Coldwell Lower Reservoir - Weighted Filter, Wave Wall and Overflow Improvements

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SYNOPSIS. An improvement project has recently been completed on a United Utilities dam at Coldwell Lower Reservoir in Lancashire comprising:

- crest lowering and slope slackening incorporating an integral weighted granular filter
- a new reinforced concrete overflow
- a reinforced concrete masonry clad wave wall
- various associated ancillary works

The site is quite constrained and has posed many construction difficulties. The paper describes the history and engineering background to the scheme followed by a description how these were overcome as part of the design and construction of the scheme.

DESCRIPTION OF THE PROJECT

Coldwell Lower Reservoir was formed by the construction of an embankment dam across the valley of Catlow Brook, and is located approximately four km southeast of Nelson, Lancashire. The embankment is a typical “Pennine” type dam with an upstream slope of 1 in 3 and a downstream slope of 1 in 2.0 to 2.25, and a narrow central puddle clay core (see Figure 1).

The embankment was constructed mostly of material dug from the reservoir basin and has a crest length of 120m, a maximum height of 20m and a maximum reservoir depth of about 18m. It is understood that the Nelson Water Board promoted the scheme in the 1880s with Newton as the Engineer and took approximately three years to construct.

Dams: Engineering in a Social & Environmental Context. Thomas Telford, London, 2012

Figure 1. Panoramic view of the existing embankment with lower Coldwell Reservoir to the right and the existing pump house at the toe of the embankment.

The reservoir has a capacity of 364Ml, at a full supply level of 287mAOD. The reservoir supplies water to a pump house at the foot of the dam which pumps to Laneshaw WTW and provides a compensation flow of one Ml/d back into Catlow Brook. The embankment has previously been raised to make good settlement and has had modifications to the existing masonry overflow and draw off works. A Statutory Inspection under the 1975 Reservoirs Act in 2001 recommended that a flood study be undertaken to establish the adequacy of the overflow arrangements (Figures 2, 3 and 4).

A physical hydraulic model study of the existing overflow and spillway was built in 2004 which indicated shortcomings in the existing arrangements and made recommendations for improvements.

Figure 2. View of the existing spillway winding around the pump house.

As the embankment had a history of movement and repairs had previously been carried out to restore the freeboard and raise the wave wall, the Inspecting Engineer recommended that embankment stability and assessments of the risk of internal erosion be undertaken. The constrained nature of the site and the closeness of the existing spillway to the embankment would mean that any potential improvements to the stability of the embankment would impact on the design and construction of a higher capacity spillway. United Utilities agreed to this approach and commissioned slope stability and seepage studies.

Figure 3. View from the overflow weir showing the existing spillway falling down the embankment to the pump house.

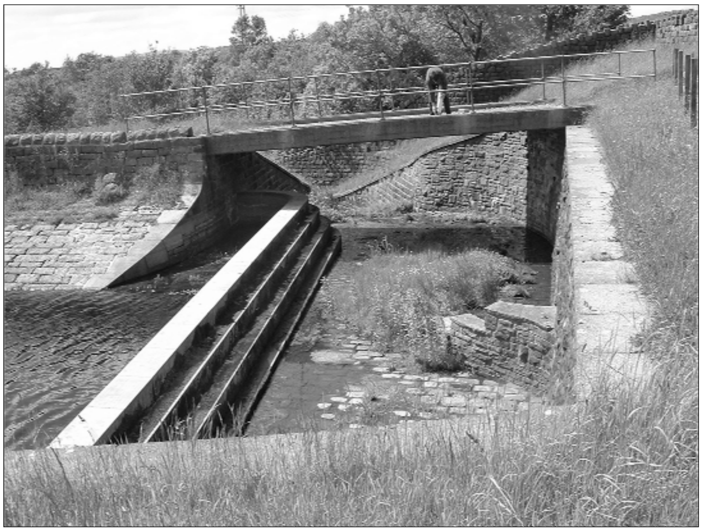

Figure 4. View of existing overflow and bridge over embankment crest

Historical records from the time of construction indicate that the earth embankment is a typical Pennine type dam, with narrow central puddle clay core and cut off trench. Ground investigation findings were consistent with details shown on the historical drawings and the slope stability assessment model was developed on the basis of this information. The slope stability analyses indicated that the dam did not have a Factor of Safety against sliding that met current dam safety standards and a Quantitative Risk Assessment indicated that there was a risk of internal erosion occurring through the embankment.

This information was reported back to United Utilities who reassessed where the dam was ranked in its overall Portfolio Risk Assessment of its total stock of dams to determined future Capital Investment priorities. The results indicated that Coldwell Lower was a high priority dam that would require works in the current water company Asset Management Plan (AMP4). A subsequent statutory re-inspection of the dam recommended that the following works were required in the interest of safety:

- Works are to be carried out to enable the design flood to be safely accommodated
- Remedial works to improve the stability of the dam
- Works to be completed by September 2011

The assessment for internal erosion indicated that the filter works would not need to be undertaken until a future AMP, but since UU were already undertaking interest of safety work at the site and the proposed spillway and slope slackening may have had an impact on latter internal erosion works they decided to progress the filter works at the same time.

CONCEPT

The concept for the scheme was driven by interest of safety recommendations of the Inspecting Engineer but the project team also considered the needs of other key stakeholders to provide a solution that:

- would demonstrate to the client that the scheme could be constructed at a site location where the topography, existence of historical landslips, presence of existing structures and width and gradient of site access would pose safety and logistical constraints during construction (Figure 5).

- would enable UU Operations to undertake future monitoring of the embankment to meet the requirements of the Reservoir Act and continue to operate the existing pump house at the toe of the existing embankment.

- would result in minimal visual, community and environmental impact in an area. A key stakeholder was the Coldwell Activity Centre immediately adjacent to the reservoir that specialises in providing holidays for young people with a disability, or from a disadvantaged background.

- would minimise impact on the keen fishermen from Nelson Angling Club who were asked to relocate to the Coldwell Upper Reservoir while the works were undertaken.

A series of ground investigations were undertaken, including geophysical, as part of the slope stability and seepage studies for the new overflow arrangements.

Figure 5. Access Constraints

A number of key design and construction requirements had to be taken into account as the work progressed including:

- slope stability analyses of the existing embankment to optioneer potential remedial works.
- gathering relevant data to design a filter to resist internal erosion to recognised international standards. These included those under development at various organisations such as the International Committee on Large Dams (ICOLD), US Bureau of Reclamation (USBR) and Imperial College.
- safe temporary and permanent works design of the new overflow arrangements to accommodate revised slope profiles.
- temporary works design required to support existing Pump House Structure.
- temporary flood control and compensation flow during construction.
- reservoir embankment monitoring requirements during construction, during refilling of the reservoir and for long term monitoring

BGS geological mapping of the local area shows that the valley in which the embankment dam was constructed is within an area of potential ancient post glacial landslips. These occurred on steepened valley sides produced by ice and melt water. With the supporting ice removed material slipped down the slope, leaving a scar at the highest point and mixed soil and rock debris in the valley floor. Whilst many of these slips have not moved for over 10,000 years it was considered that the forming of excavations to enable construction of the deep overflow channel (maximum depth up to 8m) could re-activate movement along pre-existing shallow and/or deep seated failure surfaces, some of which may extend below rockhead. Such failure surfaces had the potential to exist around all sides of the excavation.

DESIGN AND PLANNING

The interrelationship between the various elements of the work, site location and site constraints necessitated that the construction sequence and methodology would have a major influence on the final design solution.

The initial stages of the design were focused on the need to confirm the solution for the embankment stability so that the downstream profile would be known before the overflow weir and spillway design works could be finalised. In addition the spillway alignment would need to be aligned to pass through the limited space between the embankment and the existing pump house building. Two main options were considered to stabilise the slope: soil nailing or similar and slope slackening. Soil nailing whilst having the potential to limit the impact on the spillway design was discounted over concerns of increasing the potential pathways for internal erosion due to drilling in the embankment in close proximity to the embankment’s clay core. It would also make it difficult to incorporate protection measures to alleviate the threat of internal erosion. The slope slackening option allowed the use of some locally won materials from the reservoir basin limiting the environmental effects of importing materials to site. However space constraints meant slackening the slope pushed the toe outwards towards the existing building United Utilities wished to retain with the overflow chute running in the very limited space between the toe and the existing building.

The solution selected was to slacken the slope whilst also lowering the embankment crest. The lowering of the crest reduced the impact of the slope slackening at the toe but introduced the need for a new wave wall to retain the existing top water level. However, United Utilities had programmed to construct a new wave wall in a subsequent AMP and agreed that this work be brought forward and included in the project. The final design included stabilising the embankment by slackening the downstream embankment profile to a gradient of 1 in 2.8. A retrofitted weighted granular filter and monitoring system was also designed to current best international practice being developed by ICOLD and USBR to be incorporated against the existing slope to provide additional protection against internal erosion.

With the geometry of the downstream embankment confirmed, the design turned to the overflow weir and spillway. An earlier hydraulic model study of the original overflow and spillway (2004) had made a number of recommendations for modifications to the existing structure to increase its capacity but they were so extensive that United Utilities decided to investigate the option of providing a new structure to completely replace the existing one. A further physical hydraulic model was constructed. During the model testing, the two main concerns were the likely depth and proximity of the new spillway where it passed the existing building and the proximity of the new spillway to the toe of the slope downstream. The width and depth of the spillway chute were adjusted and modelled where it passed the existing building to minimise the impact on the building and finalise the overall design.

In order to ensure that sufficient information and provision was included in the proposed competitive tender procurement arrangements, MWH and UU met with proposed tenderers at an early stage and additional investigation including permanent ground monitoring instrumentation was undertaken and provided with the tender information.

CONSTRUCTION

An extended tendering period allowed for detailed discussions with the tenderers to ensure that site and environmental constraints, temporary works requirements and appropriate construction planning could be sufficiently developed. J N Bentley was awarded the construction contract. The constraints previously outlined meant that no material deliveries could be made by articulated vehicles and temporary access (Figure 6) provided to build the spillway chute down a steep slope and provide a stable base for cranage had to be planned agreed and provided prior to undertaking the construction works.

Figure 6. Construction of temporary access track across embankment

The works were planned in four phases as follows:

Phase 1: Temporary works and construction of the spillway adjacent to the existing Pump House (Figure 7)

Phase 2: Temporary works and construction of the main spillway chute (Figure 8).

Phase 3: Overflow weir, tumble bay, crest bridge and wave wall construction (Figure 9)

Phase 4: Installation and quality management of filter, drainage and embankment stability works

Figure 7. Phase 1 Temporary works adjacent to pump house

Figure 8. Phase 2 Temporary Works along new spillway chute

Figure 9. Phase 3 Temporary Works for crest bridge and tumble bay

The complex geometry and limited space adjacent to the Pump House required extensive temporary works designs to be formulated by MMB in conjunction with MWH, UU Site Management, UU Operations and Reservoir Safety. This involved specialist temporary works designers and checkers to ensure an effective and safe support system was installed to allow the access to construct the tightly curved spillway chute. The main steep spillway chute ran along the toe of the existing embankment to the east and an existing slope potentially affected by relic landslips to the west that needed to be accommodated. A curved section of temporary works to take excavations through the crest of the embankment incorporating a new bridge over the spillway and excavations into the new tumble bay completed the spillway works.

Having safely completed construction of the overflow channel, work commenced on modifications to the downstream embankment shoulder. This required close control on the placement of granular filter and drainage materials, of bespoke and narrow grading, which were sourced from a site in mid-Wales. Construction of the filter arrangement entailed the sequential placement of filter and drainage layers against the existing slope gradient of around 1V:2H, prior to covering with a protective separating geotextile layer and overfilling with general embankment fill to the design profile. The existing embankment shoulder fill had to be protected from the elements at all times, to prevent deterioration of the sub-grade, and this placed a significant constraint on the working area available at any time. To ensure that this was achieved to meet the required performance the site team developed a Filter and Drainage Layer Reservoir Best Practice Guide and a Total Management Plan for completion of the operations from source selection to final installation (Figure 10).

Representatives from all parties visited the proposed sources of materials and evaluated production and quality control methods that would ensure a consistent product be supplied to site. The site materials storage approach incorporated storing the filter and drainage materials in separate skips to ensure no cross contamination. A trial placement of the filter layer was undertaken and attended by all relevant parties to ensure that this critical element of the works would perform as designed. The trial proved that the selected filter material could be compacted on the slope using Ho-pac compacting plates attached to a long reach backactors which allowed placing of the filter and drainage layer to progress up the slope followed closely by the placing of the general stabilising fill won from the reservoir basin to complete the works successfully. J N Bentley opted to defer the embankment modification works until after the winter season and this was agreed with United Utilities. The embankment modification works were completed in spring 2011 and the Qualified Civil Engineer issued a 10(6) certificate, confirming completion of the ITIOS action (Figure 11).

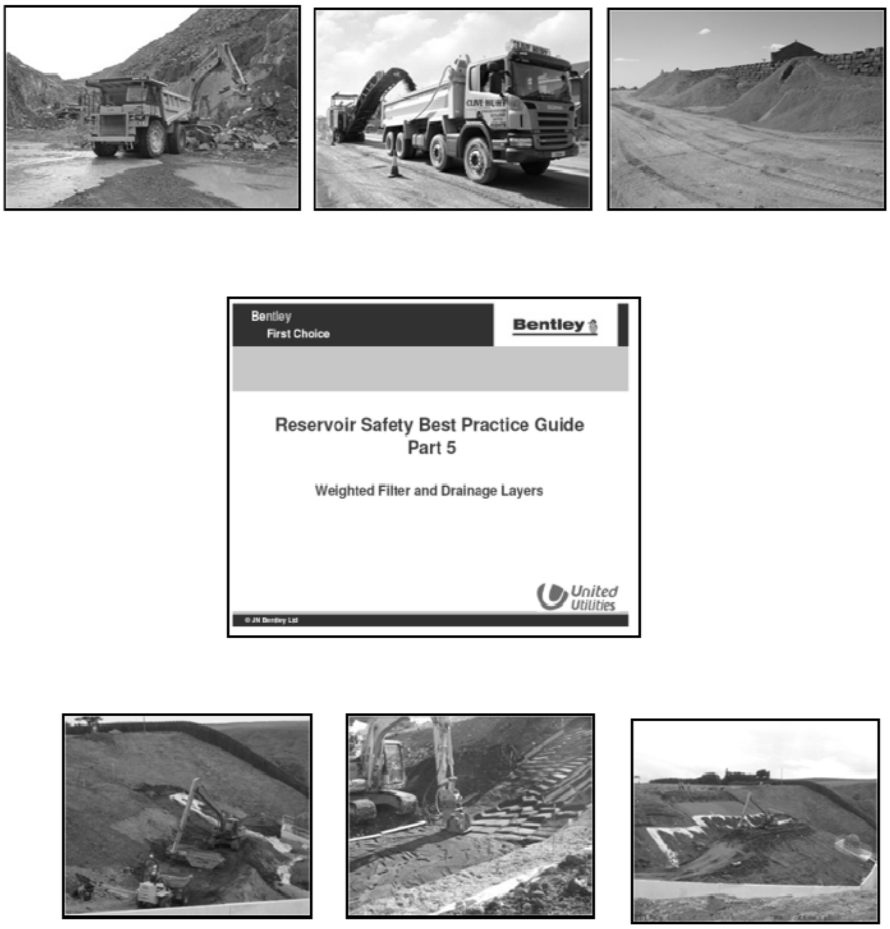

Figure 10. Placing Filter and Embankment Stability Works

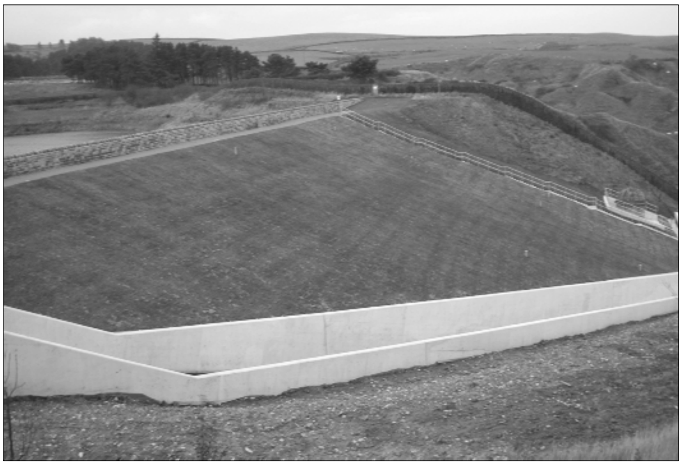

Figure 11. Completed Works

ACKNOWLEDGMENTS

The authors acknowledge the permission of United Utilities to publish this paper.