Old Mangere Bridge

Review of Current Strategy

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1 Introduction

WSP Opus were approached by the Auckland Motorway Association (AMA) to provide a "Senior Engineer's Review" on the asset condition and suitability of the current strategy for maintaining and managing Old Mangere Bridge (OMB) in Auckland. Following a start-up meeting on the 29th March with Jennifer Hart from the AMA; we were tasked with providing a high-level review to determine whether the current "Holding Strategy" for the bridge is appropriate considering the demolition and reconstruction has been pushed back due to East West Link project review and light rail. This report seeks to review the currently available information and the current risk-management strategy and to suggest possible solutions, with safety of users and maintainers paramount.

From our understanding, the proposed and imminent reconstruction of OMB was part of the wider East-West connection project which is no longer a funding priority for the Government. The current holding strategy for OMB was based on the knowledge that the bridge would be decommissioned in a very short space of time (1-2 years). This strategy was essentially a "managed decline" until the replacement could be procured, the risks of which, although significant, were mitigated partly by the short time-scale and temporary measures put in place such as fencing off the weaker/most deteriorated parts of the structure, regular inspections and monitoring.

2 Background

OMB was constructed circa 1914 and consists of 17 simply supported reinforced concrete spans varying in length between 11.43 & 15.24m and measuring 243m in total. Until 1985, the bridge formed the main road link between the city of Auckland and the airport; whereupon it was replaced by the current motorway bridge and downgraded to a pedestrian and cycleway bridge due to its deteriorating condition. OMB has arguably reached the end of its useful life due to its current condition. Despite its location in an exposed marine environment and being constructed from comparatively understrength materials (for contemporary standards), OMB has managed to survive for over 100 years. OMB is still in service as a cycle / pedestrian bridge and benefits from monthly special inspections and a cloud-point 3D survey to check for any sudden change in its condition. In 2016, a live load assessment concluded that large areas of the bridge could not safely support a *reduced* crowd loading event of 3 kPa. This reduced loading is based on engineering judgement at the time and is typically reserved for structures which are deemed to be lightly loaded. However, the Bridge Manual specifies a crowd loading of 5kPa in clause 3.4.14. There have a been a number of crowd loading events on OMB in the past 8 years and this remains a significant risk.

There is an alternative cycling and walking route across the Mangere Inlet via the motorway bridge. On the west side of the westernmost span, is a dedicated, cantilevered access route with a raised footway and textured cycleway.

It is understood that the AMA has commenced separate work assessing the adequacy of this facility in the event that the OMB needs to be closed.

3 Observations from a site visit on 19th April 2018

On 19th April 2018, Engineers from WSP Opus inspected the bridge by boat at low tide with particular attention paid to the soffit and visible substructure. A walkover of the structure and the most likely cycle path diversion was also undertaken. Observations from the site visit are noted as follows:

Impact damage on Column IS60 / Pier 15. Evident damage from a collision by a water-borne vehicle has caused significant damage to the edge girder haunches on the Western side of the bridge. The concrete haunches are contorted and cracked with exposed rebar visible. Repairs include a localised concrete encasing in the transition zone to the tapered section. At first glance, it is hard to see how this helps the damaged section. The concrete thickening would appear to want to attract load to this region of the structure in addition to the dead load from the additional concrete. Meanwhile the load transfer to column IS60 is compromised due to the distortion of the haunches. The area immediately above this is closed off to the public so any dead load failure in this region is unlikely to endanger life.

Photo 1 – Pier 15 (Column IS60) impact damage and repairs

Pier 7, Column IS28: On the Span 8 side there is severe loss of section on the outer girder in the shear zone haunch. The exposed bottom steel is buckled and the stirrups have corroded away leaving a rough concrete surface with approximately 300mm loss of section. The full width of Span 8 is open to the public which could pose a risk should crowd loading ensue.

Photo 2 – Pier 7 (Column IS28) loss of concrete and exposed, buckled reinforcing bars

Spans 3, 4, 5 & 6 exhibit sufficient loss of concrete to reveal two layers of steel reinforcing bars on the soffit of some of the internal girders. Stirrups are also corroded through in the zones of maximum shear.

Photo 3 – Beam soffit – Span 5

Photo 4 – Beam soffits – Span 3

A concrete overslab has been added to the structure presumably to strengthen the deck. It is assumed that the new slab has been tied in to the existing deck slab to allow some composite action which will be beneficial to the strength of the bridge despite adding considerable additional self-weight.

NB 1: During the inspection, a motorised scooter was observed crossing the bridge despite the signage.

Photo 5 – Bridge signage

NB 2: During our inspection, fishing was observed taking place away from the bridge at the southwestern end of the bridge at low tide.

4 Review of strategy

Since the closure of the bridge to vehicular traffic, Asset Managers for OMB have spent a great deal of time and expense assessing the condition and attempting to prolong the life of the bridge. The condition has consistently been assessed as poor and there is common concern expressed amongst Inspectors, Assessors and Asset Engineers that the structure is potentially unsafe. This situation has been tolerated to some extent due to the imminent replacement of the structure and with the implementation of short term mitigations and strengthening works. Now that situation has changed it is important to review the current status and condition of the bridge with a renewed vigour and an eye firmly on the safe operation of a key bridge asset over the medium to long term.

The existing holding strategy is based on an ongoing restricted operation of the bridge in conjunction with real time monitoring using an array of 100 tiltmeters running along both sides of the deck. The restricted operation has been achieved through fencing off some of the worst affected areas of the structure to reduce live loading effects and additional signage. In addition, dive inspections have concluded that the substructure below the water line is in fair condition.

The risk strategy matrix below in Figure 1 shows as red, the items where action needs to be taken to ensure the safety of the public. The orange areas also require action within a year. This matrix was used to assess the risk to OMB in 2016 including mitigations and residual risk scores as shown in Figure 2. This risk assessment has been updated with additional scoring based on the bridge not being replaced for at least 10 years.

Effect or Defect	Severity Factor	Certain	Likely	Probable	Possible	Unlikely
		5	4	3	2	1
Catastrophic / unpredictable / undetectable failure, which causes injuries and/ or fatalities	5+	25+	20+	15+	10+	5+
Predictable / detectable failure, which may cause injuries / fatalities	5	25	20	15	10	5
Predictable / detectable failure, leading to road closure	4	20	16	12	8	4
Predictable/detectable deterioration, leading to reduced usage based on assessment results	3	15	12	9	6	3
Further deterioration in condition of structure, leading to higher severity impact in future years.	2	10	8	6	4	2
Further deterioration of structure, leading to increase in eventual repair, cost and public complaints	1	5	4	3	2	1
Nil or Negligible consequences	-1	-5	-4	-3	-2	-1

Priority	H	High; work should be done during the next financial year to ensure the safety of the public or safeguard structural integrity or avoid a high cost penalty.
	M	Medium; work should be done during the next financial year; postponement carries some cost penalty.
	L	Low; work should be done within the next two financial years.

Figure 1 – Risk Strategy Matrix

		Risk Assessment carried out in 2016		(2016) Over 1-2 year period				(2018) 1-10 year period			
Number	Risk	Specific Details	Mitigation Measures	Risk Score (Before Mitigation)	Severity (Residual)	Likelihood (Residual)	Risk Score	Status & Further Mitigation	Severity (10+ years)	Likelihood (10+ years)	Risk Score
1	Collapse of the structure due to loading	Following the numberical assessment it has shown a number of elements do not have adequate factors of safety to support crowd loading	Install fencing that restricts pedestrian access to the substandard elements	20	5	3	15	Further restriction / new fencing	5	4	20
2	Collapse of the structure due to condition	The quarterly inspections have noted cracking and deterioration of structural members	Install steel collars and bracing to hold/strengthening substandard members	20	5	3	15	Real-time monitoring & continuing inspections	5	4	20
3	Collapse of the structure in remaining open section	The central carriageway section of the bridge still remains open including the full central 4 spans as they have a factor of safety greater than 1 and better condition factors	Monitor the structure through quarterly inspection and real time monitoring which will capture any significant deterioration of the structure	15	1	2	2	Real-time monitoring & continuing inspections	5	3	15
4	Falling debris on boat users	Large sections of concrete have the potential to fall off the structure and hit boat users underneath	Install signs warning people not to enter the worst spans. Warning signs paced in the spans less likely to have falling debris	12	4	2	8	No change	4	2	8
5	Hidden detail such as under water of behind delaminated concrete	The piles under the water have not been inspected which could be hiding more significate conditional deterioration.	Carry out underwater inspection	20	5	2	10	Inspection has taken place and condition is fair	5	1	5
6	Assumed section loss and section sizes used in the assessment are not conservative	An assumption had to be made on the loss of section and some of the section sizes due to the extensive deterioration	Continue with quarterly inspection. Once the real time monitoring is set up this can monitor ongoing deterioration and progress failure to allow enough time to evacuated the structure	15	1	2	2	Load testing to calbrate monitoring	5	2	10
7	Reputional risk to the Agency	If the structure were to fail and collapse there would be reputional risk to the agency	By restriction access to the worst areas, and a strigent monitoring regime the risks can be managed. If the structres RTM levels get triggers or further significant deterioration the structre will have to be closed	15	5	2	10	Risk of structural failure can be managed but not eliminated. Risks from tides, flood, deterioration and overload are significant over 10 year period.	5	4	20
8	Reputional risk to the Agency	If the structure has to be closed before the new structure can be constructed	If the structure deteriorates further that affects the safe usage of the bridge it will have to be closed down. If this were to occur the underslung walkway under the mainline bridge could be utiliised but would need to be upgraded at a cost and will not accommodate people fishing.	15	5	3	15	Structure will almost certainly need to be closed within 10 years. The alternative walkway remains sub-optimal	3	5	15
9	Community Relations	Backlash form the community	Keep the community infomed	8	4	2	8	Effective public relations and media campaign	2	2	4

Figure 2 – Risk Strategy Matrix for Old Mangere Bridge 2016 & 2018

One of the key mitigations for the current holding strategy is an implemented system of effective real-time monitoring. Unfortunately, this hasn't been functioning recently due to some installation difficulties, although a small amount of data was recorded at first. The monitoring is proposed to be reinstalled in the near future with equipment and expertise provided by WSP Opus Research Labs in Petone. This monitoring will allow for an alarm system to alert the On-call Engineer. Assuming the monitoring can be used for advising of a potential collapse scenario, the key issues to be solved and agreed upon are:

- Calibrating the alarm triggers to differentiate between an in-service dynamic loading event and an overload event or displacement due to structural failure.
- Rationalising length of time between an event occurring and alerting users of the bridge to evacuate if required.

Strengthening work has been carried out near the span supports to reduce the likelihood of a sudden catastrophic failure. Steel clamps and braces were installed as holding measures in the event of a dead load failure. These mitigations are designed to be a last resort and should not be relied upon during a crowd overload event. To reduce this likelihood of the risk, the deck area could be better protected and further restricted to pedestrians / crowds.

Three-dimensional surveying is currently being carried out on an ad-hoc basis and the results are compared against a baseline for changes in the deck level. This cloud point data is a very useful tool for monitoring alignment changes over time. We believe that surveying either by total station or 3D scanning should be continued at 3-monthly intervals whilst the bridge remains open.

The bridge beams have been externally post-tensioned which is providing a much-needed boost to flexural capacity especially considering that the section loss is so severe in many areas. This is fine whilst the post-tensioning remains functional. A small risk remains that a failure may occur at an anchoring point due to the condition of the concrete, leading to an abrupt change in load path which could initiate a structural failure.

Regular inspections by boat are ongoing to look specifically at existing problem areas such as the bridge strike area and the worst corrosion. Whilst these provide important qualitative photographic and journaled reference information, they may not necessarily advise of an imminent failure which could arise from a hidden critical element. Also, there is the risk that the inspector will become desensitised to the inherent risk of a bridge in this condition.

The worst parts of the structure have been fenced off to reduce the live loading demand, particularly on the edge girders. This fencing, although effective in normal daily situations is however not impregnable. Should an emergency occur on the bridge it would be quite easy for people to access the weak and dangerous parts of the structure. In addition, the unlocked gate could provide very easy access for crowds during an incident. Ideally the fencing and gates should be reviewed and upgraded as soon as possible. Consideration should also be given to fencing off more of the structure (see recommendations).

Closure of the bridge has been considered previously but not implemented due to pressure from stakeholders who use it for leisure and commuting by walking and cycling. Work to assess the alternative route is the subject of a separate report.

Fishing could continue at the southern end of the bridge as was observed during our site visit. Closure would clearly be an advantage by eliminating the risk to the public but the disadvantage around stakeholder relations remains. From our experience, this option would be highly likely in a similarly high-profile area in the UK where risk to the public would be the paramount consideration and the public would expect such a response. This also aligns with the new focus areas within the NZ Transport Agency Statement of Intent, in particular the effort to “Keep People Safe”.

A partial demolition where the riskier sections of the bridge could be dismantled has been considered but ruled out due to the unknown consequences of residual stresses in the structure. This option would have been beneficial if only to remove dead load and to prevent accidental loading of the weakened parts of the structure. This is particularly so due to the retrofit post tensioning and it would not be advisable to remove any of the structure until decommissioning begins.

5 Recommendations

There are clearly risks to the public with Old Mangere Bridge remaining open which can either mitigated through the measures outlined below or eliminated through a permanent bridge closure. Having been to site and having reviewed all available documentation on the current condition of Old Mangere Bridge including the latest assessment reports; it is clear to us that the structure is not currently fit for purpose and is continuing to deteriorate and weaken as more of the reinforcement becomes exposed. It is hard to justify keeping the bridge open to the public for much longer without urgent strengthening work taking place. Indeed, from a UK perspective, it is considered likely that a well-used bridge in this condition would be closed immediately to eliminate the potential risk to the public. In addition, the assumptions made in the 2016 assessment may have underestimated the degree of corrosion in the reinforcement and the exact combined effect of post tensioning with exposed longitudinal reinforcement, failed stirrups and spalling concrete.

Assuming that OMB will not be replaced for the next 10 years, our recommendations for a revised strategy are based around an updated and phased strategy. This strategy seeks to put in place a structured approach to managing the risk and protecting the users and stakeholders of the bridge. This strategy should be reviewed on a regular basis to ensure that it remains appropriate and is outlined as follows:

1. We would recommend initially load testing the bridge with operational monitoring in place. The phased approach would depend on the outcome of this. Assuming a structural failure does not occur, the monitoring information can be used to set trigger and alert levels for future events. We would suggest keeping the bridge open as it is for the first 12 months with monitoring and upgrades to the fencing including providing an adequate locking system. Fencing should also be reconfigured to restrict access to the edges of Span 8 due to the condition of the concrete edge girder at Pier 7.
2. After one year and assuming no further significant deterioration has been noted, we would recommend narrowing the useable portion of the bridge to the minimum footpath and cycleway standards along the full span. This could be implemented fully or in sections dependent on condition. This will reduce the live load demand from recreational users. Fishing can still be carried out from the approaches to the bridge as was evident during our inspection (even at low tide). This strategy could potentially remain in place until year 4 with functioning real-time monitoring, scheduled 3D surveying and regular inspections.

3. Proceed with upgrade works to the alternative cycling and walking route along the motorway bridge so that it is available in the event of the closure of OMB.
4. After 4 years, it is possible that OMB will need to be closed if it has not been already. Although it is difficult to predict the situation this far in the future, we anticipate that the effect of storms and high tides combined with continued deterioration will have increased the risk profile of the structure substantially beyond the current situation.
5. Cyclists and pedestrians to be rerouted over the motorway bridge until a replacement structure for OMB is procured and built.

Looking at the first point in more detail, we recommend repairing the faults to the monitoring system and instigating the real time monitoring as soon as possible. In advance of testing, using the media the public should be kept informed of this critical safety work to keep the bridge open. Once the monitoring equipment has been tested, the bridge should be temporarily closed to the public and a load test should be conducted using water tanks that can be easily filled to achieve the desired load case and easily drained with minimal risk of harm. The critical spans should firstly be loaded to 3kPa to check for effects and then to 5kPa whilst monitoring continues and with safe observations by boat. The outcomes of the testing can be used to calibrate the monitoring system for when the bridge reopens to the public. If any structural damage should occur during testing, then the outcome of the test will be that the bridge is no longer safe for use and should be closed immediately and an alternative route should be devised as per point 3 above.

We believe this phased strategy will help to keep the bridge open in the short term and transition through to permanent closure using evidence-based engineering judgement. Keeping the public informed through a multimedia approach and the strategy of introducing safety measures by degrees, will provide a useful means of managing the expectations of stakeholders throughout until the inevitable closure of OMB. This approach will also help to put across the message to the public that everything is being done to try to keep the bridge open, but that the safety of members of the public is ultimately the principal consideration.