CASE STUDY

RIVER EMBANKMENT
Environment Agency

Figure 1 – Flood Defence Embankment on the River

Figure 2 – Evidence of Seepage through Embankment Retaining Wall.

Project Overview

There are around 7,500 km of coastal and river flood embankments in England and Wales. Effective performance of these embankments during extreme flood events is critical for the provision of sustainable flood risk management.

Embankments can become less effective over a period of time. The tendency for the performance of earth embankments to deteriorate over time is of particular concern when considering the increasing loading that will continue to be placed on flood defences as a result of climate change and the increasing rate of occurrence of extreme events.

It is the Environment Agency's responsibility to ensure that flood embankments are designed and maintained to achieve optimum performance.

This project related to the effective maintenance of a section of the River Flood Defence System near Goole. The River is a re-engineered section of the River Don between the River Went and River Ouse. The River has a significant tidal influence.

The flood embankments on the River essentially act as 'low-level dam' for short retention periods. For the majority of the time, the embankment is exposed to minimal or low hydraulic heads and remains largely unsaturated. However, during flood events and / or particularly high tides, the embankment needs to withstand a rapid rise in water level on the outward face, along with the corresponding changes to internal water pressure driven by the higher hydraulic gradients across the embankment.

Seepage was occurring along an extended length of the embankment section requiring improvement. This seepage was clearly visible in a section supported by a retaining wall and in adjoining fields, where ponding was observed.

Seepage through or under an embankment constitutes a failure of a flood embankment to perform its main function of water retention. However, especially in early stage failure, the volume of water lost is often relatively small and this seepage is considered acceptable.

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If seepage is not addressed in the longer term, finer particles of soil will probably be washed out of the embankment / foundation by the flow. Progressive deterioration is likely to occur. As the soil becomes more permeable, the flow rates will increase and consequently more particles of soil will be eroded, leading ultimately to catastrophic failure.

On the basis of this identified seepage the Environment Agency commissioned WYG Environmental to undertake an investigation into the material properties within the embankment and to assist in the selection of an appropriate remedial solution.
WVG proposed three potential solutions:-

- *Sheet pile cut-off wall extending into the natural material below the embankment,*
- *Soil mix wall to improve the existing embankment materials in situ,*
- *Slurry cut-off wall to replace the embankment core with concrete and/or an impermeable membrane.*

Design

Based on the WVG investigative studies, DSM were able to design a strategy to resolve the perceived problems with the embankment. This design is depicted in Figure 3 below.

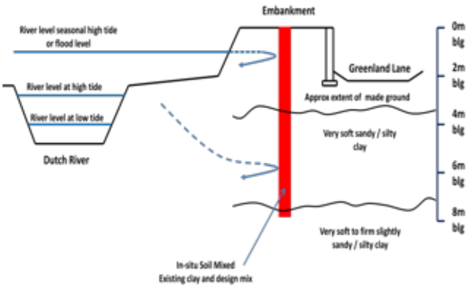

Figure 3 – Design.

In summary the design consisted of in-situ soil mixing of the embankment and underlying soils with a purpose designed cementitious /bentonite mix. The objective was to 'toe' into the underlying clay to create a continuous cut-off curtain which would minimise water ingress and egress through the embankment during high tides and flooding. The water ingress / egress was considered to be as a consequence of fissures within the embankment structure and permeation through the embankment under constant hydraulic pressure.

Installation

Prior to installation, DSM conducted a series of pilot trials to determine the correct auger drilling / mixing head, additive consistency and mode of DSMimplementation. undertook the installation. A Continuous Flight Auger (CFA) rig was employed to soil mix the additive slurry with the embankment material. The order of column mixing was column No.1 followed by column No. 3 then No.2, No.5 and No.4. This sequence was repeated along the length of the barrier.

The column diameter was 700mm with a column overlap of 200mm.

The barrier was installed to a depth of 7.0 to 8.0m below ground level and keyed into underlying clay layer.

Figure 4 – Barrier Installation.

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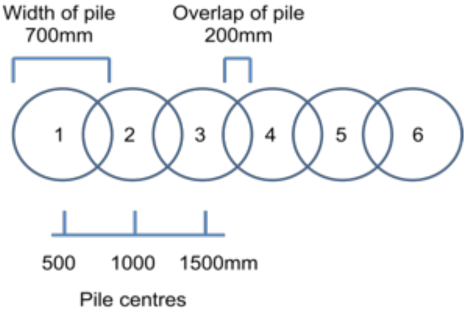

Figure 5 – Column Arrangement.
The original proposal required the repair of a 270m stretch of embankment - this was later extended to 500m.

DSM adhered to a strict Quality Assurance Programme which demonstrated confidence in the installation process. This included:

- Onsite observations both at the rig and batching plant (which were some distance apart).
- QA output from the batching plant performance - this confirmed that each and every treatment slurry batch had been manufactured as specified.
- QA outputs from the CFA rig - these clearly showed the depth of the installation of any soil mixed column, the quantity of the additive injected into the column and the injection /mixing time.

Results
Several methods were utilised to demonstrate the efficacy of the process. Visual observations following installation demonstrated that the adjoining road and fields rapidly dried out. No water egress was observed through the embankment wall as shown in Figure 6. Borehole sample cores were taken along the barrier installation and analysed / evaluated to confirm compliance with target objectives (see Figure 7). All core samples demonstrated effective mixing with permeability values less than 10-9m/s. WVG also installed a series of boreholes complete with data loggers which demonstrated that the barrier was functioning in accordance with the design. The complete barrier installation is shown in Figure 8.

Figure 6 - Adjacent road following installation. Significant improvement compared with Figure 2.

Figure 7 – Borehole Core. Showing Bentonite Plugging.

Figure 8 – Location and Extent of Complete Embankment Barrier Installation.