Bridge scour

Brian Bell

BoF 30, Cambridge 19th Jan 2010

Historic events

Some numbers

- A March 2004 report by Jeremy Benn Associates for RSSB contains the following data

  (http://www.rssb.co.uk/pdf/reports/research/Impact%20of%20scour%20and%20flood%20risk%20on%20railway%20structures.pdf)

  - 3,000 highway bridges and 9,000 railway bridges in the UK cross watercourses.
  - Since 1840 for railway bridges, there have been
    - 129 structural failures.
    - 15 fatalities (6 by drowning, the rest as a consequence of derailment. 2 not directly related to scour damage).
    - £1m costs per annum on average.

River Wye March 1947

Scottish borders August 1948

Glanryhd October 1987

Wraysbury May 1988

River Ness Feb 1989

Glanrhyd inquiry report

- The incident was subject to three separate inquiries
  - Internal BR inquiry
  - HMRI inquiry
  - Coroner's inquest
- Coroner's jury returned a verdict of unlawful killing
- HMRI recommendations
  - BR to implement an action plan to identify bridges susceptible to damage by river action
  - BR to improve bridge inspection and assessment procedures, including increased understanding by the staff involved of the effects of hydraulic action on bridge foundations
  - BR to improve operational procedures that apply at times of flooding, including the receipt of flood warning information

Network Rail processes

Background

- As a result of the Glanrhyd inquiry report BR commissioned HR, Wallingford to produce a scour risk assessment tool.
  - This was delivered in 1989 (BR Handbook 47) and updated in 1993 (HR Contractor Report EX2502).
- The EX2502 method was subsequently computerised and is known as BSIS (Bridge Scour Information System).
- Arrangements were made for NR control offices to receive flood alerts from EA.
- Bespoke weather forecasts are available through a dedicated web site.
- Flood action plans have been prepared.

Using BSIS

- All relevant bridges were subject to an initial BSIS assessment and the majority of high risk sites had had remediation action undertaken.
  - Those where action was not practicable are subject to special instructions in the “Flood action plan”; this normally entails closing the railway until a diver can physically inspect for scour damage.
- Underwater examinations form an integral part of all detailed (6 yearly) inspections of relevant structures
  - If hydraulic changes become apparent from inspection or other sources of information, the BSIS scoring is rerun and appropriate mitigation action planned.

Controlling standards

Ref	RT/LS/S/021
Issue	2
Date	October 2004

Company Standard

Weather – Managing the operational risks

Endorsement & Authorisation

Endorsed by:

W Weatherill, Professional Head of Operational Safety Policy

Authorised by:

Abbott, Director, Health Safety & Security Policy

Accepted for issue by:

P McAleer, Head of Standards Development Process

Published & Issued by: Network Rail 40 Melton Street, London NW1 2EE

Network Rail

Ref	RT/CE/S/080
Issue	1
Date	April 2004

Business Process Document

Specification Volume EX(A) 1
Management of Existing Bridges & Culverts

Endorsement & Authorisation

Endorsed by:

K. Teager, Professional Head of Structures Engineering

Authorised by:

A. McNaughton, Chief Engineer

Accepted for issue by:

P. McAleer, Head of Business Standards

Published & Issued by: Network Rail 40 Melton Street, London NW1 2EE

Network Rail

Relevant RT/CE/S/080 requirements (1)

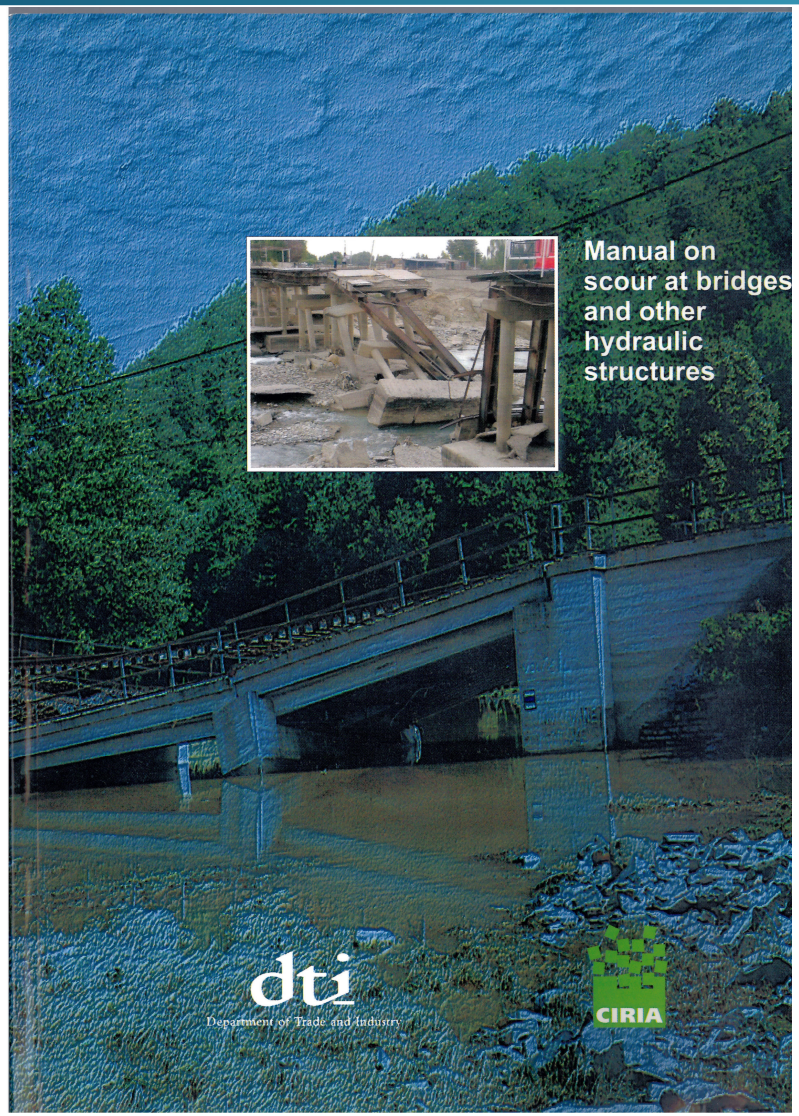
- Initial assessment
  - Each bridge or culvert that either crosses a watercourse, is adjacent to flowing or tidal water or at risk of flooding shall be assessed for susceptibility to damage or reduced load carrying capacity as a result of scour or flooding.
- Review of initial assessment
  - The initial assessment shall be reviewed every three years
- Assessment of the need for a flood warning plan
  - Assessment to include consideration of overturning, sliding and/or uplifting effects of high water levels either alone or in combination with the effects of scour
- Review of flood warning plan assessment
  - As appropriate

Relevant RT/CE/S/080 requirements (2)

- Preparation of flood warning plan
  - Plan for all bridges and culverts assessed as being susceptible to damage or reduced load carrying capacity as a result of scour or flooding
  - Shall detail actions necessary to safeguard railway operations
- Action to reduce risk from scour or flooding
  - Shall be considered and action prioritised, starting initially with the highest safety risk
- Receipt of flood warnings
  - A process shall be put ion place and reviewed annually to confirm currency and efficacy
- Actions in the event of a flood warning
  - The relevant flood warning plan shall be implemented
- Records
  - All decisions and action must be recorded and retained for the lifetime of the structure

Other reading

CIRIA report C551



Is research needed?

A few thoughts

- CIRIA is currently considering a revision to C551
  - Have there been any material changes to “scour engineering” since 2002?
- Will real time monitoring of scouring and backfilling assist the management of scour susceptible structures?
  - US DOT and FHWA have done some work in this area (NCHRP reports 396, 397A & 397B are summarised in Appendix 1 of C551) and there are later reports listed – should we discuss further in the context of IBOF?
  - HR, Wallingford developed a monitor that was deployed on some railway bridges but with limited success
  - Strainstall UK has sold a system to one of NR’s maintenance contractors

Minnesota DOT report MN/RC 2009/29

Company: North American Geotechnical (1 of 4)

(1) What is the purpose of the system?

- **Long-term monitoring**
  Monitor depth of scour around bridge piers or abutments on demand
- **Short-term monitoring**
  Operates during both floods and non-flood river stages on demand, so it can be used also to determine scour conditions on a short term basis and provide early warning of dangerous scour conditions.
- **Inspection**
- **Early warning**
  Operates during a flood so early warning of critical scour condition is available
- **Other (please specify)**

(2) What types of sensors or equipment are used?

- **Accelerometers**
- **Acoustic Emission**
- **Strain Gauges**
  - **Fiber-optic**
  - **Electric Resistance**
  - **Vibrating Wire**
- **Load Cells**
- **Wind Gauges**
- **Tilt**
- **Temperature**
- **Displacement**
  - **GPS**
  - **3-D Laser Scanning**
  - **LVDT**
  - **String Potentiometers**
- **Other (please specify)**
  The probe contains a vertical array of filters attached individually to pneumatic hosed brought to the bridge deck for access. Each filter is attached to a fixed volume of high pressure air which is released into the river bottom sediments. The electronics measures the pressure decay rate at each filter in the vertical array, providing pressure decay graphs at multiple depths.

(3) What performance measures are monitored and how are these helpful (e.g., crack formation and propagation, strain, displacement, corrosion, vibration, chloride content)?

The pressure decay rate is significantly higher in soft, unconsolidated soils vs. competent soils. The distinct break in pressure decay rate vs depth when the probe crosses the boundary between unconsolidated soils into consolidated soils identifies the depth of scour.

A-81

Some International papers

- E.J. Mercado (ejmer@aol.com) and M.W. O'Neill (mwoneill@central.uh.edu) "Methods to measure scour depth and the depth of unknown foundations" (2004)
  - (Background paper to system described in Minnesota DOT report featured above)
- G. Ruocci, R. Ceravolo, A. De Stefano (Department of Structural and Geotechnical Engineering – Politecnico di Torino, Turin, Italy) "Monitoring scour problem on masonry arch bridges" *in 4th International Conference on Structural Health Monitoring of Intelligent Infrastructure (SHMII-4) 2009 22-24 July 2009, Zurich, Switzerland*