2010/11 Queensland Floods and Cyclone Events: Learnings for Structures

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Abstract The summer of 2010 / 2011 represents an extreme event. The majority of Queensland was declared a natural disaster zone as a result of the damage caused by non-typical flooding and cyclones throughout the State. It is estimated $4.5 billion dollars worth of damage was done to the State declared road network. This paper identifies a range of issues that were encountered as a result of these natural disasters, including the demolition of select timber bridges, settlement of piers, and scour at abutments and partial damage to bridges. The paper also examines the actual loads bridges were subjected to and compares this to current AS 5100 design loads. Some load cases not addressed in AS 5100 have been identified. Inspection procedures, including a navy hydrographical survey, that were undertaken prior to reopening the bridges to traffic are also considered in this paper. The conclusion of the paper discusses the procedures that were put in place to rectify the issues identified by post analysis and inspections of the State declared road network. It is recommended such learnings be considered and applied to new works and remedial works in conjunction with suggested possible amendments to AS 5100 Bridge Code.

Introduction: Summer 2010 / 2011 (1/12/10 – 28/2/11)

The 2010 / 2011 summer in Queensland was not the wettest in history but was noticeable for the fact over 80 percent of the State was declared a natural disaster area, intensified by a Category 5 cyclone that impacted weather patterns in South Australia. These events were tragic and life threatening. In Grantham, lives were lost.

The wide average and high intensity rainfall is summarized in Table I.
Table I. 2010/11 Summer Rainfall

<table>
<thead>
<tr>
<th>Town</th>
<th>Rainfall (mm)</th>
<th>% Above average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cairns</td>
<td>1795</td>
<td>173</td>
</tr>
<tr>
<td>Ingham</td>
<td>1711</td>
<td>127</td>
</tr>
<tr>
<td>Brisbane</td>
<td>952</td>
<td>229</td>
</tr>
<tr>
<td>Toowoomba</td>
<td>920</td>
<td>293</td>
</tr>
<tr>
<td>Cooroy</td>
<td>1604</td>
<td>249</td>
</tr>
</tbody>
</table>

Rainfall was up to nearly 300% above average. Higher above average rainfall was experienced in southern Queensland compared to northern Queensland. The magnitudes of the natural disaster were unprecedented. The extent of the flooding in Brisbane CBD is demonstrated below (Fig. 1.).

Fig. 1. Brisbane River in Flood

Key factors contributing to the flood damage were:

- Maximum rainfall was 4,512mm at Mt. Bellenden Ker
- Cyclone Yasi was Category 5 with wind gusts to 285 km/h and 5m tidal surge off Cardwell.
Queensland Declared Road Damage Bill (April 2010 – February 2011)

The extent of the damage to the State declared road network is $4.5 billion dollars of which $3 billion of the damage resulted from the floods in summer (December to February). The distributions of financial costs are:

- 85% to roads. This was primarily to pavement damage, loss of seals and damage to culverts.
- 10% to landslide stabilization. There are in excess of 100 sites around the state.
- 5% to bridges.

- Needed replacement of two timber bridges due to severe flood damage
- One bridge recorded 70mm pier settlement
- One bridge was closed with 4m scour and piles undermined
- Scores of scoured abutments
- Scores of bridge approaches were washed out.

Timber Bridges to be Replaced

Two timber bridges required replacement due to flood damage. Damage to the timber bridge in Fig. 2 included:

- Bridges lifted and moved side ways
- Spliced piles no longer connected
- Piles broken.

The bridge was damage beyond repair.

Fig. 2. Timber bridge damaged by floodwaters
Flood Debris and Ship Impact

The involvement of the Queensland Department of Transport and Main Roads in the flood recovery effort provided an opportunity to reflect on possible differences between actual flood debris and the debris discussed in AS 5100.

AS 5100 flood debris loading is based on:

- Water flow
- Debris mat
- Log impact.

Upon reflection, debris loading on bridges is typically based on rural situations. The Brisbane flood events are considered an urban flood event that differed significantly from the design assumptions of the Bridge Code. Increased debris in the Brisbane River and other possible debris had not been previously considered in the design assumptions of the Bridge Code.

Fig. 3. Urban debris; pressure vessel / grain silo against a bridge pier
Examples of unexpected debris in the Brisbane River included:

- City cat catamaran ferry terminals
- Numerous private pontoons
- 300 tonne ‘Island’ pleasure craft upstream of the Goodwill pedestrian bridge and bridges in city reach of river
- Large segments of concrete Riverwalk
- Pontoons carrying the Drift Restaurant (which sunk)
- Shipping containers.

Elsewhere in the State, debris included:

- Cars and 4 wheel drives (Fig. 4.)
- Delivery trucks (2 axle)
- Pressure vessels and grain silos (Fig. 3.)
- Traditional debris mats
- Pleasure craft (Hinchenbrook Channel).

**Fig. 4.** Urban Debris (Toowoomba); Cars & 4-Wheel drives

It is concluded the current Bridge Code is too small for some urban debris loads.
Design Criteria Footbridges – Urban Debris and Ship Impact

AS 5100 does not presently:

- Address ship impact on superstructure
- Identify types of potential debris in urban areas (e.g. Brisbane River)
- Impact of urban debris on piers during flood events.

Scour at Bridge Abutment

The scouring of approaches to bridges and removal of spill through bridges was widespread across all bridges throughout Queensland. The impact of this on the flood recovery will be discussed later in this paper. (Fig. 5. and 6.).

- Traditional abutment protection is currently not suitable for high velocity situations. Consideration needs to be given to high velocity situations.
- Scour depth needs to be better understood. Many papers have been written on this subject but little guidance is provided for bridge designers.
- Abutment scour is a major cause of connectivity issues.
- Design piers for scour of stream. Armouring the streambed against scour should only be used as a means of last resort.

Fig. 5. Abutment Scour
Bridges play a key role in post disaster recovery. Bridges are critical infrastructure links are serviceable once floodwaters have receded. Consequently, it is essential heavy-duty abutment protection be used in scour prone locations.

Stone pitched spill through abutments are not serviceable for high velocity flow (greater than 4m/s). If a road approach embankment is overtopped, scour will occur on the down stream face unless the downstream face is protected against scour.

Gabions (Fig. 7.) provide a means of achieving a heavy-duty abutment protection.

**Fig. 6.** Scoured road approach at bridge abutment

**Fig. 7.** Heavy-duty gabion spill through abutment protection
Long Span Bridges compared to Short Span Bridges and Culverts

It is acknowledged that span lengths of bridges and culverts are often selected on economic grounds without consideration to stream flow.

The graphic news photos of Toowoomba highlighted these issues. The hydraulic jumps created in streams were in part caused by the damming of waterways due to small bridge spans being blocked by cars and delivery vehicles that had been washed into the river from surrounding urban areas. The afflux caused by stream blockages may also result in an inundation of water to adjacent houses and/or businesses. Detailed investigation needs to be undertaken to provide justification for each design and guidance needs to be provided in design codes.

Services

The attachment of services to bridges should be such that:

- The services do not block the stream.
- The services are not exposed to flood unless the service can sustain impact from the flood.
- Services support to extend behind the abutment.

For example, a dislodged thrust block being supported only by spread testing in front of an abutment could damage services attached to bridges. Figure 8 demonstrates a major potential health risk and loss of services due to a collapsed sewer main. Hence, it is critical that services meet the above criteria.

Fig. 8. Collapsed sewer main
Changes in Land Use

The change of land use can improve bridge performance during a flood. Examples include:

- Urbanization of former rural areas increase runoff.
- Upstream dams may be forced to release discharge rates in excess of the natural flow in the event of excessively high dam levels. The understanding of dam release is critical when designing for scour and waterway areas, down stream from dams.

These major flood events provided an opportunity to reflect upon improvements that may be required to the AS 5100 to ensure bridge designs and standards withstand the impact of natural disasters.

Inspection of Submerged Bridges Prior to Opening

Queensland Department of Transport and Main Roads policy is that all submerged bridges are required to be inspected prior to opening to traffic.

Special Procedures for Natural Disasters

Natural disasters provide challenges and opportunities. Opportunities that arose during these extreme events include:

- The Navy undertook a hydrographic survey of the Brisbane and North Pine Rivers.
- Navy divers inspected all bridges along the Brisbane River to Jindalee.
- Use of helicopters to travel to the Lockyer Valley.
- A fire brigade was called to wash mud off a bridge deck to reopen the road.

Natural disasters mean resources not normally available are provided for disaster recovery in extreme events.
**Suggested AS 5100 improvements**

AS 5100 needs amending to account for the learnings gained during Queensland’s extreme event. Areas to review include:

- Flood loads on pedestrian and rail bridges
- Ship impact in flood
- Debris type in urban areas
- Debris loads on piers
- Abutment scour
- Armour of stream bed against scour
- Tidal surge
- Land use changes, including bridges designed downstream of dams.

**Conclusion**

In spite of the extreme weather conditions and events enacted in the summer of 2010 / 2011, the bridge infrastructure throughout the State has performed well compared to the road network. The learnings gained as a result of these noted extreme events identified areas of AS 5100 require review and possible amendment. It should be noted amidst the distress of these events, the inspection process utilised throughout Queensland, prior to reopening bridges and roads after submergence, worked well.

Supporting research should be undertaken to ensure in preparation for future like-events, flood design criteria is currently under development and planned to be fed into bridge standards and design code in the near future.

**References**

[1] AS 5100, Bridge design