Lower Laithe Reservoir

spillway improvements and clay core raising

by Natalie Evans, MEng

Lower Laithe Reservoir, located south west of Keighley in West Yorkshire, was officially opened in 1925. The reservoir receives water from a natural catchment area totalling 4.75m^2 and supplies raw water (for treatment and eventual distribution) to a water treatment works, located downstream. Lower Laithe Reservoir, like many of its era, is retained by a typical earthfill embankment, 275m in length, with a central puddle clay core above a concrete cut off trench. The embankment crest is crossed by a public highway lined with a masonry wall on the downstream face and an upstream masonry wave wall. Spill flows discharge to the spillway channel, which discharges to the watercourse via a stilling basin at the toe of the embankment.

New spillway looking downstream - Courtesy of MMB

Lower Laithe Reservoir

The reservoir retains a volume of 1,275,000m^3 of water when full to its top water level of 226m AOD. As such, the reservoir falls under the legal obligations of the Reservoir Act 1975. A statutory inspection of Lower Laithe Reservoir carried out in 2008 in accordance with the Act revealed potential inadequacies with the ability of the existing overflow arrangement to safely convey the design flood.

Scope of works

Following the inspection, Mott MacDonald Bentley (MMB) were instructed by the reservoir owner, Yorkshire Water (YW), to undertake investigation works and any resulting remedial works to ensure legal compliance under the Act. An initial flood study and physical model showed that spill flows could be expected to overtop the spillway walls during the design flood, causing extensive damage to the existing masonry lined channel and the embankment toe. Resulting safety improvement works have therefore included:

- Lining the existing spillway base and walls to mitigate the risk of damage from high velocity flows.
- Raising the spillway walls in concrete to prevent out of

channel flow during the design flood.
- Constructing a training wall in the existing stilling basin to divert flows to the watercourse.
- Raising the level of the clay core above the design flood using a cast in-situ concrete nib.

During the detailed design stage and implementation of the scheme on site, a number of issues were successfully addressed.

Flood contingency

The main challenge during construction works to the spillway channel and stilling area concerned carrying out works on the existing spillway structure whilst maintaining operation of the reservoir. Consequently, stringent flood contingency measures were implemented to ensure the safety of the reservoir and the workforce.

The first measure was a drawdown of the reservoir water level to provide flood protection for the works. Due to the dry period preceding the works, it was possible to achieve the required drawdown - calculated as 2.6m below the top water level (TWL) - by controlling the inflows and compensation flows.

A second measure involved the use of a red-amber-green alarm system to allow protection to be maintained throughout the works. The amber alarm was set to trigger when levels rose above 2m below TWL. Operation of the scour valve at this time would be sufficient to prevent the reservoir overtopping.

As use of the reservoir's scour facilities was required as part of the flood contingency works, it was necessary to divert the scour flows whilst works on the stilling area were carried out. This was achieved through the use of an existing bypass channel which discharges on to the downstream side of the gauging weir. Installation of a temporary weir plate and ultrasonic level transducer on the outlet from the bypass channel has allowed these flows as well as the compensation flows) to be monitored throughout the works.

Given its location in a "flashy" catchment, it was necessary to monitor the water level at Lower Laithe Reservoir at half hourly intervals. However, no storm events large enough to trigger the alarms during construction occurred.

Spillway and stilling basin remedial works

Due to the space constraints on site, and cost considerations, it was decided to undertake the required modifications to the existing spillway channel as opposed to constructing a new channel. The new channel lining is of reinforced concrete construction; dictated by the high flows in the channel.

Relining has taken place from 25m downstream of the crest bridge, where spill flows exceed 8m/s. The spillway walls have also been raised in concrete to provide a freeboard for the spill flows. This has resulted in an internal wall height of 2.5m on the outside of the chancel, and 2m on the inside. Upstream of the transition with the existing channel, some wall raising has also taken place in masonry to tie in with the existing spillway construction.

During construction it was necessary to keep the spillway channel dry for the new concrete walls and base to be poured. This was challenging as significant seepage took place though the existing masonry walls. The combination of a land drain laid to the rear of the left spillway wall, and gravity fluming of residual runoff past the working area, allowed this to be successfully managed on site. Innovative design for the remedial works to the spillway included the use of a structural lining within the existing channel - allowing for thinner walls than a stand-alone structure.

An innovative solution was also required in the stilling area to direct flows into the watercourse, preventing damage to the embankment

toe. This has been achieved by constructing a training wall with an overhang within the existing stilling area to direct high velocity flows back into the channel. This has allowed for a smaller wall than would traditionally have been required; delivering efficiencies in the design, and minimising the impact of the works.

Clay core remedial works

Various options were investigated for raising the level of the clay core. As well as a traditional approach of raising the core in puddle clay, options were also considered for raising the core in concrete or asphalt. Raising the core in clay would have necessitated the level of the crest to be raised in several locations in order to provide the required thickness to reinstate the road. By using concrete it was possible to remove this issue, as well as resulting in cost savings and a reduced construction time - ensuring less impact on local residents as the clay core is beneath a public highway.

The clay core was raised using a concrete nib, cast in-situ, with crack inducers fitted at 5m centres. The raising was undertaken in 20m sections and the excavations covered or backfilled at the end of the day to maintain reservoir safety.

Further safety considerations

The team achieved an exemplary safety record and there were no reportable injuries whilst on site; 990 hours of behavioural discussions took place on site, with 53 unsafe observations corrected and 31 safe observations recognised. Behavioural discussions are actively encouraged on site, with observations held to praise safe behaviours and correct unsafe behaviours.

Minimal impact

Every effort has been made to limit the impact of the works on the local community, with close communication maintained throughout the project. The team worked hard to ensure that the spillway works were completed in as short a time as possible, completing an impressive 106 concrete pours in 73 working days. Safe pedestrian access was maintained throughout the works (the embankment crest is crossed by a public highway).

Use of a fair faced concrete finish has meant it has not been possible for the new concrete lining to match the existing Victorian masonry construction. In spite of this, the project team have worked hard to ensure that the new works cause the minimum possible impact to the landscape. Therefore, at the transition, the concrete and masonry meet in a stark contrast between new and old. The upstream wall raising has been constructed in masonry to maintain this transition, with the new section of wall stepping down to meet the existing; mimicking the design of the existing bridge parapet.

Summary

The original investigation works, flood study and physical model completed for Lower Laithe Reservoir identified significant inadequacies with the overflow arrangement. The remedial works designed and undertaken by MMB have now ensured the future safety of the reservoir.

Reservoir safety contingency measures were in place throughout the construction works and carefully monitored. The project overcame tight site constraints to be delivered in the minimum possible time, reducing the impact of the project as much as possible. Works were completed 5 months ahead of the statutory compliance date.

The editors and publishers would like thank Natalie Evans, Engineer with JN Bentley, for preparing the above article.

Additional thanks to Tim Dyke, Yorkshire Water Solution Manager; Richard Robson, Designer at Mott MacDonald, John Greenwood, Framework Manager for Reservoirs, and Rob Dunn, Communications and CR, with JN Bentley, for their input.

Existing spillway prior to construction - Courtesy of MMB

New spillway viewed from Cemetery Road - Courtesy of MMB

Masonry wall raising - Courtesy of MMB

New spillway looking upstream from stilling area - Courtesy of MMB