Newbridge Long-Term Management Strategy

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This report has been prepared by Oxfordshire County Council's (OCC's) bridge engineers in consultation with OCC's highway engineers and OCC's archaeological officer. This report, once ratified by the relevant OCC elected members will be circulated to English Heritage and the conservation officers of the two relevant District Councils for comment.

Introduction

The strength of Newbridge has been assessed in accordance with national guidelines and has been found to be theoretically structurally inadequate to sustain any level of traffic loading reliably and safely in the long term. OCC are currently still permitting its continued use on the understanding that bridge assessment techniques are intended to be conservative, that masonry arch failure mechanisms are not sudden and that cracking and surface deformation would become apparent before any catastrophic collapse occurred.

As an interim measure Newbridge is being closely monitored and now benefits from the limited protection of an 18 tonne MGW (maximum gross weight) structural weight limit. It is possible that the current 18 tonne MGW limit could need to be lowered still further or perhaps the bridge even closed to traffic completely if any further significant arch movement is detected. Clearly this uncertainty with respect to the availability of the A415 is extremely undesirable and therefore a reliable long term solution for the A415 and Newbridge needs to be found and instigated as soon as possible.

The accepted way to ensure structural reliability and the safety of the travelling public in the long-term with respect to any weak bridge is to implement measures to ensure that traffic loading on the bridge does not exceed its assessed capacity. This can be done by taking steps to increase the assessed capacity of the bridge (usually by strengthening), by reducing vehicle loading on the bridge, or by a combination of both.

The aim of this report is to provide some background information regarding Newbridge and the constraints involved, to explain its structural shortcomings and why some action is required, to discuss the options that are available to address these shortcomings, and to conclude what would be the most appropriate long-term solution.

Background

Dating from the 13th Century, Newbridge is arguably the oldest complete original bridge crossing the Thames, and still carries the A415 Witney to Kingston Bagpuize road over this navigable river. Newbridge is a 750 year old six-span masonry gothic arch bridge that enjoys the statutory protection of being both a Grade 1 listed structure and a scheduled Ancient Monument. Newbridge is both narrow and has a hump-backed vertical profile so in 1987 shuttle working traffic signals were installed to reduce the frequency of accidents and parapet impacts.

OCC is both Newbridge's owner and also Oxfordshire's Highway Authority, and as such we have a statutory duty not only to preserve Newbridge as a scheduled Ancient Monument for future generations, but must also ensure the safety of the travelling public whilst maintaining adequate availability of the highway network.

Newbridge has been assessed as having a live load capacity of zero, i.e. it is theoretically unable to sustain the loads from even just cars in the long term. In addition its parapets have been assessed as weak, not providing even the minimum containment capacity required to contain a light vehicle travelling at 30 mph. As Newbridge is a scheduled ancient monument it benefits from statutory protection designed to protect its historic importance. Newbridge therefore cannot effectively be replaced, reconstructed, strengthened or altered in any way unless there is no other practical alternative. This protection covers not only its external appearance but includes all aspects of its internal fabric too. Because of its historic value we need to consider the need very carefully (and seek Ancient Monument Consent) before commissioning any work at Newbridge, including even just further investigative work such as excavation or coring which might help to better inform our assessment or strengthening work. We must be satisfied that any proposed work will either not be detrimental in any way or else is unavoidable and is in the best interests of the structure before attempting to seek consent to proceed.

In managing the inevitably steadily increasing risk that any already weak and progressively deteriorating ancient bridge will pose, OCC has now reached the conclusion that Newbridge can no longer be relied on to carry unrestricted A415 vehicular traffic safely in the medium and long term. It is now therefore being more closely monitored and since 2006 benefits from the limited protection of an 18 tonne MGW structural weight limit. In the short term a weight restriction and an increased inspection regime were the inevitable next step, but OCC also needs to identify and then instigate a satisfactory long-term solution.

OCC has commissioned a range of work intended to help identify the best long term solution for Newbridge and the following draft reports are now available:

1. Maintenance and Strengthening Feasibility Study. (June 2008)

2. Maintenance and Strengthening Supplementary Feasibility Study. (September 2009)

3. Thames River Crossings West of Oxford. (October 2009)

Conservation Constraints

As Newbridge is a scheduled ancient monument and therefore any work affecting it requires formal consent from the Secretary of State for Culture, Media & Sports who will consult English Heritage on the application. English Heritage therefore needs to be consulted with respect to any proposed maintenance or strengthening work, or any issues that could affect Newbridge's setting.

The principles of conservation against which any proposed works are to be evaluated are summarised below:

- Bridges are best used and maintained in their original form, performing the same function and structural action.
- Minimal changes are to be made to the structure and its appearance
- Works should involve no loss in character, and minimal loss of historic fabric
- Works should be non intrusive, and be reversible
- Works should involve minimal introduction of new material
- Works should be undertaken using appropriate materials & methods

Stakeholders

In addition to conservation interests with respect to Newbridge's ancient monument status, the long term solution also needs to be in the best interests of Oxfordshire as a whole and therefore must consider the interests of the following:

1. Road users, including public transport, public and emergency services, private cars, commercial vehicles and farm machinery.
2. Pedestrians and cyclists.
3. River and tow path users.
4. Residents and businesses in the immediate vicinity of Newbridge.
5. Residents and businesses in the wider area, including not only those in the vicinity of the A415 corridor, but also those in the vicinity of the other relevant Thames crossing routes within the County's highway network.

Previous Conclusions

OCC Bridge Engineers had already reached the following conclusions:

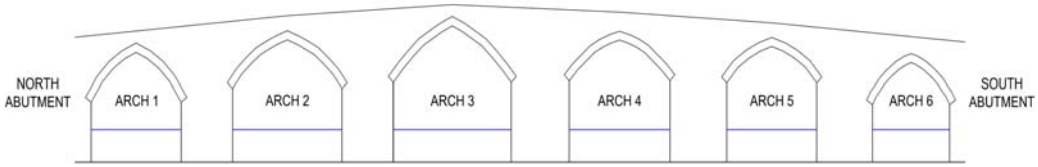
1. As a scheduled ancient monument, Newbridge cannot be demolished and replaced, and must be adequately maintained and protected for posterity.

2. The structural shortcomings of a weak bridge on the A415 should not dictate the route strategy for the A415 or be relied on to provide a long term traffic control measure.

3. Newbridge in its current form cannot be relied on to safely carry unrestricted A415 traffic in the medium and long term.

Newbridge: Current Situation

Newbridge comprises six spans, which have been numbered as follows:



Arch Locations

The individual arch strengths of Newbridge have been assessed and the assessment results are as follows:

	Assessed Capacity	
	Critical axle for 40 tonnes	**2009 Assessment**
Arch 1	Twin axle (19t)	3 tonnes
Arch 2	Single 11.5t axle	3 tonnes
Arch 3	Twin axle (19t)	Fails to carry dead load
Arch 4	Twin axle (19t)	13 tonnes
Arch 5	Twin axle (19t)	13 tonnes
Arch 6	Single 11.5t axle	13 tonnes

Newbridge Arch assessed capacities

OCC are currently still permitting traffic to use Newbridge despite that fact that all its arches are weak, and have implemented an 18 tonne MGW limit as an interim measure. Newbridge's continued use by traffic above its assessed capacity is currently still being permitted on the understanding that:

- Newbridge has been carrying unrestricted A415 traffic (i.e. including a full range of HGV's) prior to the 18 tonne weight limit being imposed.
- The 18 tonne MGW limit will significantly reduce the number of the heaviest HGV's using the bridge.
- Arch failure mechanisms are not sudden and that cracking and surface deformation would become apparent before any catastrophic collapse.
- If any signs of further movement are identified, that the existing weight limit would be reviewed and could need to be lowered further or the bridge closed completely, possibly at short notice.

As well as more frequent physical inspections, remote crack and tilt monitoring equipment has been temporally installed in various positions on the bridge and reports via and an internet based system every 24 hours. This remote monitoring and inspection regime has been in operation since March 2008 and currently has not yet identified any movements sufficient to cause concern or require the current 18 tonne weight limit to be lowered any further.

The 2006 decision to impose an 18 tonne MGW level of restriction was based on the assumption that this should theoretically prevent the closely-spaced multi

axle loading from any 3 to 6 axle HGV's and therefore would significantly reduced the magnitude of loading considered most likely to cause a short-span arch failure. An 18 tonne MGW limit was selected rather than any lower limit as this level would continue to allow local bus services, fire engines and all two-axle HGV's to use Newbridge and therefore would not be unduly disruptive.

Newbridge has recently been re-pointed and has also had some stone work repairs undertaken, though these repairs were mainly to address damage inflicted by a previous boat impact. Re-pointing is routine maintenance work and does not serve to significantly improve its strength, but should play its part in slowing its deterioration and will also help engineers identify any future structural distress/movement more easily.

Weight Limits: Effectiveness and Enforcement.

OCC's Trading Standards section are responsible for enforcing structural weight limits, but obviously cannot maintain a constant presence at Newbridge and this weight limit, like many others, is frequently flouted by drivers of prohibited vehicles. OCC have installed camera enforcement system which should be operational shortly and will then provide 24 hour surveillance and record evidence sufficient to secure prosecutions. It is hoped that the presence of this camera and associated signage will significantly reduce the incidence of prohibited vehicles using Newbridge.

Weight limits alone (with or without cameras) realistically can never be relied on to absolutely prevent the use of a weak bridge by prohibited vehicles and therefore cannot be relied on to completely prevent overloading. There is no effective way of physically enforcing an 18 or 7.5 tonne weight limit by use of physical height or width restrictions as lighter vehicles are frequently just as wide and/or high and therefore such measures would also serve to exclude the generally far more numerous larger permitted vehicles too. In addition to permitted lighter HGV's and LGV's, buses and fire engines would also be excluded. A physical width restriction would perhaps only be viable to support a 3 tonne weight limit, where bollards perhaps 2.1m apart would serve to exclude almost all prohibited heavier vehicles without also excluding a significant number of permitted vehicles such as cars and light panel vans. Obviously in this case as most buses and fire engines are over 3 tonnes and are wider than 2.1m, so these too would also be physically prevented from passing.

Background to assessment techniques

In practice, bridge assessment techniques can never exactly quantify the strength of a bridge. For relatively modern bridges constructed using steel or concrete beams for example, less structural, geometric and material unknowns mean a more accurate assessment of strength is possible and a greater degree of certainty can be achieved. The effectiveness of strengthening techniques too can generally be more readily assessed.

The structural action of an arched bridge is less well understood and is consequently harder to accurately analyse. Of these, perhaps brick arches are the simplest to assess as the construction and materials are generally relatively consistent and therefore relatively straight forward to investigate.

Stone arch bridge construction and material properties are prone to more uncertainty as the properties of natural stone, the form of construction and the individual block sizes can vary more widely. Very old stone bridges such as Newbridge pose the most difficulties, given that they generally have greater historic importance, usually warrant statutory protection, have no construction records available, and are the hardest to investigate/survey as they require a more thorough and consequently more invasive investigation. Such investigations might unacceptably damage or interfere with the original condition and historic fabric and could have a permanent detrimental effect on the strength and durability of the structure.

For any stone arch bridge the following arch properties are of interest:

- the stone strength, condition and consistency
- the arch barrel thickness, geometry and variability
- the arch fill properties
- the presence and extent of any arch structural backing
- the properties and the effects of spandrel walls (and the possible existence of internal spandrel walls, internal vaulting or other internal structures)

These factors will all have an effect on an arch bridge's strength. With such potential for variability and difficulty in identifying all the unknowns it is unsurprising that assessments techniques are intended to be reasonably conservative. It is therefore not that remarkable that though Newbridge has obviously been carrying A415 traffic successfully over previous years without collapsing, that it never the less has an assessed capacity of zero. What must clearly be in question is what factor of safety Newbridge has against collapse and just how long it can carry on carrying modern traffic before it starts to fail or becomes irreversibly damaged.

Maintenance and Strengthening Feasibility Studies

The original Maintenance and Strengthening Feasibility Study (June 2008) was commissioned to look primarily at the feasibility of strengthening Newbridge to full strength. This was because:

1. It is not generally considered prudent to only partially strengthen a weak bridge from a public safety perspective, given the difficulty of ensuring 100% compliance with any weight limit.

2. Because when this report was commissioned it had been assumed that having a permanent weight limit on the A415 would be unacceptable from a highway network point of view.

The Supplementary Maintenance and Strengthening Feasibility Study (September 2009) was commissioned primarily to look at partial strengthening options and also to investigate Newbridge's parapet containment capacities.

These reports identified that:

- Further structural investigation would be necessary to properly assess the structure and the practicality and effectiveness of any particular strengthening option, but also confirmed that these investigations would themselves be intrusive and would permanently damage the bridge to some extent.
- All methods of strengthening Newbridge to partial or full strength would be intrusive and consequently detrimental to the historic fabric of the bridge.
- All arch strengthening options would effectively be irreversible to some extent.
- All strengthening options are of relatively unproven durability when compared with the current 750 year life span of the Newbridge's current original form of construction.
- All arch strengthening options would place the bridge at increased risk during construction.
- All arch strengthening options would alter the structural action of the bridge to some extent, be likely to detrimentally affect the Newbridge's inherent flexibility, would introduce new stresses into the existing fabric and could therefore detrimentally affect the condition of the original fabric.
- There is only a very marginal difference between structural factors required to achieve an 18 tonne or 40 tonne arch strength, therefore these strengthening options could be considered as a single option.
- Strengthening to 18 or 40 tonnes is likely to require the intrusive work on all six arches. Strengthening to 3 or 7.5 tonnes would involve strengthening of one to three arches and would therefore be less intrusive.
- None of the arch strengthening options are considered to be structurally acceptable or appropriate for use at Newbridge and that therefore there are no acceptable methods available to strengthen Newbridge's arches.
- The parapets cannot be practically strengthened without complete reconstruction involving either widening of them or use of high strength

mortar. High strength mortar however will adversely affect the durability of the stone.

- The substandard width and alignment of Newbridge can never be addressed within the constraints of conservation principles.

Thames River Crossings West of Oxford

This report was commissioned to help establish the appropriate solution for Newbridge by understanding how the A415 and Newbridge fit into Oxfordshire's highway network, with particular reference to the other Thames crossing routes in the vicinity.

The report indicated that from a highway network perspective:

1. Ideally a full capacity A415 crossing is required over the Thames so that no A415 HGV traffic is required to divert.

2. The absolute minimum structural weight limit considered acceptable for the A415 in the long term (if it proves feasible to strengthen Newbridge adequately) would be 18 tonnes MGW. This is mainly due to the excessively detrimental affect any lower structural limit would have:

    a. on public transport viability along the A415 corridor.
    b. on communities, roads and bridges on the other local alternative Thames crossing routes, as these are themselves generally unsuitable to carry additional HGV traffic.
    c. on hauliers and local services and deliveries etc and consequently the financial and commercial viability of the area served by the A415.

3. If Newbridge itself cannot be relied on to provide an 18 tonne MGW capacity crossing in the long term then a new full strength A415 Thames crossing should be provided.

Discussion

It has been concluded that from a highway network perspective the absolute minimum level of permanent structural weight limit that would be acceptable on the A415 would be 18 tonnes MGW. It therefore follows that no strengthening options to a capacity lower than 18 tonnes should be considered further.

It has been concluded from a strengthening feasibility perspective that strengthening to 18 or 40 tonnes will require the same magnitude of intervention and would therefore effectively be equally achievable, carry equal risk, and be equally intrusive with respect to the fabric of Newbridge. Given this and the difficulty of physically enforcing any weight limit, it seems clear that the only strengthening option that should be considered further should be strengthening to full strength.

Irrespective of whether any environmental weight limit might be deemed appropriate for the A415 in future, if a new A415 Thames crossing were to be constructed, prudence dictates that any new structure should not be designed and built to be deliberately weak. Any new bridge must be designed and built to current standards and therefore built to full strength, given the difficulties of enforcing structural weight limits generally, so that it poses no unnecessary risk to the travelling public and so that it is fully available for use by all emergency vehicles.

From the conclusions above, it follows that OCC has only two options available with respect to Newbridge, namely:

1. To construct a new full strength off-line crossing.
2. To strengthen Newbridge to 40 tonnes MGW.

In considering these two options further the reader should be aware that OCC have concurrently commissioned Jacobs to look at the feasibility of constructing a new alternative A415 Thames crossing in the vicinity of Newbridge, and that English Heritage have already formally confirmed that they consider the preferred route option (approximately 250m upstream of Newbridge) would not be detrimental to the setting of Newbridge with respect to its ancient monument status. It can therefore be assumed that it is both practical and acceptable from a conservation perspective to construct a new A415 Thames crossing. The decision therefore can be distilled down to whether or not it is acceptable to strengthen Newbridge to 40 tonnes MGW capacity.

Newly constructed bridges and strengthening options have a notional design life of 120 years. Premature failures obviously do happen and numerous modern bridges have been replaced due to shortcomings in knowledge, understanding, construction, materials and/or detailing. The A34 Wolvercote Viaduct built in 1962 in Oxfordshire is a very large notable local example that has clearly failed to reach its design life and is currently being reconstructed at considerable cost. Newbridge in contrast has obviously stood successfully for 750 years effectively unchanged, and is designated a scheduled ancient monument that must be maintained for posterity. It could be argued therefore that OCC, in contemplating

strengthening Newbridge, must be absolutely confident that any “modern” change made now, will not compromise Newbridge structurally for at least the next 750 years, unless of course any change is completely reversible.

The strengthening feasibility report appears to indicate that there are four possible options available to strengthen Newbridge:

1. Increasing backing level (by grouting).
2. Plain concrete saddling.
3. Cintec Arch Tec arch strengthening.
4. Bersche-Rolt arch strengthening.

It is the OCC Bridge Office’s view that option 1 is highly likely to prove impractical to implement effectively, if attempted would be unacceptably detrimental with respect to ecology, and that none of the strengthening options listed above are consistent with “The principles of conservation” listed in the section titled “Conservation Constraints” above.

To varying degrees all the options would:

1. Expose Newbridge to new risks, both during construction and afterwards in service.
2. Alter the bridge’s structural action with uncertain and potentially detrimental effects.
3. Involve loss/damage of historic fabric.
4. Be intrusive and effectively irreversible.
5. Introduce new materials.
6. Could not be undertaken using appropriate materials and methods.

It is the OCC Bridge Office’s view that none of the short-listed arch strengthening options would be appropriate to use at Newbridge from both a conservation perspective and due to technical concerns regarding risk, structural effectiveness, design life and irreversibility. Given that partial strengthening options have also been discounted, it would be inappropriate to undertake any further intrusive investigation work if this information is not going to be required for the long term solution.

In addition even if a satisfactory arch strengthening solution could have been found, there would still be a significant issue regarding the weak parapets to address, an issue that itself appears impractical to remedy satisfactorily without unacceptable alteration of Newbridge’s historic fabric.

Conclusion

It appears apparent that the only satisfactory option available to OCC to address the structural and physical shortcomings of Newbridge, whilst also adequately protecting its existing condition, structure and original historic fabric, is for OCC to construct a new A415 Thames Crossing in the vicinity which could then allow Newbridge to be closed to all motorised vehicles.