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Improvements in emergency responses for geotechnical failures – a case study from the 2015 Boxing Day floods

R. Spence

Mott MacDonald Infrastructure Ltd, Sheffield

1 Introduction

This paper will cover some of the learning outcomes and strategies for future emergency responses to large flood events. A number of case studies are presented for sites which required damage assessment, design, and construction of remedial measures in very short time frames. Learning outcomes and best practices going forward are suggested which focus on delivery of scale, procurement strategy and connected thinking for efficient delivery of geotechnical structures from feasibility to construction.

1.1 National Impact

On the night of Boxing Day 2015 Storm Eva peaked and flooding impacted more than 9,000 householders and businesses across the North East and Yorkshire. Figure 1 below shows the “amber” and “red” flood alerts on Boxing Day.

Asset Recovery projects were awarded to BAM Mott Macdonald Joint Venture (BMMJV) between January and March 2016. The projects comprised assessment, design, and repairs to numerous geotechnical structures to provide resilience of flood defenses before the subsequent winter season.

The programme areas covered in this paper, were awarded to BMMJV for River Aire and Ouse catchment and North East areas. An illustration of the site locations is given in Figure 2.

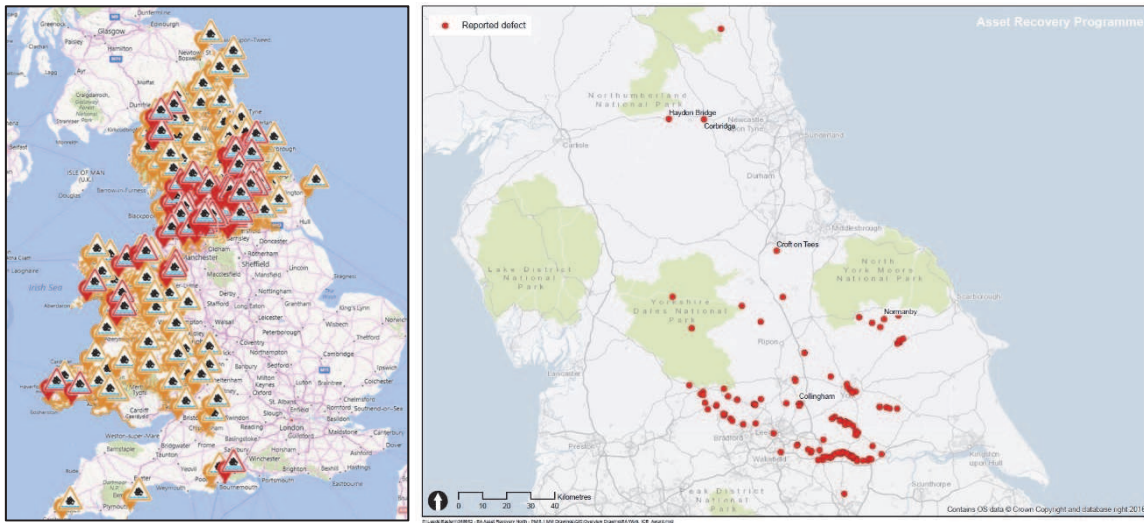


Fig. 1: Left – flood alerts on Boxing Day

Fig. 2: Recovery Programme sites requiring remediation.

2 Examples of Remedial Works

Remedial solutions for sites within the project have included: sheet pile walls; cantilever and anchored mini contiguous piled walls, timber soldier piled walls; gabion walls; earthwork repairs; rock armor and stone pitching scour protection; seepage cut-off walls; and structural repairs to flood walls, culverts and bridges. A selection of storm damaged geotechnical assets are described in order to illustrate the nature of the Works.

2.1 Linton Bridge

Linton Bridge is an attractive Grade II listed structure located about 15km NE of Leeds. It was constructed in the mid-late 1800s to join the villages of Linton and Collingham to shorten the 6km route round via Wetherby.

On the night of 26th December 2015, the south pier of Linton Bridge was undermined by scour and suffered 200mm settlement and minor rotation, which in turn caused cracks to form through the arch barrels which continued to the top of the keystones, indicating a loss of compression in the arch and a risk of bridge collapse.



Fig. 3: Temporary support scaffolding and permanent piling works at Linton Bridge

Remedial works comprised emergency underpinning, temporary piled scaffold to support the south arch for permanent construction works, as illustrated in Figure 3 above, and the design and construction of a new integral bridge deck with mini piles through each abutment and pier. This achieved a strengthened bridge, with lower maintenance liability without compromising the original character of the listed structure.

2.2 Croft on Tees

Environment Agency flood defence inspections revealed a new depression 8m wide and 8m high in the upper river bank and riverside face of a flood berm near the village of Croft on Tees. BMMJV carried out a walkover survey in April 2016 to assess this feature, which was indicative of an early stage rotation slip, and consider the requirements for further investigation, design, and construction. This revealed that a 500m long haul road (illustrated in Fig 4) would be required to get plant and materials to site for a typical shear key and counterfort drain repair and an alternative solution of a mini piled wall was developed in which very small plant could access the bridge via the public footpath, as in indicated in Fig 4.

The cause of the instability was thought to be a combination of the surcharge load of the flood bund on the crest of the river bank, positive pore water pressure in the slope after rapid drawdown and a localised occurrence in 1 bore hole of soft alluvium. Back analysis of the slope was carried out on the slope which confirmed a Factor of Safety (FoS) less than 1 was likely during rapid draw down conditions with water pressure in the alluvium above river level.

The location of the slip plane was indicated by the presence of a toe bulge and by small movements detected within inclinometers installed beneath the depression.

The design method was based on an approach described by J.P. Davies for the stabilization of a landslide on the M25 (Davies et al. 2003). The analysis method took the back analysis with a FoS 0.951 and applied a shear force working to resist the slip at the position where the slip plane crossed the proposed bored pile wall until a FoS of 1.25 was reached. This indicated that a new embedded wall through the middle of the depression, designed to provide a resistance of 25kN/m shear at the level of the slip plane would provide the ULS margin of safety required by Eurocode 7. The solution comprised 15No. 450mm diameter piles at 1.2m centres so that soil arching would occur between the piles preventing further soil movements.

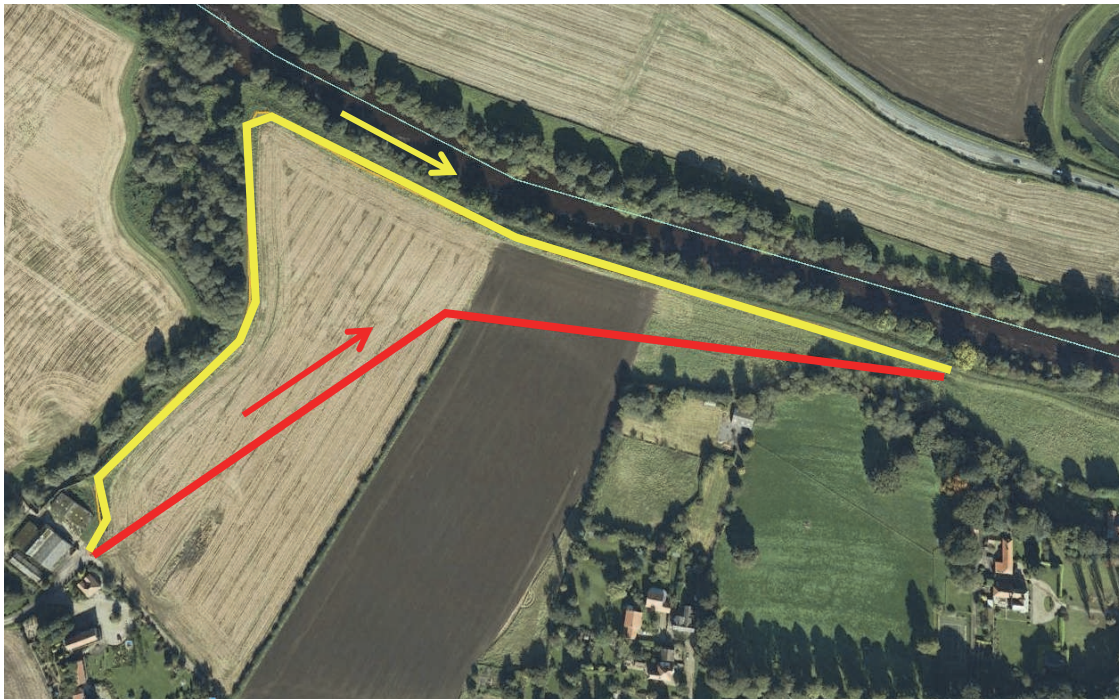


Fig. 4: Proposed temporary haul road (bottom) and actual route used on embankment crest for access by mini piling rig (top).

2.3 Water End, York

Water End is a modern flood wall (constructed in 2011) sitting on top of 600mm diameter bored piles at 2m centres at the crest of a road embankment behind a river bank. A slip occurred immediately after Storm Eva peaked, during rapid drawdown conditions. The slip threatened the stability of the road side flood wall and the integrity of several buried services. BMMJV designed and constructed a sheet piled wall and counterfort drains on the foreshore in November 2016.



Fig. 5: Water End river bank failure

2.4 Haydon Bridge

The main works at Haydon Bridge comprised an extension of the stone pitching currently under the main highway bridge to repair the scour damage downstream of this 'hard' defence which threatened to undermine the flood wall. Care was taken to mitigate the risk of future scour causing the same problem immediately downstream of the new stone pitching, and a transition detail was included to return the toe of the sheet piles up the bank with a taper.

This site was on a critical programme due to salmon migrating upstream in the autumn and all temporary works in the river were completed before the end of September. This site included working with other partners to address recovery to assets other than flood defences, including stone pitching repair to scour upstream of the bridge to protect a NWL sewer and underpinning the highway bridge concrete apron which was being under mined by scour.



Fig. 6: Haydon Bridge reinforced concrete stone pitching revetment with sheet piles at toe.



Fig. 7: Eastern half of Collingham bank slip

2.5 Collingham

A series of large scale slope failures resulted from the Boxing Day flood event. The largest of these were at Collingham and Knaresborough. These were assessed during a site inspection with the client and JV present, agreeing the probable remedial measures and timescales for ground investigation and reporting. Stability assessments were undertaken and lifetime cost/risk analysis, alongside flood modelling, led to a managed retreat for some of the landslides.

2.6 Corbridge

Corbridge flood embankment was one of many flood bunds which were damaged and subsequently repaired on tight timescales. At Corbridge the river overtopped the flood bund at a transition point where a masonry wall inside the bund terminated and scoured a large hole landside of the earthwork.

Damage at Corbridge can be seen in Figure 8 below. The image shows the flood waters still high two days after the flooding occurred on site.



Fig. 8: Damage to Corbridge flood bund

3 Learning Outcomes

3.1 Scale

Due to the large number of sites requiring assessment and the reduced timescales, standard designs were applied where applicable. A number of sites (20+) had scour damage to the top of flood embankments repaired with a standard detail comprising rip-rap overlain by geosynthetically strengthened earthworks. More complex sites did require bespoke designs, this was usually identified during the constructability assessment following the initial site walk over and inspection.

3.2 Project staging and Reporting Style

Initial site inspections were carried out with all parties present; client, contractor, asset maintainer and designer.

Following the inspections, a site walkover memo was produced for each significant site which identified constraints such as land ownership, third party consultees, environmental issues, GI or other survey requirements, proposed concept solutions, risks and opportunities, and key contacts.

Following client review and acceptance of the proposals for GI and other surveys, the walkover memos were developed into conceptual design option reports including the required EC7 desk study and GIR information. Following the next client and principal designer review to approve the recommended conceptual

design option the report was then developed to design report level with construction drawings and specification.

Following construction a final version of the report was produced to incorporate records of any changes to the design and as built drawing construction records, as well as relevant email communications with client and Principal Designer. This provided a single document per asset for the H&S file which captured the design rationale, development and construction.

3.3 Connected Thinking – JV

The BAM Nuttall and Mott MacDonald JV was awarded the large-scale Asset Recovery Program following a short tender process within the EA WEM Lot 4 framework (Environment Agency 2013). It was fortunate that the EA had this D&B framework in place which enabled a rapid procurement process and achieve a collaborative team with connected thinking for complete project delivery.

A number of benefits were noted from the “JV” approach, carried forward from earlier projects under the BMMJV.

1. Reduction in adversity between contractor, designer, client parties.
2. Better communication.
3. Large increase in delivery speed.
4. Greater emphasis on economical and buildable designs
5. Rapid cost estimating of design options

3.4 Procurement

Some of the more significant flood damage sites were awarded as emergency work compensation events to existing contracts, as was the case with Linton Bridge. This approach allowed work to be started almost immediately and removed delays from the procurement process. Many sites had design phase work carried out under C. Es to existing contracts, with construction phase work moved into a separate contract, which had been awarded following Lot 4 tender procedure.

3.5 Conclusions

A response to large scale natural disasters differs greatly from conventional civil engineering projects. There is time pressure to repair flood defence assets before the next winter season when the likelihood of further storm events is high. Undertaking inspections and remediations at hundreds of sites simultaneously needs a tailored style of design of construction to systematically prioritise works and apply standard solutions to multiple similar storm damaged assets.

Having undertaken a major asset recovery programme the following learning outcomes were found. These are recommended for future projects, specifically relating to the response of wide-scale damage caused by flooding and potentially other natural disasters.

- Early involvement of all parties – awarding CEs to existing contracts for initial professional services.
- Use of standard designs for multiple sites. with common types of damage.
- Condensed reporting style, up-revving initial recommendations report, to GIR/GDR stage, then as-built in one document.

References

Davies, J. P. et al. (2003)

Stabilization of a Landslide on the M25 Highway London's Main Artery. 12th Pan-American Conference on Soil Mechanics and Geotechnical Engineering.

Feltham, I. (2007)

Shear in reinforced concrete piles and circular columns. *The Structural Engineer*. Vol 27.

Heibaeum, M.H. (2006)

The use of geosynthetics in scour protection. Proceedings Third International Conference on Scour and Erosion. Amsterdam. November 1-3, 2006

Orr, J.J. et al. (2010)

Shear design of circular concrete sections using the Eurocode 2 truss model. *The Structural Engineer*. Vol. 88.

Turmo, J. et al. (2009)

Shear truss analogy for concrete members of solid and hollow circular cross section. *Engineering Structures*. Vol. 31.

The Environment Agency (2013)

Water and Environment Management Framework 2013 – Lot 4 Asset Delivery.