Soil Nailing the A610 at Buckland Hollow, Derbyshire

Example of Collaborative Project Delivery

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Executive Summary

In June 2016 a failure occurred in a steep slope between the River Amber and A610 in Derbyshire, threatening both the road and a major water main beneath it. Derbyshire County Council commissioned AECOM to investigate the failure and design a solution to stabilise the slope and protect it from future erosion. The chosen solution comprised soil nailing of the slope with rock roll erosion protection in the river. Soil nails had to be designed so that the risk of damage to the water main was eliminated during installation. Close collaboration between all parties ensured that the scheme was successfully completed in September 2017.

1.0 Introduction

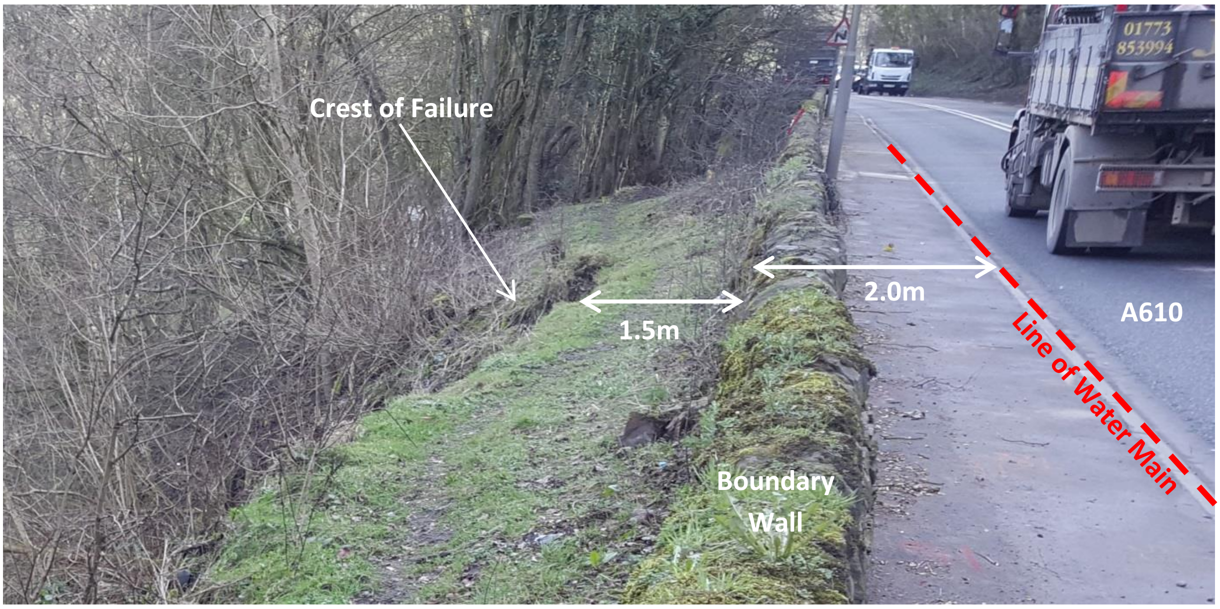
The A610 forms a critical part of Derbyshire County Council's Primary Highway Network, linking the Derbyshire Dales to the wider Strategic Highway Network, and typically accommodating around 14,000 vehicles per day. In addition to this, it also provides a conduit for a number of vital services, including the Derwent Valley Aquaduct; a 375 mm diameter water main that supplies water from Ladybower Reservoir to much of the East Midlands.

Between the villages of Ambergate and Buckland Hollow, the road runs along a terrace above the adjacent River Amber. At one point, a meander in the river cuts into this terrace, producing a 9 m high, 45 degree slope located just 1.5 m away from the highway boundary. In this location, the Derwent Valley Aquaduct lies directly beneath the edge of the highway carriageway, approximately 3.5 m away from the crest of the river slope.

In June 2016, Derbyshire County Council (DCC) became aware of slope failure at this location and instructed AECOM's Ground Engineering team to conduct an emergency site visit to assess the risk to the highway, water main and other services originating from the failure.

AECOM and DCC operate under the Midlands Highway Alliance (MHA PSP2) Framework, which allows DCC to engage AECOM directly. The strong client-consultant relationship fostered by this long-standing framework arrangement meant that AECOM were able to respond immediately to the potential emergency, visiting the site the same day.

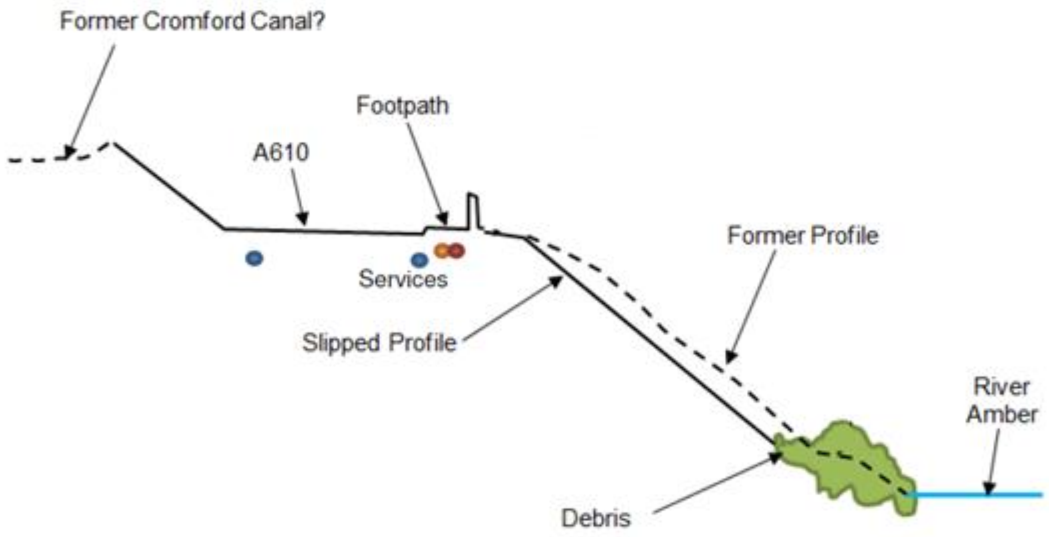
Figure 1 – Crest of Failed Slope



2.0 Assessment of Failure

The inspection found that a shallow translational failure had occurred over a 10 m section of the slope below the road, completely removing the root zone and exposing bare ground beneath. Vegetation and earth was piled in the river, which lay directly at the toe of the slope. Due to the risk of the now bare and extremely steep slope eroding back the short distance to the infrastructure beyond, AECOM determined that the failure posed a significant risk to the future integrity of the road and water main.

Figure 2 – Sketch of Failed Section



Following this initial assessment, AECOM was commissioned to further investigate the failure through a desk study and ground investigation (GI). The desk study was undertaken locally in AECOM's Chesterfield office, and the GI performed by AECOM's investigation team based out of Nottingham. These studies found that:

- The likely cause of the failure was saturation of the root zone by heavy rain, in an area of slope where few trees were present to provide deeper mechanical anchoring with their roots.
- The ground at the site comprised sandy gravelly clay, considered to be a colluvial material derived from sandstone bedrock higher up the river valley. Bedrock was only found to be present at around river bed level.

This information confirmed our initial assessment and the risks to the infrastructure, and that a total slope length of 40 m above the meander could pose a risk of similar failures in future. As a result, AECOM and DCC agreed on a full slope remediation.

Although it was concluded that the river had not directly contributed to the June 2016 failure, it was considered that it still had significant potential to erode the toe of the slope. Only treating the upper part of the slope would therefore not be a sustainable long-term solution. As such, AECOM's water team were also engaged to assess the erosive potential of the river and design a suitable erosion protection solution.

Figure 3 – View of Slope Failure

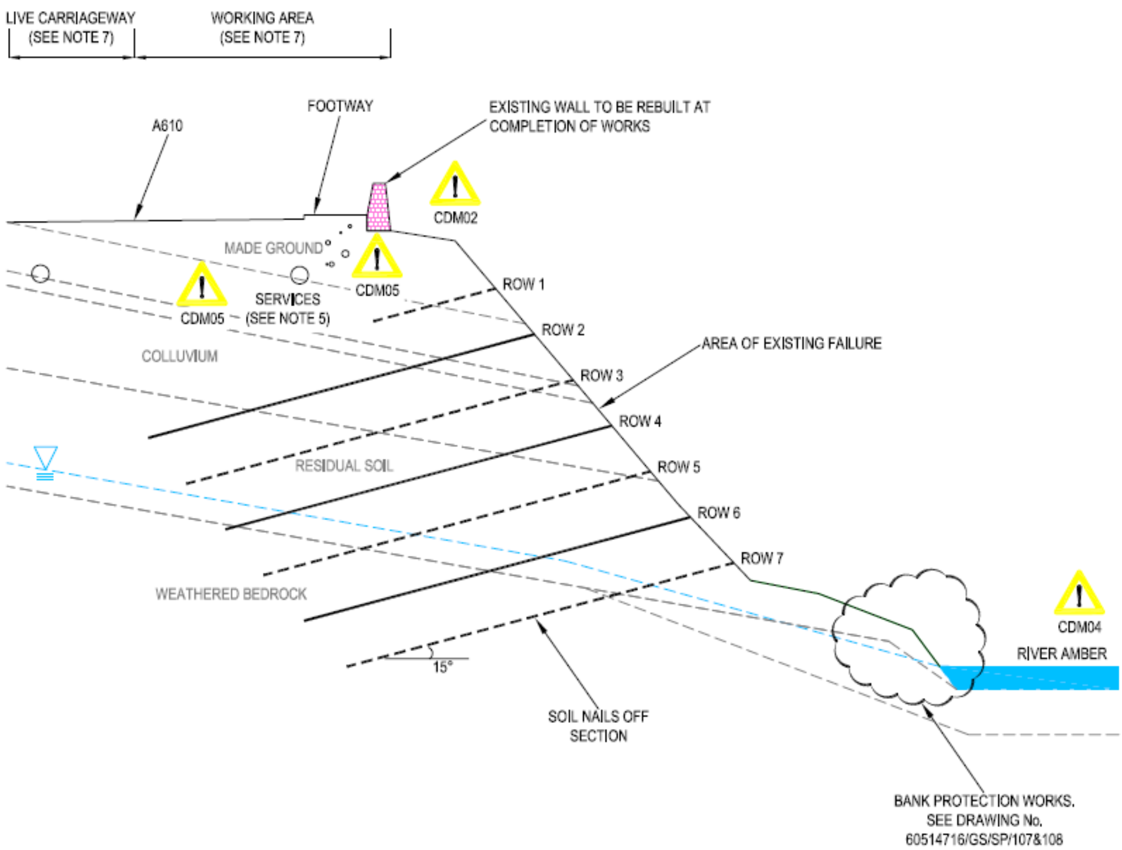
Figure 4 – Failure Viewed from Slope Crest

3.0 Remedial Design

Due to the tight geometrical constraints present at the site, AECOM recommended that the failed slope and adjacent areas were remediated through the installation of soil nails. Eurocode compliant design was carried out to BS8006 Part 2, and produced an initial solution comprising six rows of nails installed on a 1 m by 2 m isometric grid. The nails were generally proposed to be 8.75 m long self-drilling nails, inclined at 15 degrees to the horizontal.

Nail lengths were chosen to suit the 3 m bar lengths that would be used on site to minimise cutting. The top row of nails were designed to penetrate only 2.75 m to eliminate the risk of striking the services located at the crest of the slope. Facing was to comprise a pvc coated hexagonal mesh with integral erosion protection matting, fixed in place with steel head plates.

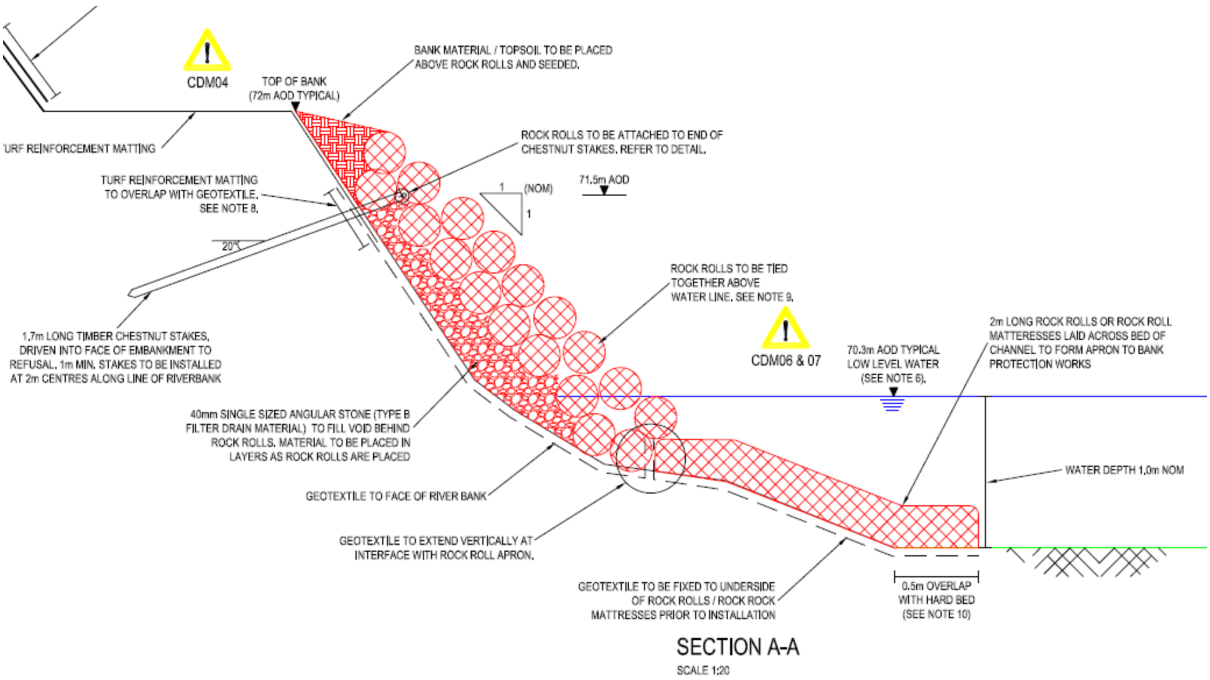
Figure 5 – Slope Remediation Solution



For the erosion protection works, AECOM first undertook a geomorphological study, which indicated that the location of the river channel was likely to be relatively stable over time. Modelling of the response of the river to various flow levels indicated that during extreme events, the river was likely to flood rather than stay in its banks, thus dissipating the additional energy and limiting its erosive potential. Such flooding was witnessed during the lifetime of the design process, backing up our analytical conclusions.

Based on consideration of buildability, long-term stability and environmental impact, AECOM recommended rock-rolls as the most appropriate form of erosion protection. These comprise a roughly 2 m long geogrid tube filled with stone. Whilst soft protection options were explored, it was considered that these would not provide a viable long term solution due to the steepness of the river banks and potential difficulties with installation due to access constraints. The rock-rolls were also considered to provide a solution that would be safer and easier to install than conventional rip-rap. They also present a better habitat for ecologically beneficial vegetation growth.

Figure 6 – Erosion Protection Solution



4.0 Preparation for Construction

Following submission of the initial designs in early 2017, Balfour Beatty was engaged by DCC under the SCAPE framework contract. As main contractor for the construction works, their early involvement would be highly beneficial for the smooth progression of the scheme from design to construction. The specialist roped access firm CAN were also consulted at this stage as the likely choice of soil nail sub-contractor.

Permits to work in the river were arranged from the Environment Agency by AECOM. Whilst there were no particular ecological constraints at the site, significant quantities of Himalayan Balsam were found to be present. Devegetation was undertaken prior to the 2017 bird nesting season, and the cut Balsam was left to rot down under tarpaulins at the edge of the site to prevent spreading the seeds of this invasive species.

Figure 7 – Devegetated Slope

Due to the high pressure (approx. 12 bar) of the Derwent Valley Aquaduct, any damage to it could have severe consequences. Therefore, the risk of rupture of this pipe - either caused by a nail deflecting and striking it, or through vibration induced by drilling - had to be minimised.

After consulting with Severn Trent Water (STW), it was initially hoped that the main adjacent to the works be switched off, and flows diverted to a sister main on the far side of the road. However, other network considerations meant that this would not be possible.

To positively identify the location of the water main, DCC excavated a trial trench across the road, which allowed the soil nail design to be modified slightly to further reduce the risk of striking the main. Vibration monitoring equipment was installed on the pipe to enable the current levels of vibration from passing vehicles to be assessed. This information was provided to STW, who derive allowable vibration limits on the pipe during the works. CAN advised that these levels were unlikely to be breached if the top two rows of nails were installed with no hammer action.

Construction

Site works were undertaken in September 2017, with Balfour Beatty as Principal Contractor and CAN as sub-contractor. The works were undertaken under a single lane closure of the road, with a total of 125 nails installed in the slope. The top two rows of soil nails were installed from the crest using a zero tail swing excavator, which enabled rapid installation of the nails without any risk to the open carriageway. Lower rows were installed using a tripod rig using roped access techniques.

Figure 8 – Soil Nailing using Roped Access Techniques

Only small alterations were required to the design through Technical Queries, and CAN were complimentary over the consideration that had been given to buildability at the design stage. Load testing of the soil nails corresponded well to design assumptions.

As part of the river works, several fallen trees were removed from the river channel, which visibly improved river flows. Pollution of the river was prevented through the use of silt screens at the downstream end of the works. Balfour Beatty and CAN were particularly impressed with the ease of installation and flexibility of the rock rolls as an erosion protection solution.

The scheme was successfully delivered 2.5 weeks early and to less than the tendered sum.

Figure 9 – Whole Site during Construction

Conclusions

Failure of a slope below the A610 had threatened the future operation of the busy road and the integrity of vital services affecting a wide area. Value engineering and collaborative working between Client, Consultant and Contractor allowed a potentially dangerous situation to be successfully remediated to the satisfaction of all parties, ahead of schedule and under budget. The road is now fully reopened and secure from the risk of further failures at this location.

Figure 10 – Finished Works