

Gorple Upper Reservoir Spillway Improvements

investigating and addressing deficiencies in the capacity of the overflow system

by Kate Speirs MEng

Gorple Upper Reservoir is owned and managed by Yorkshire Water Services (YWS) and supplies water to the Calderdale region of Yorkshire. The facility is a large raised reservoir impounding over 1,700ML of water by means of an earth-fill embankment dam spanning some 300m across the valley, and is the upper reservoir in a cascade of two, constructed in 1935. The reservoir's overflow facilities consist of a weir which spills flows into a masonry tumble-bay and then into a masonry spillway channel which passes under a bridge located at the north end of the dam. The spillway runs parallel to the toe of the embankment and into a circular, masonry stilling basin. At the downstream end of the stilling basin, flows discharge into a natural watercourse.



Raised masonry walls to spillway - Courtesy of Mott MacDonald Bentley Ltd

Background

The Reservoirs Act 1975 requires Category A dams, such as Gorple Upper Reservoir, to be designed to withhold the Probable Maximum Flood (PMF). The PMF flow at this reservoir was calculated to be 26m³/s.

The reservoir was inspected in 2011 by the Qualified Civil Engineer (QCE) under the Reservoirs Act 1975 and received a recommendation in the interests of safety that the capacity of the overflow system was to be investigated and any deficiencies addressed by September 2013. Subsequently, YWS employed their framework delivery partner, design-and-build contractor Mott MacDonald Bentley (MMB), to develop a solution to meet the prescribed requirements.

Solution development

MMB developed a solution to the safety recommendation based on physical scale modelling of the overflow system. This demonstrated that during a PMF event, the spillway channel and stilling basin were under capacity. The modelling also revealed that flow velocities in the spillway channel reached a maximum of 17.5m/s at the downstream end, which was well beyond Yorkshire Water's Asset Standard limit for masonry spillways. Therefore, the risk of masonry blocks being pulled out by the PMF was high.

By working with YWS to reassess asset standards, MMB used learning from previous projects to develop a leaner solution which reduced the scope of works and led to cost savings of over £600k. The speed of construction was also increased and the

project exceeded its completion deadline by one month. This was an impressive achievement, considering the challenging eleven month detailed design and construction programme, and the site being located within a Site of Special Scientific Interest (SSSI).

Quality of design and workmanship

The model results led to the outline solution that the spillway walls required raising and the lower section of masonry spillway, where flow velocities were predicted to exceed the asset standard, required replacing with reinforced concrete as per Yorkshire Water's Asset Standard. A number of design concepts for dealing with flows overtopping the stilling basin were trialled during the physical model testing, with the most successful being the placement of a rectangular culvert in the stilling basin to direct flows to the downstream watercourse.

Following MMB's investigations at another YWS reservoir, it was proved that in some cases there is justification to reassess YWS' Asset Standard with regards to the flow velocities that a masonry spillway can withstand.

At the other site, pull-out tests were performed in order to assess the forces required to pull out the masonry blocks from the spillway invert. This demonstrated that the actual forces required were much greater than the calculated theoretical forces and the pull-out tests led to a leaner solution which deviated from YWS' Asset Standard. Therefore, there is some scope in making case-by-case investigations at sites to tailor solutions depending on the condition of the existing masonry and its bond with the concrete backing underneath.

YWS was keen to adopt the same approach at Gorple Upper; however the spillway was too small to conduct pull-out tests. As an alternative, MMB cored through the spillway to assess the condition and depth of the masonry and concrete backing, and the bond between the two. A detailed inspection of the spillway with YWS and the QCE facilitated the shared conclusion that the existing masonry spillway was in good condition and therefore should be able to withstand higher flow velocities than specified in the Asset Standard. MMB, YWS and the QCE agreed to deviate from the Asset Standard in this case and allow the spillway to be constructed in masonry up to the beginning of the steepest section of the spillway. Beyond this point, the spillway would then be constructed in reinforced concrete.

Innovations

The existing masonry spillway channel was raised via a double-skinned masonry wall, with a concrete in-fill, dowelled into the top of the existing wall.

Downstream of the raised masonry wall section of the spillway, it was originally intended to reconstruct the spillway in concrete, by demolishing the existing channel and building a new, in situ channel. However, considering the excellent condition of the existing spillway, demolishing a perfectly sound structure that could still be utilised seemed an inefficient approach in terms of cost, sustainability and programme.

An alternative approach was therefore considered. This was to retain the existing spillway channel and simply line it with concrete in order to raise the walls and protect the existing masonry channel from high PMF flow velocities.

MMB considered a number of lining options including the use of in situ and sprayed concrete, however precast concrete wall units offered the greatest time, cost and safety benefits, and were therefore chosen as the preferred option to take forward. This utilised the standardised precast concrete wall panel product that MMB have developed in collaboration with supply chain partner Carlow Precast Concrete Engineering Ltd. It was important



Spillway improvement works at Gorple Upper Reservoir
Courtesy of MMB Ltd



Challenging Site Logistics - Courtesy of MMB Ltd



Precast concrete wall panel culvert construction - Courtesy of MMB Ltd



Spillway concrete backing underneath masonry - Courtesy of MMB Ltd



Culvert with porcupine block downstream headwall
Courtesy of MMB Ltd



Completed spillway improvements - Courtesy of MMB Ltd



Completed spillway improvements - Courtesy of MMB Ltd

to maximise the channel's internal width and therefore the standard wall panel design was altered for this project by means of shortening the rear stabilising feet and lengthening the front feet so that the main body of the wall panels could sit as close as possible to the existing channel walls, without compromising the wall panel's stability during construction.

The wall panels were placed within the existing spillway channel and jointed together with minimum 400mm wide concrete infills. The channel invert was then lined with a 200mm thick in situ concrete base which covered the front feet of the wall panels. The 150mm wide void between the back of the wall panels and the existing channel walls was filled up to ground level with concrete.

In order to minimise visual impact, the wall panels were cast with a masonry-effect form-liner finish on their outside faces for the portion that would extend above finished ground level. In addition, a 'false coping' was cast at the top of the wall panels.

As the culvert would efficiently direct flows from the stilling basin to the downstream watercourse, the remaining volume of the stilling basin was effectively redundant, except for taking drainage flows, and flows from the scour and supply mains discharging from the valve house. Therefore these pipes were extended through the stilling basin and the surplus stilling basin volume was backfilled.

To retain this backfill material a downstream headwall was required. Due to the site having difficult access routes for concrete delivery, the headwall was constructed from Porcupine blocks which provided a much more practical solution than in situ concrete. These also allowed increased drainage through the headwall compared to a solid concrete headwall.

Conclusion

The spillway improvement project at Gorple Upper Reservoir is one of Yorkshire Water and MMB's significant AMP5 achievements. This project is an example of positive collaboration between the client, the design team and the construction team, yielding positive results for all parties.

MMB has demonstrated interesting and innovative design techniques on the Gorple Upper Reservoir spillway improvement scheme. Faced with challenging site constraints and a tight construction programme, the focus of detailed design was to make construction as efficient as possible, without compromising quality or safety on site. As a result, the scheme was constructed 1 month ahead of programme.

The works at Gorple Upper also demonstrate the success in utilising precast products, such as MMB's standard precast concrete wall panel. MMB also achieved savings associated with challenging the client's specifications in 'special cases', with a view of making the most of good quality existing assets and engineering an overall more sustainable solution.

On other schemes, MMB is now doing more intrusive tests of existing masonry structures at the investigation stage, to assess their capacity to withstand greater velocities and therefore develop more tailored and cost-effective solutions for each site. A strong relationship with the client is helping in this process by working together to challenge asset standards and agree more flexible solutions without comprising on asset quality.

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