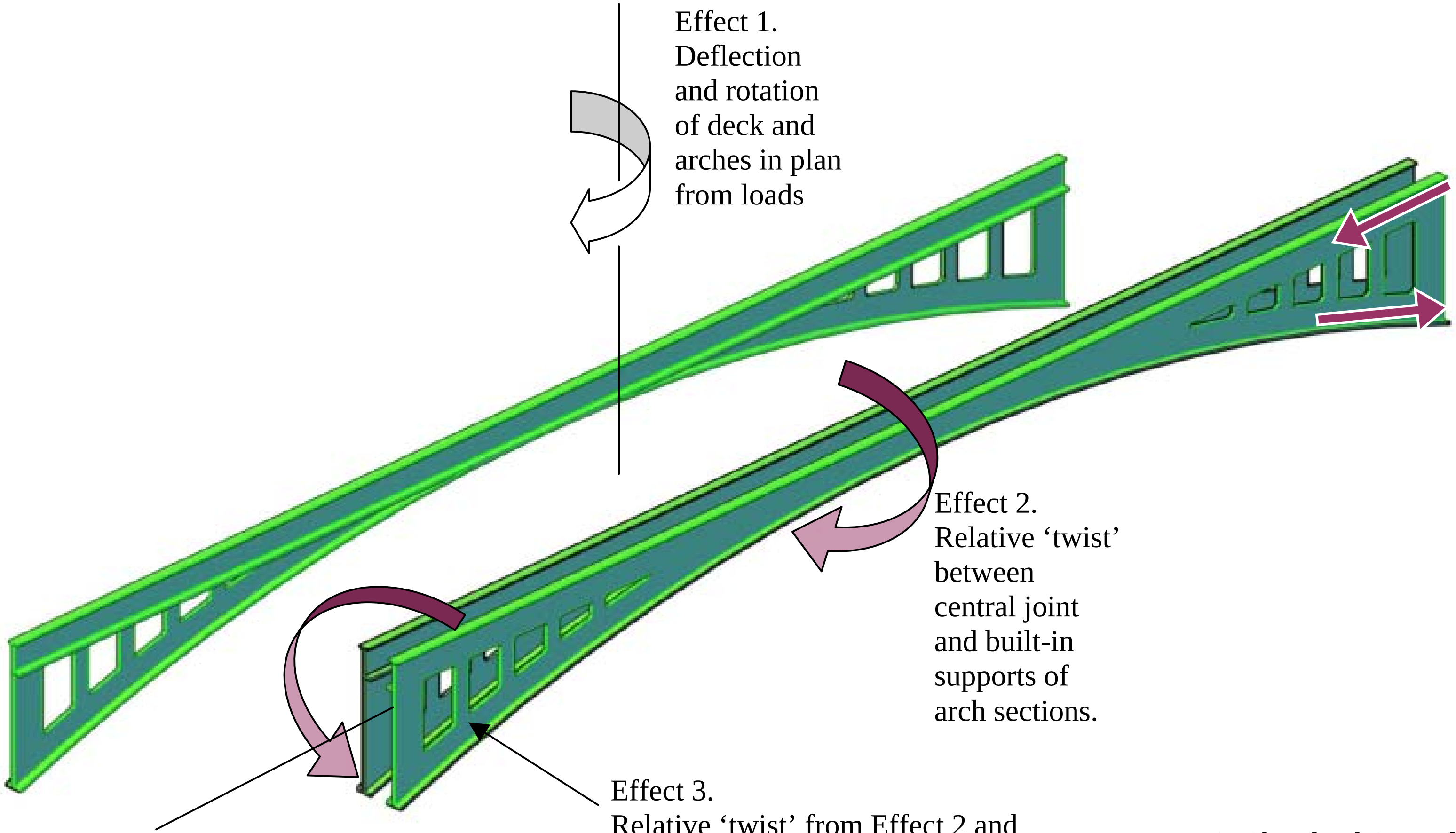
i. Longitudinal loads along the direction of the arch sections, brought about from the effects of driving traction and braking of passing rail vehicles;
ii. Lateral loads perpendicular to the direction of the arch sections, brought about from the effects of 'nosing' and centrifugal forces from the curved track alignment.

C.3 Applied Loads and Effects Sketches

The sketches overleaf diagrammatically represent the applied loads from the relevant codes of practice, and the resulting effects. This demonstrates that the effects of the design loads give rise to increased stresses and deflections into a structure already assessed as being over capacity.



Isometric Sketch of CI Arches
Applied Loads
(Deck omitted for clarity)



<u>Isometric Sketch of CI Arches</u>
<u>Effects of Applied Loads</u>
(Deck omitted for clarity)

C.4 Observations from Analytical Modelling of Bridge 42

Overview of modelling cast iron arches

A 3D space frame model of the cast iron arches and wrought iron crossgirders has been developed in a structural analysis programme (Superstress version 6.7C manufactured by Integer). The model can be seen in figure 1:-

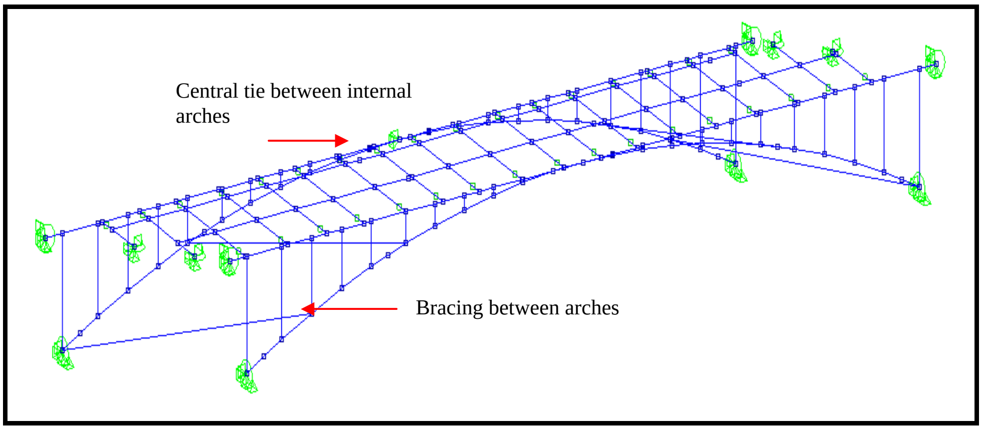


Figure 1 3D space frame model of BEJ42

The model represents two cast iron arches supporting cross girders and one track. The geometry of the 3D space frame has been developed from topographical survey data in conjunction with archive drawing information. The information gained in determining the section properties were confirmed on site from tactile investigations. Therefore the section properties used in the analysis are representative of insitu conditions. The orientation is representative of the eastern side of the superstructure carrying the Up Main railway line between Buxton and Edgley Junction.

The model is limited to two arches as the fixity between arches is limited to the midspan location only, this is shown in figure 2. The central tie will not allow any transfer of vertical load into the adjacent arch. It may provide limited lateral restraint from horizontal forces induced by railway traffic loading. The tie has been represented in the model as a lateral support shown in figure 1 at midspan. The bracing shown in figure 2 has also been incorporated into the model, again this is not considered as fully effective due to the limited fixity between the bracing and the cast iron, coupled with a shallow rake angle.

Each line of the model shown in figure 1 represents the relative sectional and torsional properties of the arch and cross members. The rails are represented by the longitudinal properties of the deck system.

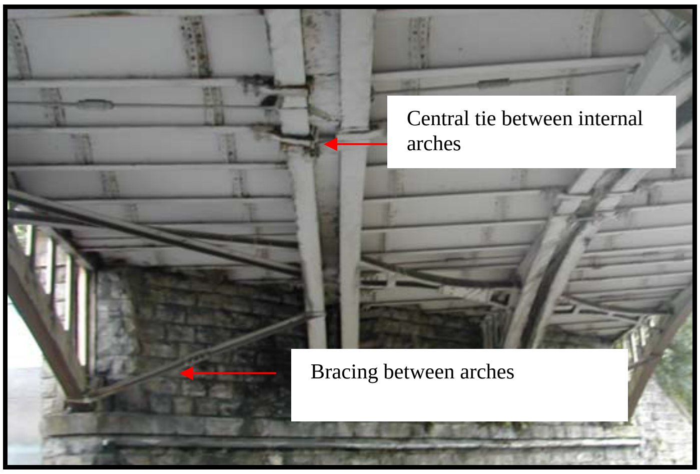


Figure 2 Location of bracing

To enable the stresses in the cast iron at the fractured midspan connection to be quantified, different configurations of railway traffic loading have been assessed to demonstrate the effects of vertical and horizontal loads imparted on the superstructure.

Railway loading considerations

The applied vertical railway traffic live load is taken from the most recent issue of Network Rail's assessment code NR/GN/CIV/025 issue 3. The loading used takes into account the bridge skew and therefore values for the live load span have been used. See figure 3 for outline derivation of live load.

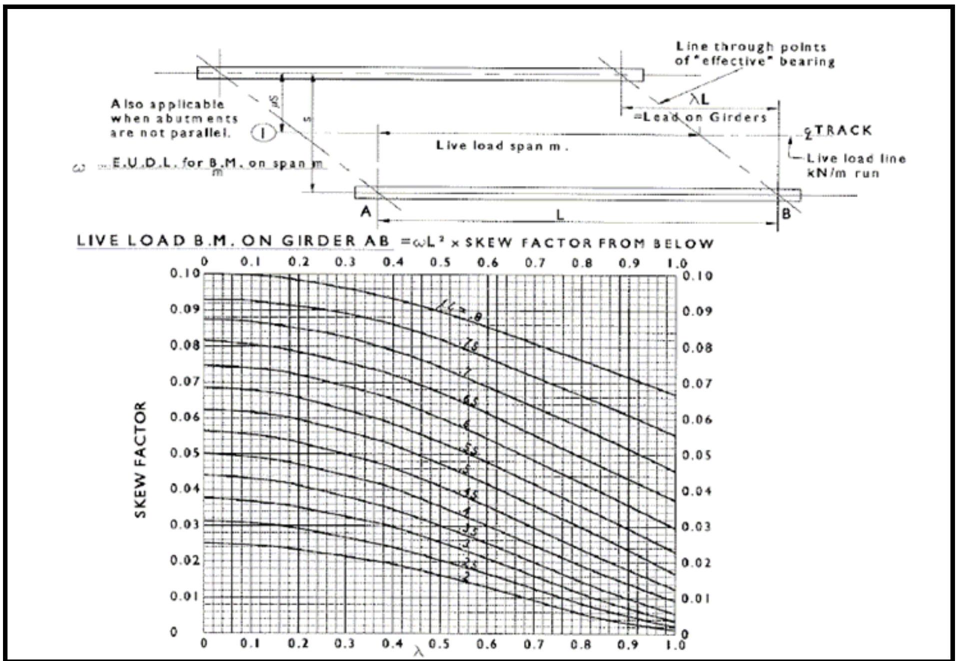


Figure 3 Live load skew parameters

The structure has been modelled incorporating the following loading patterns and speeds:-

1. Quarter span loading 10mph, 25mph and 50mph;
2. Half span loading 10mph, 25mph and 50mph;
3. Three quarter span loading 10mph,25mph,50mph;
4. Full span loading10mph, 25mph and 50mph.

Due to the brittle nature of cast iron and its limiting capacity to resist tensile forces, lateral influences from train loading have to be considered in the 3D model. These secondary effects considered are taken from BS5400 part 2 2006. Railway specific lateral effects applied are centrifugal effects caused by the curvature of the railway alignment and the lateral kinetic effects of a railway vehicle passing over the bridge.

The most onerous load case assessed when considering the forces at the midspan connection is as a result of three quarter span vertical loading with lateral loading from centrifugal and nosing depicted in figure 4.

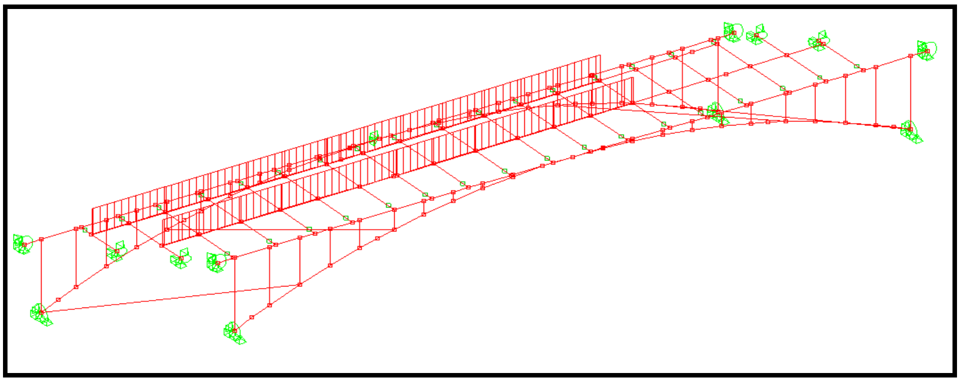
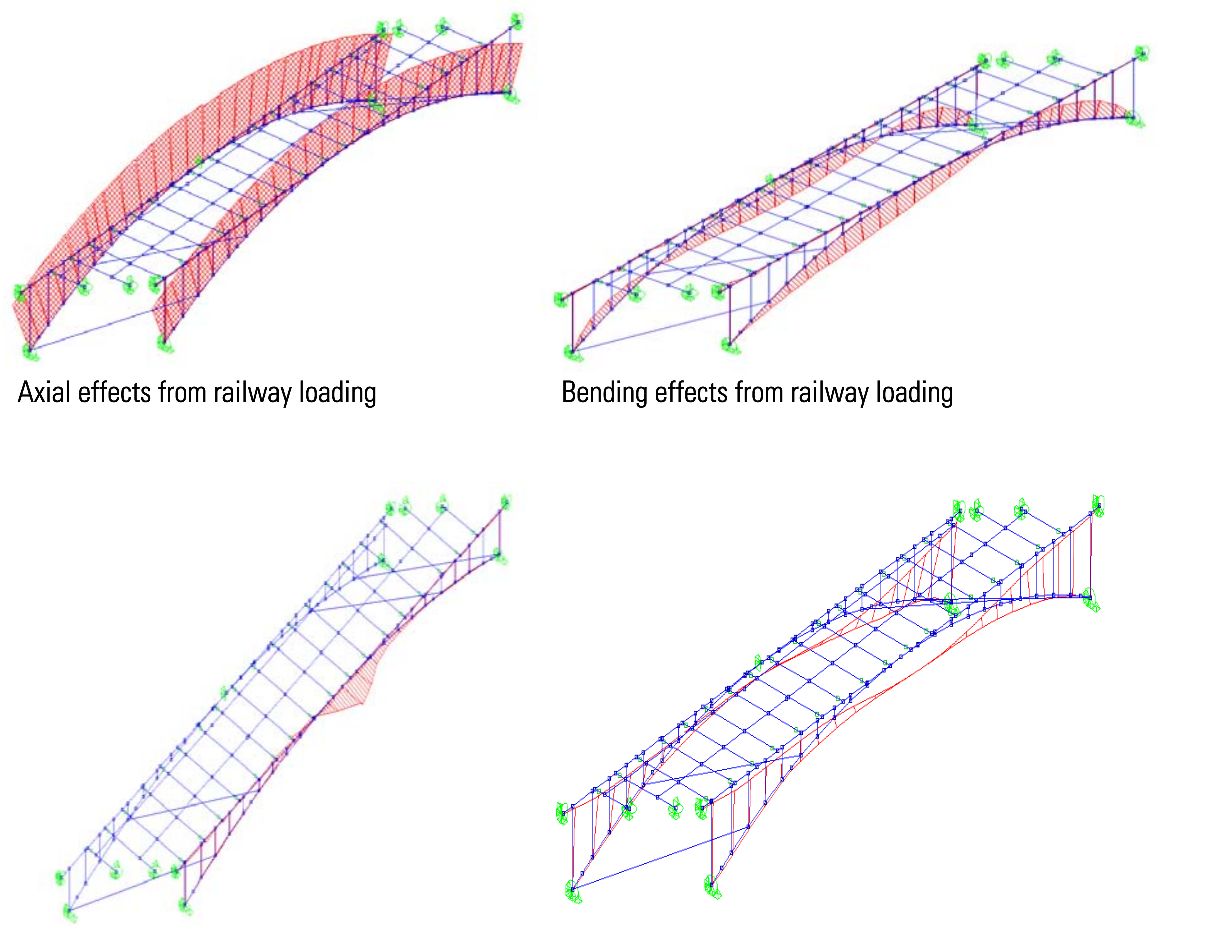


Figure 4 Most onerous load case position

3D Modelling results

The output of the 3D model demonstrates typical arch behaviour due to the applied loading. The effects of the loading are illustrated in figure 5.



Axial effects from railway loading

Bending effects from railway loading

Transverse bending effects at midspan from railway loading

Deflected shape from railway loading

Figure 5 Illustration of resultant effects from combined vertical and lateral effects.

The results shown in table 1 are the values obtained from the 3D analysis, the stresses have been calculated based on the cast iron properties at the midspan location:-

	10mph	25mph	50mph
Axial stress (N/mm^2)	64.82	69.9	74.36
Compression bending stress (N/mm^2)	64.82	50.16	62.94
Tension bending stress (N/mm^2)	50.16	33.56	37.35
Lateral bending stress (N/mm^2)	0	108.42	108.42

Table 1 Resultant stresses for differing speeds

The results from table 1 have been resolved to obtain the net stresses in the compression and tension zone of the cast iron as shown in Table 2. Table 2 shows the overstress percentage due to the combined net effects:-

	10mph	25mph	50mph	25mph % over capacity	50mph % over capacity
Net compression *(Permissible 154N/mm²)*	85.21	234.94	245.72	53%	60%
Net tension *(Permissible 49N/mm²)*	29.77	72.15	71.41	47%	46%

Table 2 Summary of resultant stresses and percentage capacity in cast iron

Concluding remarks

The analysis has only considered the cast iron as an uncracked section. If the evident fractures were taken into account the magnitude of stress is increased locally around the cracked section. This is a phenomenon which has not been quantified; however a further detailed assessment such as finite element analysis would demonstrate an increase of stress compared with the modelling of the uncracked cast iron undertaken.

Furthermore, deflected shape analysis identifies that further strains will be imparted on the arch section elements, such as spandrel posts, these already exhibit fractures in some locations.

The results demonstrate that the fractures identified currently and historically to the midspan connections and spandrel upstand are likely to be caused by railway traffic loading pre the 10mph restriction imposed on the bridge by Network Rail.

Appendix D

Letters of Support from Freight Operators

Mailbox
100 Wharfside Street
Birmingham B1 1RT
Tel: +44 (0) 121 345 3366
Fax:+44 (0) 121 345 4004

Lee Robb,
Birse Rail,
Lyndon House,
58-62 Hagley Road,
Edgbaston,
BIRMINGHAM.

25th June 2008

Dear Lee,

Re: Whaley Bridge - Future Freight Requirements

Further to our recent conversation, I am writing in support of the Planning Application to de-list and reconstruct Structure 42 on the Buxton to Edgeley Junction (BEJ) railway line to enable regular freight use without restriction.

As the Senior Route Freight Manager for the London North Western Route of Network Rail, I am responsible for liaison with our freight customers, predominantly EWS and Freightliner Heavy Haul in the Peak District and end-customers such as Cemex and Lafarge.

I would strongly support the provision of capability to operate aggregate trains along the Buxton to Edgeley Junction route for the following key reasons:

- There is an existing requirement to divert freight trains on certain weekends via Whaley Bridge to permit engineering works on the Chinley route. There is a risk that these services will be prevented from operation should the condition of BEJ 42 structure not be improved.

- Growth from the quarries at Dowlow, Tunstead and Peak Forest has been strong in recent years leading to congestion on the Hope Valley rail route. Strong growth is predicted to continue and some of this traffic could be diverted via Whaley Bridge routinely.

- As Freight traffic (and therefore tonnage) grows from the Peak District quarries, the need to gain access to lines to maintain these increases. In order to retain access to terminals such as Dowlow and Tunstead it is imperative that a second usable route is created for aggregate trains from the Buxton area.

For these reasons this note is intended to support the proposed scheme.

Yours sincerely,

Steve Rhymes
Senior Route Freight Manager

Birse
Rail Consultancy

Network Rail

Lee Robb,
Birse Rail,
Lyndon House,
58-62 Hagley Road,
Edgbaston,
BIRMINGHAM
B16 8PE

17th July 2008

Dear Lee,

Bridge 42 at Whaley Bridge

EWS has been asked by Network Rail if we would support your Planning Application in respect of the proposal to de-list and reconstruct Bridge 42 on the Buxton to Edgeley Junction route. This would enable EWS to operate freight traffic over this route without additional restriction.

EWS is strongly supportive of your Planning Application for the following reasons:

- There is an existing requirement to divert freight traffic via Whaley Bridge, principally at weekends, to facilitate the maintenance and renewal of the network on the core route via Chinley. Any deterioration in the condition of Bridge 42 could see Network Rail preventing the operation of freight trains via this route which will severely restrict Network Rail's opportunities for maintenance and renewal.

- Network Rail is consulting with customers, including EWS, regarding the closure of Dove Holes Tunnel on the core route for a possible 10-12 week period during 2010. This is due to calctic deposits causing the track geometry to become very unstable and with a poor drainage system the deposits are setting like concrete around the track fittings.

- It will be absolutely critical that the route from Buxton to Edgely Junction is in a robust state to take large volumes of additional traffic if this possession proposal is agreed and goes ahead.

- Freight trains are already subject to a maximum of 25 mph between Buxton and Hazel Grove. The existing 10 mph restriction over Bridge 42 at Whaley Bridge further restricts the pathing opportunities that exist between the regular passenger service operated by Northern Trains. Any improvement in the speed permissible over Bridge 42 will benefit the operational performance of the route.

- There is continued growth in traffic from the various quarries served by terminals at Dowlow, Tunstead and Peak Forest. This has led to difficulties in pathing trains via the core route and on the Hope Valley line between Sheffield & Manchester.

- As the volume of traffic increases it is imperative that Network Rail provides not only a robust core route, but a second or diversionary route which is capable of accepting traffic without restriction.

EWS hopes that this letter of support for your Planning Application delivers the desired result.

Yours sincerely

Nick Gibbons
National Planning Manager
EWS Railway Ltd

Copy:

Robin Gisby – Network Rail
Steve Rhymes – Network Rail