RESTORATION OF SCOURED OUT BRIDGE APPROACHES AND FOUNDATIONS – A QUEENSLAND DEPARTMENT OF TRANSPORT AND MAIN ROADS (QDTMR) PERSPECTIVE

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ABSTRACT

The Queensland Department of Transport and Main Roads (QDTMR) standard flood immunity criterion for all new bridges is an average recurrence interval (ARI) of 50 years unless there is an appropriate documentation in support of ARI greater than 50 years. Following severe wet weather events associated with ex-tropical Cyclone Yasi and Oswald in late 2010 / early 2011 and early 2013 respectively, Queensland public infrastructure were severely impacted. Apart from pavements, roadway side slopes, causeways and other private assets that were washed away, several roads, railways and bridges including their approaches were also damaged.

The level of damage on some of the bridges were such that their post-disaster functionality was zero leading to their closure to public use. The closures required motorists and other stakeholders to embark on long detours of affected bridges. During the closure, inspections were carried out to determine the extent of damage, followed by design and remedial works to restore the bridges to pre-disaster or improved condition.

To guide engineers and asset managers towards restoring the damaged public infrastructure, the Transport Network Reconstruction Program (TNRP) design guidelines were put in place to provide guidance in areas where the existing QDTMR design specifications did not cope with the flooding and to ensure consistency in designs put forward for the reconstruction effort. This paper describes the design methodology adopted by QDTMR in fixing scoured (washed) out bridge approaches and foundations that resulted from the severe wet weather events during the 2010/11 and 2013 floods. It also discusses the options in building resilient approaches that can perform satisfactorily in similar extreme wet weather events in the future.

INTRODUCTION

Following a period of sustained wet weather associated with intense low of ex-tropical Cyclones Yasi in 2010/2011 and Oswald in early 2013, Queensland public infrastructure suffered significant damage. Cyclones Yasi and Oswald brought heavy rains estimated to be in the order of a 1 in 200 year to 1 in 300 year average recurrence interval (ARI) events which is in excess of the existing QDTMR standard flood immunity criterion of ARI 50 years. This resulted in severe flooding that led to the wash out of roads, railways and bridges. According to QDTMR Hydraulics Section, the flood velocities that could have left such trail of destruction would have been in excess of 3m/s.

The pattern of the wash out was consistent and involved the removal of variable lengths of the bridge approach embankments, the complete or partial removal of the spillthrough embankments leading to the exposure of a length of up to 5m of the piles supporting the bridges. Within the QDTMR network, some of the washed out bridges included the Gatton – Esk Bridge over Lockyer Creek, the Geoff Fisher Bridge at Fernvale, the Tallon Bridge in Bundaberg and the Neerkol and Double Creek Bridges near Rockhampton in Central Queensland among other numerous bridges.

The existing QDTMR Standard Drawings Roads, Numbers 1540 to 1548 [1] contains the methods used in QDTMR for managing scouring issues. The methods cater essentially for the protection of spillthrough batters on overpasses and drainage (bridge) structures where stream
velocities are less than 2m/s. These standard QDTMR protective measures against scour were breached during the flooding of 2010/2011 and 2013. As part of the efforts towards reconstructing the damaged infrastructures, the Transport Network Reconstruction Program (TNRP) [2] was put in place by QDTMR. In the guidelines, the recommended protection against scour is similar to the recommendations contained in AUSTROADS, 1994 [3] and consists of the use of gabion, wire mattresses and rock riprap.

Due to the limited number of piles used in the foundation of QDTMR bridges, QDTMR bridges are considered as having low redundancy, signifying the potential of serious danger should the carrying capacity of any of the piles be compromised. With the loss of up to 5m of soil around the piles, the residual axial and lateral capacity of the piles at the affected bridges were concerns due to the loss of shaft capacity and fixity that had been provided by the washed out soils. As a way to address these concerns, it was considered that the introduction of materials that will promote adhesion to the piles and consequently improve the shaft capacity and fixity was needed as the gabion and rock riprap are considered less efficient at providing adhesion.

The procedure used in remediating the scoured out bridge approaches and spillthrough embankments using the TNRP guidelines in combination with cement stabilised sand and grout filled mass block is discussed in this paper.

CURRENT STATE OF PRACTICE

The current state of practice in the treatment of bridge approaches recognises the need to:

1. ensure that the bridge approach is globally stable by stipulating limiting batter geometry in the transverse (1V : 2H or flatter) and longitudinal (1V : 1.5H or flatter) directions
2. ensure that selected fill materials are used in construction of the approaches. In this regard, the QDTMR Geotechnical Design Standard – Minimum Requirement [4] (currently in draft format) stipulates that “only Class A material compacted to 98% minimum compaction density or rockfill is accepted within the structure zone. The Structure Zone is defined as a length not less than 25m within the approach to any structure”
3. protect the bridge from being undermined by erosion and scour by ensuring that any of the appropriate abutment protection measures as outlined in the Departmental Standard Drawing Numbers 1540 to 1548 is implemented
4. control settlement at the approaches with a view to limiting differential settlement and by doing, manage rideability concerns. In this regard, the Departmental Geotechnical Design Standard – Minimum Requirement [4] which is currently in draft format stipulates that “the design change of grade due to differential settlement over any 5m length of pavement must be maintained to 0.5% in any direction of the carriageways during the defects liability period and that settlement must not create any abrupt step larger than 5mm.

Following significant damage after the floods, the Transport Network Reconstruction Program (TNRP) design guidelines was subsequently drafted and put in place to assist engineers and asset managers in the design for remediation.

THE PROBLEM

Currently, there is strict compliance to the items discussed in Section 2 (Current State of Practice) above in the delivery of QDTMR projects. A team approach by design engineers, construction and maintenance personnel backed up by site supervision by appropriately trained staff has helped in ensuring that compliance to relevant QDTMR specifications are met. The provision of relevant training such as the Bridge Design and Construction workshop has also helped in ensuring a better understanding and implementation of the design requirements relevant to the delivery of bridge projects.

Considering the observed exposed materials at the approaches to the washed out bridges suggest that the current state of practice may not have been in place and observed during the construction of the affected bridges. Suspect materials which do not meet current design
requirements such as silty materials that are highly vulnerable to scour even under normal flooding conditions were observed to constitute part of the fill materials at some of the bridge approaches. The presence of these unsuitable materials may have played a key role in the sustained damages to the bridges. Figures 1 to 4 show images of some washed out bridge approaches and footings following the floods.

Figure 1: Washed-out Abutment B of the bridge over Lockyer Creek on the Gatton-Esk Road.

Figure 2: Washed-out Abutment A of the bridge over Neerkol Creek near Rockhampton.

Figure 3: Washed-out spillthrough of the bridge over Double Creek near Rockhampton.
As observed at the various affected bridge sites and as captured in Figures 1 to 4 above, it is estimated that the operational stream velocities that would have left the trail of destruction at peak flood could be in excess of 3m/s (based on the information from the QDTMR Hydraulics Section). While Class A material or rockfill to QDTMR technical Specification 04 (MRTS04) [5] as required for structure zone construction in the QDTMR guidelines is a robust building material and a better candidate material for constructing approach embankments when compared to silty materials, its vulnerability to wash-out in the event of floods at the scale similar to those of 2010/11 and 2013 remains a concern. This has necessitated an improvement in the QDTMR Standard Drawings for scour protection.

POSTULATED FAILURE MECHANISM

The patterns of destruction at the affected bridgesites were similar. It is considered that they may have resulted from similar flow patterns during the flood event. Based on the footprint left at the approaches, the spillover through and around the piers after the flood waters had receded, it is considered that the mechanisms that led to the washed-out approaches and piers consisted as follows:

1. initial high flow velocities contained within the main flow channel with undermining due to scour affecting mainly the piers
2. further increase in flows due to increased rainfall, resulting in higher flow velocities. The flows at this stage may have overtopped the bridges as well as flowing behind the abutments. These flows may have been at supercritical velocities (flows with Froude Number, which is the ratio between flow velocity and the square root of the product of acceleration due to gravity and depth of flow greater than 1) thereby resulting in the undermining of the downstream abutment spillover batters and creek banks
3. while the flood waters persisted, the approach embankments in the immediate vicinity of the bridge abutments and the materials at the spillover become saturated with significant reduction in strength (softened strength conditions)
4. resulting from the applied force due to the column of water upstream, the softened strength of the approach embankments and its foundation as well as the undermining of the downstream approach embankment batter, a push through of the materials located immediately behind the abutments in the direction of flood flow may have occurred
5. further collapse of the banks adjacent to the abutment due to rapid draw down conditions. At the bridge sites where silts were predominant, it was observed that the bank collapse was more severe.

REMEDIAL APPROACHES

As shown in Figures 1-4, a common feature of the washed out bridge approaches and piers consisted of loss of up to 6m high and 10m length of the approach embankments. The loss of
the approach fill embankment material left the bridge supporting piles exposed. The following were the major issues raised by the QDTMR in respect of the wash-out and exposure of pile foundations:

- concerns over the residual capacity (axial and lateral) of the exposed piles
- concerns over the residual structural strength and durability of the piles
- concerns over the availability of suitable materials that could promote friction along the shaft of the piles with a view to restoring some of the lost shaft capacity and fixity
- finally, concerns over limiting any accidental impact on the piles during remedial works.

The remedial efforts at the affected bridge sites targeted the concerns listed above. The following options were given consideration:

- the introduction of extra spans to increase the channel width and moving the abutments couple of meters away from the main channel thereby minimise the risk of abutment wash-out. Due to cost considerations and time required to go through a design cycle and construction, this option did not receive much support
- the use of grout filled mass block
- the use of cement stabilised sand around the piles surrounded by rockfill capping layer and finished off with rock riprap dressing. The cement stabilised sand should be to the requirement of MRTS04 [5] and the rock riprap should be sized to account for the estimated flow velocities in accordance with TNRP guidelines.

In the majority of repairs the mass block or the cement stabilised sand with rockfill options were used. Cement stabilised sand or grout around the piles were considered necessary to promote adhesion between the piles and the replacement, thereby improving fixity, lateral resistance and the overall geotechnical axial capacity of the piles.

A design issue that need to be catered for with the mass block option is settlement concerns due to debris filled and weakened foundation. For the cement stabilised sand alternative, the use of form work need to be planned for. Where difficulties were envisaged in constructing formwork to contain the cement stabilised sand, finer rock (-75mm) aggregates were used as replacement.

Critical to the success of both options is the need to ensure minimal impact on the exposed piles by construction machinery during remedial works.

Following repair works carried out after the 2010/11 and 2013 floods, the mass block option was used in remediating the Tallon Bridge in Bundaberg. At the Geoff Fisher Bridge in Fernvale, the Gatton – Esk Bridge over Lockyer Creek, the Neerkol Bridge and the Double Creek Bridges near Rockhampton, cement stabilised sand or finer rock aggregates encapsulated with rockfill with rock riprap finish option was used. Compared to the additional span option, the mass block and cement stabilised sand options had a lower overall capital outlay and were implemented within a short time frame. Shown in Figure 5 below is a typical drawing for the repair works carried out at the Lockyer Creek Bridge on the Gatton – Esk Road.
Figure 5: Details of the adopted approach for remediating the washed-out approaches.

Typical photos of the finished works at Lockyer Creek and Neerkol Creek Bridges are shown in Figures 6 and 7 below.

Figure 6: View of Lockyer Creek Bridge on the Gatton – Esk Road after repairs

Figure 7: View of Neerkol Creek Bridge approach after repairs
CONCLUSIONS AND RECOMMENDATION

The QDTMR standard flood immunity criterion for all new bridges is ARI 50 years unless there is a documented reason to adopt a different value. As witnessed in the 2010/11 and 2013 flood events, this standard immunity criterion was breached, resulting in severe damage to Queensland public infrastructure, with several bridge approaches and footings washed out in the process.

As financial considerations prohibits designing out rare flood events, it is prudent to have a documented design and reconstruction procedures for repair works for such events. As there was none prior to the 2010/11 and 2013 flood events, the approach used in QDTMR in implementing repairs at washed out bridge approaches and footings was presented. The considered measures consisted of the use of additional spans with a view to increasing the channel width, the use of grout filled mass block wall and the use of cement stabilised sand with rockfill capping layer and rock riprap finish. Of these methods, the use of grout filled mass block wall and cement stabilised sand with rock riprap finish were adopted because the methods had the ability to restore some of the lost shaft capacity and fixity of the exposed piles, thereby resulting in improved overall geotechnical capacity of the piles. The methods have also the advantage of being relatively cheap and have short implementation duration.

Since the implementation of repairs of the affected bridges, no significant flood event has occurred and as such the post construction performance of the repairs cannot be commented on. However, considering that the design of the remedial works recognised construction materials and adhesion issues as well as flood velocities, it is considered that the adopted remedial options met all the requirements to ensure robustness.

The successful implementation of the designs within a relatively short time frame led to the re-opening of the bridge crossings to public use in good time making the adopted design and remedial options attractive. It is recommended to monitor the long term performance of the finished works as they could form the basis for design and repair of similar flood damaged works in the future.

REFERENCES


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