

Watersheddles Reservoir Spillway Improvements

innovative solutions to meet challenging site conditions
and maintain compliance with the Reservoirs Act 1975

by Kate Speirs CEng MICE

Watersheddles Reservoir is an impounding reservoir located on the border between Yorkshire and Lancashire. Modification works were required to the ageing asset including; replacing and lining the existing spillway and stilling basin with reinforced concrete (RC), enabling the overflow system to safely pass the Probable Maximum Flood (PMF) and therefore maintaining compliance with the Reservoirs Act 1975. Yorkshire Water Services (YWS) contracted design and build contractor Mott MacDonald Bentley Ltd (MMB) to undertake the design and construction of this logistically complex £1.3m scheme.



Existing tumble-bay from Watersheddles Reservoir leading to the spillway - Courtesy of Mott MacDonald Bentley Ltd

Background

Watersheddles Reservoir was constructed in 1877. It holds 866ML of raw water collected from the surrounding 2.36km² catchment. Following an inspection in November 2011 under the Reservoirs Act 1975, the inspecting engineer made recommendations in the interests of safety that YWS make modifications to the spillway to enable it to safely pass the PMF, and to fill voids underneath the spillway and tumble-bay.

YWS subsequently employed MMB to undertake the design and construction of these works. Following initial investigations, including physical model testing of the overflow system, MMB developed the outline solution for the scheme, which included:

- Grouting voids under the tumble-bay and spillway to prevent leakage underneath the existing structure.
- Lining the spillway channel and stilling basin with new RC walls and base to protect the existing masonry structure from high PMF pressures. This also involves raising the height of the spillway walls and replacing the curved section of the right-hand-side (RHS) spillway wall with a new, straight section of wall to improve hydraulic performance.
- Constructing a 'wall overhang' on the left-hand-side (LHS) stilling basin wall to keep flows within the stilling basin and constructing a concrete ramp to direct flows over the stilling basin weir to the downstream watercourse.



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The existing spillway from the Reservoir built in 1877
Courtesy of Mott MacDonald Bentley Ltd



The original Watersheddles spillway
Courtesy of Mott MacDonald Bentley Ltd

- Replacing the existing spillway bridge to suit the new spillway channel.

Site constraints

Watersheddles Reservoir is in a remote location at the top of the catchment. The embankment and spillway are very steep with a maximum gradient of 1 in 2.5. Without constructing expensive temporary works, access to the spillway was limited to a flat berm at the top of the embankment and within the margin of the LHS embankment mitre. Due to these difficult access conditions and steep spillway, there were significant health and safety risks associated with working on the steep slope. MMB was therefore keen to drive a solution that minimised the requirement to work within the steep spillway channel. In addition, there was a risk of achieving a poor quality concrete finish if an in situ RC solution was developed.

To avoid these issues, MMB’s design team drove the development of precast concrete (PCC) channel lining options, in favour of the traditional in situ approach following the successful implementation of a PCC solution at the recently completed project at Gorple Upper Reservoir.

Traditionally, in situ concrete poured on a steep incline, such as that on the spillway at Watersheddles, would require the use of a top-shutter to stop the concrete from running down the slope, but this often results in surface ‘blowholes’ when the top shutter is removed, providing an unacceptable finish. Constructing the temporary formwork required to build an in situ spillway (including the top shutter) would also be an issue due to the logistical challenges of the site, with limited access for lifting and placing formwork.

Therefore the use of a PCC solution, with significantly reduced construction activities and therefore reduced access requirements

to the steep spillway channel, was the clear choice for the design team to take forward into the construction phase.

PCC U-sections

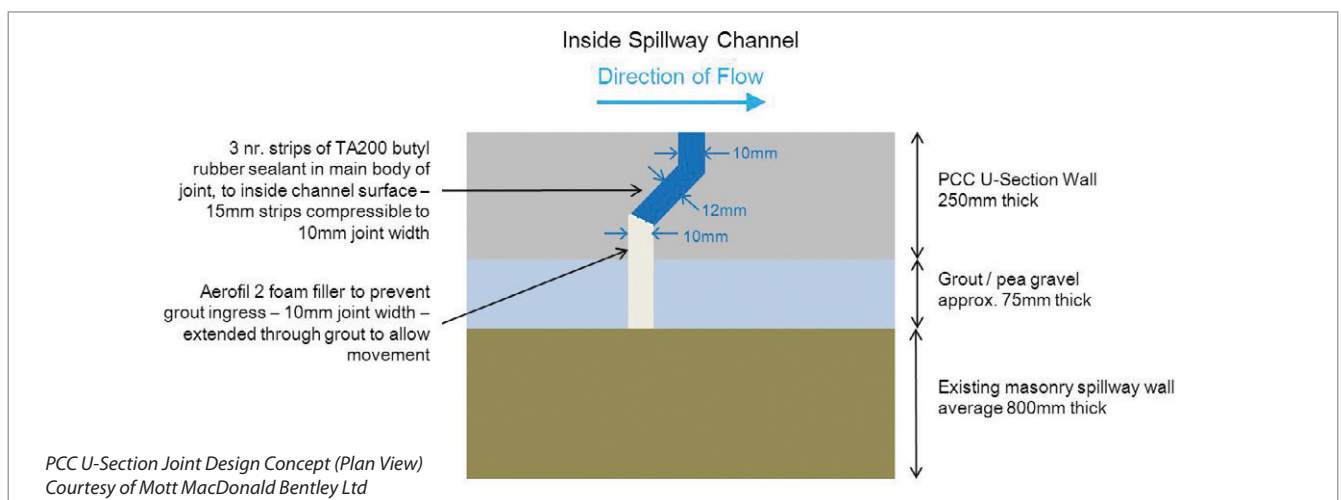
In order to eliminate any in situ concrete construction on the steepest section of the spillway, the design concept behind the PCC U-sections was to use a ‘spigot and socket’ joint with an appropriate waterproof sealant - similar to a culvert unit - rather than in situ RC wet joints which would provide water retaining joints.

YWS’ Reservoir Safety Asset Standard requires spillways to be designed and constructed as water containing/retaining structures, implying the use of the water retaining concrete design code which specifies the provision of movement joints with water-bars. A significant challenge in developing the U-section design was in developing a suitable joint detail, which would deviate from YWS’ asset standard, to gain YWS’ approval.

YWS were keen to involve an external technical advisor from Arup to give guidance on the design of the PCC U-sections and joints, and to ultimately approve the design and deviation from the asset standard.

As it was clear that a fully water retaining joint would be difficult to achieve, MMB, YWS and the external technical advisor agreed collaboratively that the joint would perform sufficiently if it was designed to be water-tight (i.e. no leaks) rather than water-retaining (i.e. in situ with water bars). MMB selected a suitable PCC supplier to manufacture the units and engaged their expertise throughout the design process to aid in developing a suitable joint detail.

Part of gaining acceptance of the joint detail involved testing the joint’s performance under hydraulic conditions similar to that which would be experienced on the spillway at Watersheddles in





3 (No.) PCC U-sections awaiting installation in the MMB site yard
Courtesy of Mott MacDonald Bentley Ltd



First U-section being winched down spillway
Courtesy of Mott MacDonald Bentley Ltd

PMF conditions - where velocities reach up to maximum of 25m/s at the downstream end of the spillway. MMB therefore arranged for the PCC subcontractor to manufacture a mock joint section and for it to be pressure tested to prove that the proposed joint design would perform to the required criteria. The joint detail surpassed the design requirements which gave YWS and the technical advisor confidence in the design.

Another key consideration in the design process was how the units were going to be installed within the spillway channel when access was limited. Although the design of the PCC U-sections eliminated the requirement for constructing any in situ RC components, the design team considered at length the methodology for installing the units in order to minimise safety risks during construction. This was fundamental to the PCC U-Section design concept.

A sacrificial rail system was developed to allow the units to be carefully slid into place on the steep spillway, utilising winches at the

upstream and downstream ends of the spillway. Once in position and secured to the rails underneath, the units were grouted into place to provide additional restraint within the existing spillway channel and to negate the risk of the U-sections being plucked from the spillway channel in the extreme case that a joint leaked and PMF pressures developed under the U-Sections.

Spillway drainage

A fundamental component of the U-Section design and making the existing spillway capable of supporting the new structure, was the filling of voids known to be present under the spillway channel.

During the reservoir inspection, the inspecting engineer noticed water disappearing through the invert of the spillway at its upstream end, and reappearing through the invert at its downstream end. This suggested that voids had formed underneath the spillway, creating a flow path. MMB investigated these voids via trial holes dug at various intervals on the spillway, and discovered that the

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Spillway rail system installation
Courtesy of Mott MacDonald Bentley Ltd



Compression of joint sealant to desired joint width
Courtesy of Mott MacDonald Bentley Ltd

voids were larger than originally estimated - in some instances leaving a clear gap beneath the entire width of the spillway. The solution to deal with this issue therefore had to be more robust than originally intended.

MMB tested the water flowing within the voids to confirm that it was groundwater coming from the adjacent hillside rather than reservoir water leaking through the existing structure.

It was decided that the voids should be filled with a combination of mass concrete and grout depending on the volume of void to be filled, and that drains should be installed to deal with the groundwater coming from the hillside, which could cause further voids to form in the future if not directed elsewhere.

MMB decided to locate the drains underneath the existing spillway channel as this was the most safe and practical option for drainage, avoiding deep excavations on the steep hillside and embankment either side of the channel.

Environmental & sustainability considerations

The design of the scheme was mainly driven by the limited access to the spillway channel and the steep gradient of the channel. However, MMB's experience of lining spillway channels rather than demolishing and replacing channels, and the use of PCC products where possible, has led to significant time, cost and waste savings on recent projects, therefore making MMB's projects more sustainable.

On the Watersheddles project, water resources were managed efficiently to provide a safe working environment during the construction period without impacting water supply too dramatically.

The use of PCC products to line the spillway, rather than in situ concrete, significantly reduced the risk of polluting the downstream watercourse and reduced the volume of traffic to site with bulk PCC deliveries replacing regular deliveries of wet concrete.

Adjacent to a Site of Special Scientific Interest (SSSI), MMB managed the site's footprint so as not to encroach on the SSSI. In addition, the site had an agricultural tenant who farms sheep in the nearby area and requires periodic access across the reservoir embankment to the adjacent hillside for grazing. MMB worked collaboratively with YWS to manage the sheep farmer's requirements without disrupting site activities or damaging the SSSI with the temporary sheep passes that the site team set up for the farmer.

Conclusion

The difficult site conditions on the Watersheddles project has given MMB the opportunity to develop an innovative approach to lining spillway channels via PCC U-Sections installed on a unique rail system. This significantly reduced the number of work activities and associated manual access to the spillway, therefore reducing health and safety risks. This, in addition to the solution's sustainability benefits, has made the Watersheddles project a leading example of MMB's Reservoir Safety capabilities.

The first U-Section was installed on site on 20 May 2015 and a further 29 (No.) units will be installed by the end of June 2015, with the construction works programmed to finish in September 2015, ahead of the Reservoir Safety Act 1975 compliance date of 1 November 2015.

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