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Improving the emergency drawdown reliability at Llyn Brenig reservoir – Part II

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SYNOPSIS This paper builds on the paper published and presented by Tudor and Morgan (2018) at the 20th BDS Biennial Conference in Swansea for the design of improvements of emergency drawdown reliability at Llyn Brenig.

Dŵr Cymru Welsh Water (DCWW) appointed Mott MacDonald Bentley (MMB) to install and commission the upgraded scour facilities, including the extensive temporary works required to enable construction to take place, and replacement of the "Goliath" crane mounted to the top of the valve tower located circa 300m from the reservoir's shoreline.

Management of water levels and isolations were required to enable gate replacement whilst maintaining a desirable volume of stored water. Draining the reservoir was not feasible due to the operational requirement to maintain flows to the River Dee for abstraction purposes. Issues arising during construction and performance of the enhanced system following commissioning and handover are also covered in the paper.

INTRODUCTION

Llyn Brenig is located in the county of Conwy around 15km south of Denbigh, north Wales. The reservoir feeds compensation flows to the River Dee and is a critical asset to the Dee Valley Consultative Committee in unison with Llyn Celyn and Llyn Tegid. The reservoir has a stated volume of 61,550,000m^3 and is impounded by a 50m high rockfill dam with a 1200m long crest length, constructed in the 1970s.

Following a statutory inspection carried out July 2015, two recommendations were made under section 10(3) of the 1975 Reservoirs Act. The first of these recommendations was thus: *"Remedial work and refurbishment of the hydro-mechanical and electrical components of the scour outlet works shall be implemented in order to improve reliability, security and operability of the system".*

Tudor and Morgan (2018) discuss how the design had been undertaken and identified the remedial action to be taken through to delivery on site. The remedial works taken forward to construction were:

- Replacement of the "Goliath" crane mounted to the top of the combined draw-off and overflow tower

- Installation of a new secondary isolation gate
- Replacement of the scour bulkhead gate
- Replacement of the primary scour gate
- Replacement of all gate control systems including new control panel and caballing

Third party users
The reservoir is a popular visitor attraction and required careful planning to minimise the effect on patrons. Osprey nesting, sailing activities, fishing competitions and even the RAC Rally had to be accommodated during the construction period.

GOLIATH CRANE REPLACEMENT
The existing crane on top of the draw-off tower was noted to be difficult to operate, unreliable and beyond reasonable repair. The decision was taken to replace the crane with an installation which could be controlled via a remote operating station, making the operation easier and safer by removing the need for elements of work at height (WAH).

The crane operates on two rails fixed to a steel structure and is supported by six concrete plinths. Following a structural assessment, the support structure was proven to be salvageable, however it required replacement of four of the six reinforced concrete supports. Temporary works were required to prop the 26t crane and support steelwork and jack the existing gantry crane and support steelwork up circa 3mm to allow the safe removal and installation of the new plinths (Figure 1). Once all the plinths had been replaced the existing crane was removed and the new one put in place, utilising the floating barge and associated lifting activities, including a 100t crane (Figure 2). The working platforms had to be anchored to the reservoir bed and a suitable weather window identified to carry out the removal and installation activities (Figure 3). Operative training was carried out following construction completion (Figure 4) and commissioning completed, should the need arise to install isolations for reservoir safety purposes.

Figure 1. Hydraulic jack supporting crane during plinth replacement (MMB)

Figure 2. Temporary quay constructed to allow installation of pontoons and lifting apparatus (MMB)

Figure 3. Pontoon in position and crane replaced (MMB)

Figure 4. Completed crane installation (ARUP)

ISOLATIONS

Llyn Brenig forms part of the critical Dee Valley Regulation system along with Llyn Celyn and Llyn Tegid. Flows are regulated in the River Dee for the benefit of water supply and industrial purposes. Initially it was requested that the reservoir level be lowered to remove the hazard associated with water pressures of up to 5 bar at the base of the reservoir tower, however this was not possible due to the aforementioned supply requirements . An alternative method had to be identified to carry out the works safely during construction and for those residing downstream. The decision was taken to isolate the tower from the reservoir body by utilising the provisions in the original design; namely to install the scour bulkhead gate (Figure 5). Given the age of the existing steel gate and condition of the assets, at a little under 50 years old, it was decided to replace the scour bulkhead gate in order to provide a guaranteed factor of safety (FOS) of 3 against failure. Finite element modelling was completed in order to provide confidence in the design and testing was carried out to prove strength and durability prior to installation. The new gate weighs 5.3t and was manufactured in Spain by Orbinox. With the existing scour bulkhead in place, a baseline for leakage flows passing the bulkhead was established as 6l/s/m. On replacing the gate with the newly fabricated gate, leakage flows were again measured and compared to that of the original gate. Leakage was established as 6l/s initially, however over a period of 10 days, the flows reduced to 3.1l/s as the seals bedded into the structure (Figure 6). In addition to replacing the scour bulkhead, work was programmed such that two points of proven isolation with continuous bleed and monitoring were maintained throughout the project.

Figure 5. New Scour Bulkhead being lowered into position (MMB)

Figure 6. Scour Bulkhead – leakage monitoring station.
Note window for visual check

Table 1. Phasing of construction works showing isolations

	Scour Bulkhead Gate	Primary Gate	Secondary Gate
Existing Installation	Closed	Closed	
Stage 1	Closed	Closed	Installation
Stage 2	Installation	Closed	Closed
Stage 3	Closed	Installation	Closed
Stage 4 – Current operation	Removed	Closed	Closed

Prior to progressing onto the next stage, it was necessary to commission and test each of the newly installed gates. This meant two control panels and electrical systems were being utilised, one to operate the new and one to operate the existing installations simultaneously. Each stage was reviewed by the QCE prior to commencing works on the next stage.

ACCESSING THE VALVE TOWER

The valve tower is located approximately 300m from the embankment of the dam with no permanent bridge in place. Under normal circumstances access to the top of the valve tower is via the draw-off tunnel, and an internal staircase ascending 50m. It was not possible to traverse the new gates in one piece along the overflow tunnel and then manoeuvre them into position due to size limitations. It was decided to float the new gates across the reservoir to the valve tower using barges and then lower them into position at the base of the tower utilising the on-site crane. This solution brought with it a few complexities, including:

- The shoreline of Llyn Brenig is generally very shallow; this causes an issue with draught of vessels.
- It was necessary to construct a temporary quay to enable barges and boats to be craned onto the reservoir body and assembled.
- Water levels had to be managed within a tight band to allow for flood contingency whilst working in the live overflow and physical quay operation.
- A freeboard of 2m from the overflow was maintained throughout the works to prevent any overflows during construction.
- A 200t crane was situated on the quay to load the barges with materials and plant which were then ferried across to the valve tower. The newly replaced gantry crane was then utilised for lifting and lowering the new gates into position.

SECONDARY (DUTY) GATE

The new secondary gate was fabricated in Spain by Orbinox (part of the AVK group) and shipped to site in one piece; this weighed in excess of eight tonnes. Flow baffles in the overflow shaft had to be removed to allow access for the new gate to be lowered into position. These baffles were re-furbished and replaced upon completion of the works.

In anticipation of undertaking works to the primary gate, the project team was faced with the challenge of developing a methodology for removing the concrete surrounding the existing primary scour gate whilst working behind single isolation (Figure 8). This was required to allow replacement of the existing gate and frame. Following extensive review and development of temporary works, where the objective was to focus on the removal or reduction of risk for operators working under single isolation, the team worked closely with a specialist demolition subcontractor to develop a method to remove the concrete with engineering precision using remote/robotic control whilst being able to monitor the structure. This methodology was utilised for the secondary gate as a precursor to the primary gate works.

A rebate was cut into the existing structure to enable the invert of the channel to remain as existing. Remote operated plant was utilised for hydro-demolition to take place safely with constant monitoring for water ingress though the structure. No ingress was identified, showing the quality of the original installation. Upon lowering into position, studs on the frame of the gate were welded to the existing reinforcement prior to grouting the remaining void, securing the gate into position (Figures 9 and 10). During this process leakage flows around the existing primary gate and new bulkhead gate were constantly monitored for changes. All works were carried out under DCWW's Gold command system to monitor progress and resolve any identified issues. Following installation, the gate was commissioned and tested against full reservoir head.

Figure 8. Installation of primary scour gate

Figure 9. Completed reinforcement assembly prior to concrete profiling installation (MMB)

Figure 10. Welding of primary gate to existing tower structure (MMB)

PRIMARY (GUARD) GATE

Following successful testing of the new secondary gate, works progressed to the replacement of the primary gate.

Over the course of developing the temporary works for the scheme, the team developed an aluminium screen (Figure 6) which help to control a number of risks for the primary gate installation. The primary purpose of the screen was to monitor the existing leakage rate passing the bulkhead gate; this was completed by installing a throttled valve on each side of the aluminium screen and a float switch connection to a visual and audible alarm. 24hr CCTV monitoring was also in place to assess the condition of the work area prior to entry, and throughout the working day by a confined-space-trained 'top-man'. The second risk was to protect the bulkhead gate from any damage from debris, which was achieved through a robust but manoeuvrable aluminium screen. The third risk/complication was managing the existing leakage water during concreting/grouting works, something overcome by installing two temporary valves within the aluminium screen to direct/pipe incoming waters around the working area.

The primary gate was also manufactured in Spain by Orbinox and transported to site in one piece, weighing 8.2 tonnes. The leakage around the bulkhead scour gate was now established and settled, and constant monitoring established the leakage rate at 6l/s, which was deemed acceptable for works to commence. In a similar construction methodology to the secondary gate, following gate removal from the supporting frame, remote operated hydro-demolition techniques were used to remove the concrete surrounding the frame. Constant monitoring was in place to identify any seepage through the structure; similarly to the primary gate, none was noted during the works. Following on from hydro-demolition the new gate was lowered into position and again welded shear connections were attached to the existing reinforcement prior to final grouting.

CHANNEL PROFILING

Upon installation of the two new gates, flow profiling was installed using reinforced concrete to assist in preventing cavitation from occurring as flow passes at high velocity (Figure 11). The reinforcement for the flow profiling was anchored into the existing structure utilising around 1000 steel dowels, each of which required a 30mm hole to be drilled 300mm deep. Remote operated plant was utilised to carry out the drilling activities.

Once the reinforcement and formwork were in place, concrete was transported from the quay to the tower in a concrete skip and then lowered to the point of use by the on-site gantry crane. The concrete specified was a high strength concrete specified to help minimise the impact of abrasion during scour operation. Although not a large concrete pour in terms of volume, the development of the mix with the supply chain, contractor, designer and QCE was key to being able to balance the functional requirements along with the practical constructability. The concrete works had to be planned and executed well, which took into account weather and transport times to enable the correct workability at the time of placement.

As part of the works to upgrade the scour system, a new motor control centre (MCC) with associated power and control cabling was installed between the valves and the operations room on site. The new MCC enables remote operation of all the gates and draw off valves, which allows for safe operation without the need to manually stand next to valves during operation.

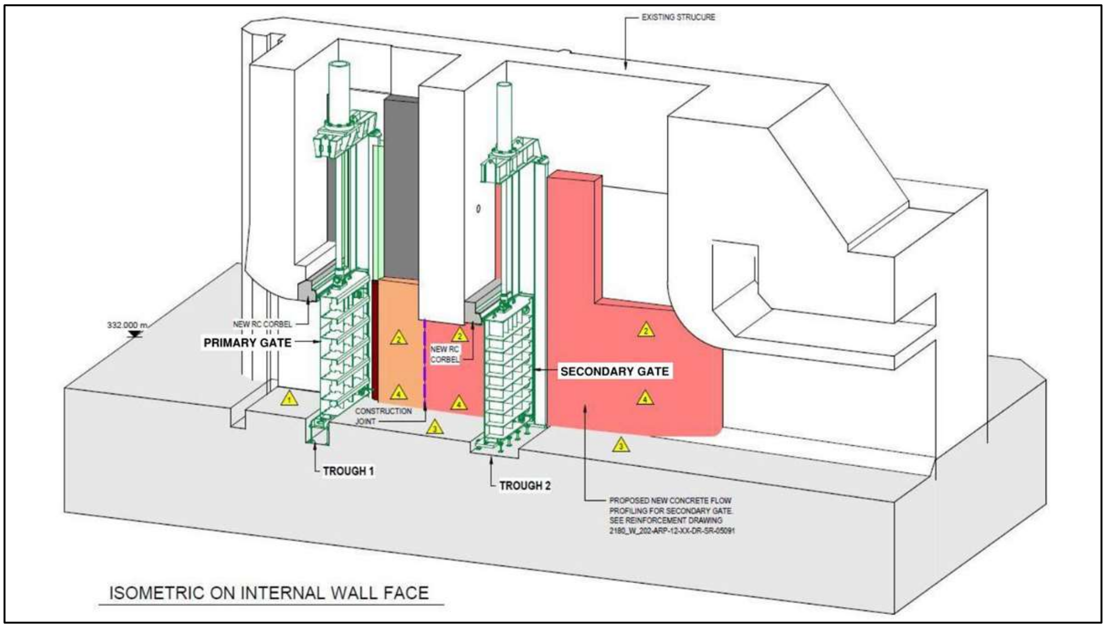

Figure 11. Chanel profiling (ARUP)

CONCLUSIONS

All valves were successfully installed, commissioned and the interests of safety recommendation certified ahead of the regulatory date. Testing of the new gates and valves is undertaken against full reservoir head on a six-month rolling programme.

The improved scour system offers greater control and safer operation both for frequent tasks and infrequent or emergency situations. The redundancy provided ensures minimum risks to the downstream catchment in the event of an emergency discharge. The high specification of all new equipment along with the facilitation of safer maintenance and testing procedures will ensure the systems reliability for many years to come.

Works to the main draw-off system, power supplies and control system also improve the everyday operations of the dam and reduce the frequency of confined spaces access.

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REFERENCE

Tudor S and Morgan A (2018). Improving the emergency drawdown reliability at Llyn Brenig reservoir. In *Smart Dams and Reservoirs. Proceedings of the 20th British Dam Society Conference* (Pepper A (Ed.)). IC|E Publishing, London, UK. pp 565-574