

Two unusual cofferdams

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1. Introduction

This paper describes two cofferdams used for protection of works during modifications to existing dam outlet works. The arrangement and details of the two cofferdams have special features that the authors consider of interest to structural engineers.



Tantangara Dam



Yallourn Weir

2. Tantangara Outlet Works

2.1 Overview

Tantangara Dam was constructed between 1958 and 1960 as part of the Snowy Mountains Scheme in NSW. It is a concrete gravity dam with a capacity of 245GL, located in the headwaters of the Murrumbidgee River. It is used to impound water for diversion to Eucumbene Dam. There is a need to send more water down the Murrumbidgee to provide more flow downstream, and possibly provide an additional source of water for Canberra. To do this required modifications to the outlet works at the dam face. This entailed works at levels significantly below the minimum operating level, and SnowyHydro Authority had allowed for the water to be pumped down to the base of the dam. This would have required drawing down the water to 15m below the minimum outlet level. Geotechnical Engineering bid for the works, with an offer of an alternative which did not require nearly as much draining of the dam or any requirement for pumping. The client accepted this offer.

The method offered was to construct a cofferdam using sheet piles, with framing to support the piles off the upstream face of the dam wall. This allowed the majority of the new outlet works to be completed in the dry. The new permanent works are another outlet tower, with screens and gates for selective drawing of water from different levels in the dam. This outlet tower is connected to the original tower by a short tunnel, as shown in Figure 1.

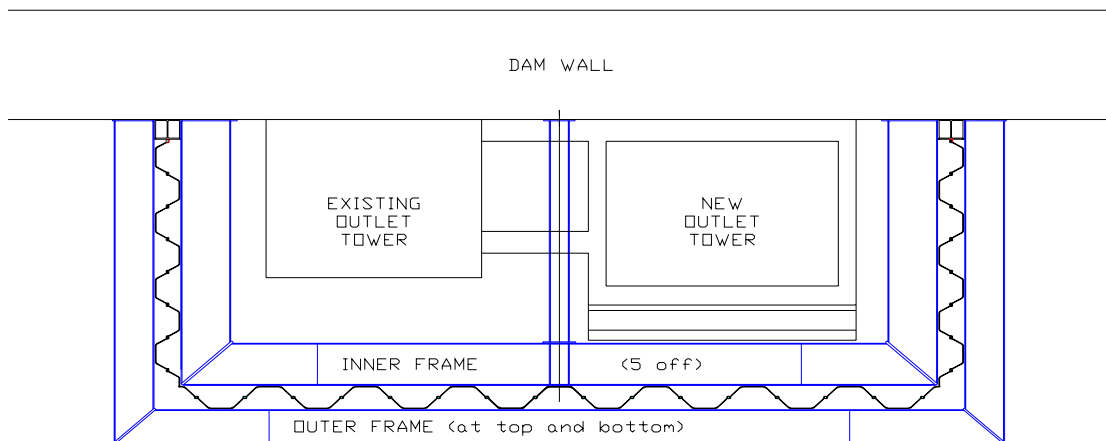


Figure 1 Plan view of Cofferdam

The sheet pile wall of the cofferdam was about 12.5m long by 5.3m wide. This was sufficient to enclose both the existing outlet tower and the new tower set 2m to one side.

The top of the cofferdam was set at 1m above the average operational level of the operating dam. At the bottom, the base rock sloped steeply along the dam face. The longest sheet pile was 17.4m and the shortest 12.4m. The base of the outlet tower is on a mass concrete footing bearing on the rock upstream of the dam face. The sheet piles served as formwork for the mass concrete. There was about 150m³ of concrete in the mass footing, made in one pour using a tremie pipe.

The contract was awarded in March 2004, and works were completed in September 2005.



2.2 Securing the base of the sheet pile wall

The first engineering challenge was to find a means of securing the base of the sheet pile wall. In normal circumstances, sheet piles are driven into sand or clay. In this case, the base material was rock, which was bound to be of relatively high strength as otherwise this would not have been a suitable place for a dam. With a cantilever of up to 5.2m, it was clear it would not be sufficient to rely upon on the guide frames to support the net pressure loads from the wet concrete inside the wall. So a decision was made to provide dowels sufficient to transfer the shear force from the wet concrete to the bedrock.

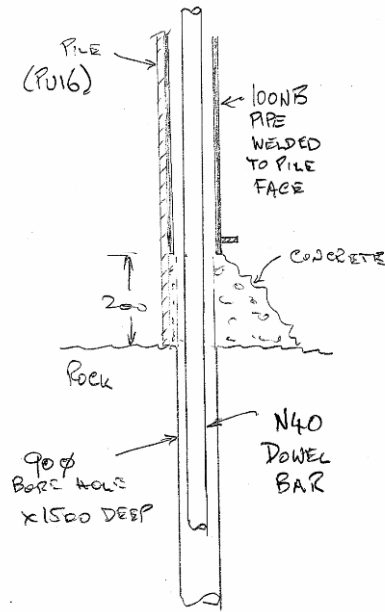


Figure 2 Dowel bar at base of sheet pile

Two dowel bars were provided on each PU16 sheet pile with a cantilever greater than 2.5m, and one on the remainder. The construction process was:

- Using the 100NB pipe, deliver blinding concrete to base of pile.
- Bore a 90 diameter hole through this concrete and into the rock.
- Place N40 dowel bar and grout.

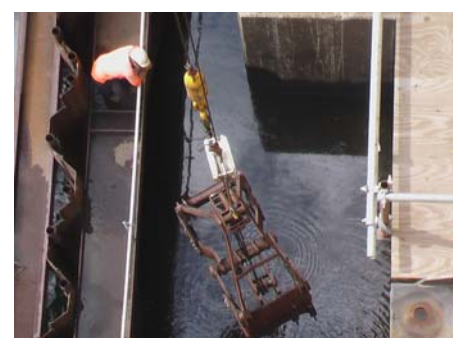
From the designer's perspective this appeared complex, but to Geotechnical Engineering, as an experienced drilling contractor, this was the best way to achieve the dual aims of securing the dowel and providing some sealing on the inside of the sheet pile wall for the later mass concrete pour.

The detail worked. The base of the sheet pile wall was secured, and there was no significant loss of concrete.



2.3 Securing the mass concrete base

With a dam that had been filled for over 40 years, there was a considerable accumulation of rotting vegetation and silt at the base of the dam wall. It was necessary to remove this carefully, minimising the extent of contamination of the relatively clean water stored above. The sheet pile wall provided a barrier to contain the vegetation during mucking-out. There was a surprising amount of debris,



mainly weed and grasses, sufficient to impede the progress of placing the sheet piles. The clean-up was completed using divers to jet-blast the exposed rock in preparation for the mass concrete pour.

There was the potential for uplift pressures on the bottom of the mass concrete. With a depth of concrete of only 200mm at the high point, there was potential for uplift from water pressure (12.5m of head during construction when dewatered). The concrete was secured to the base with 32 N32 bars grouted into the bedrock prior to concrete placement. When drilling the holes for these bars, a surprising number of faults were found in the bedrock. The original holes were then used to pressure grout the bedrock, and new holes drilled further down to give a greater degree of security against uplift.

2.4 Wall frames

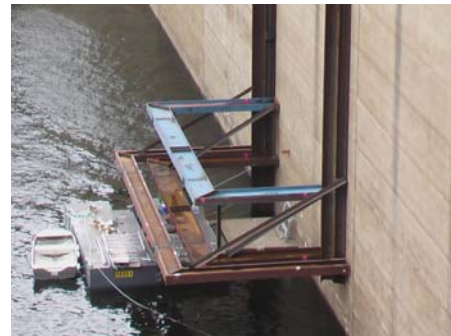
Two external frames were provided, one at the top as a guide, and the other at base level to resist outwards loads from the mass concrete during the pour. Five internal frames were provided at progressively increasing centres to resist external water pressure after dewatering.

The external frames were a composite section – 610UB101 + 2/300PFC – able to span the 13m across the front without lateral instability. The internal frames were 760UB197 and 760UB147, with a central prop to make two 5.5m spans. The internal frames were braced vertically to carry self-weight and incidental forces back to the dam wall. The dam-wall face of the frames was sealed with a 310UC158 vertical member. The frames were designed elastically, but were checked to ensure rules for plastic design were met, in case the loads experienced were outside the design envelope. The connections were designed for the full moment capacity of the sections.

The frames were sized assuming no moment capacity at the connection to the wall, but clearly there needed to be some shear resistance. A decision was made to use mechanical anchors, not chemical, as these provided immediate load capacity and were unaffected by the presence of water. The anchors used were Ramset Spatek M24 anchors, which cost about \$35 each.

The vertical 310UC158 was placed directly against the dam wall, which was very well constructed (as one expects with dam construction). The minimum number of Spatek anchors was used to secure it. Sealing was achieved using hardwood sawdust. This sinks slowly in water, and finds its way into crevices, then swells to seal the gap.

The complete frame assembly (about 35t) was assembled above the water, supported by two VSL bars. Jacks were used to lower the frame into the water as successive frames were added on top of the previous construction.



It was noted above that the internal frames were propped at mid-span. The second lowest props passed through the horizontal tunnel from the new outlet tower to the existing outlet tower and thence to the downstream works. The designer intended that these props would be “lost”. At completion of the construction works, the dam level was down about 3m below the design level, so the question was asked whether the props could be removed prior to flooding the inside of the cofferdam. The checks showed that a plastic hinge would form at the corners, but the extent of deformation would be limited by the ability of the sheet piles to transfer load to the frames above and below. The prop was then removed, and nothing untoward happened.

3. Yallourn Weir Upgrade

3.1 Overview

The Yallourn Barrel Weir was constructed in the 1920s to form a weir pool in the Latrobe River from which water supply could be extracted to meet the requirements of the power stations. It has a concrete sill structure with a fixed crest and an adjacent drum gate. Part of the upgrade work carried out by Geotechnical Engineering in 2005-6 was to replace this gate by a further section of fixed crest and to install a small diversion outlet in the new crest.

The drum gate (shown in Figure 3, below) was a 2.74m diameter, 30m long cylinder constructed of riveted steel plates. Each end of the drum was fitted with a large pinion which engaged with racks set into the concrete piers. It provided a means for accurately controlling the level of water in the pond.

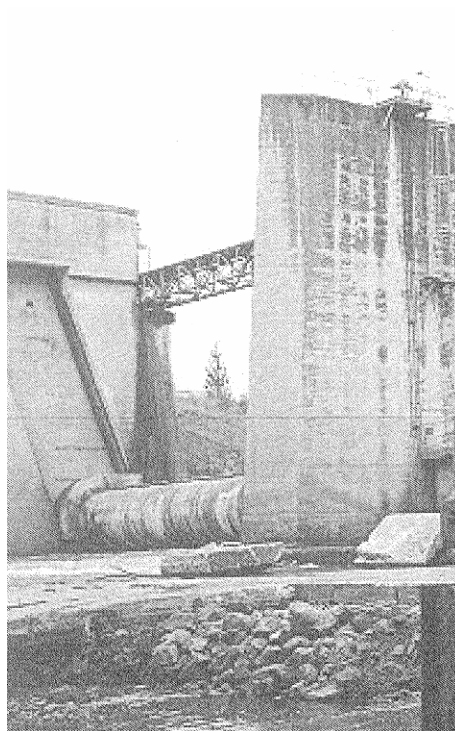


Figure 3 View of drum gate from downstream

Between 1959 and 1961 another weir, Yallourn Storage Dam, was constructed 2.5km upstream to form Lake Narracan. A more substantial dam, Blue Rock Dam, was constructed further upstream in 1979-1984 to provide better regulation of the Latrobe River.

The dam owner, Southern Rural Water, called tenders in February 2005 for the upgrade works, including removal of the drum gate. Their specification included a requirement that the cofferdam upstream of the drum gate should have a freeboard of 1m above the existing fixed crest and the weir level was not to fall more than 300mm below the full supply level. This section of the paper describes the design of this cofferdam.

3.2 Tender design

Geotechnical Engineering’s estimator provided the sketch in Figure 4 as the concept for the cofferdam to the first-named author for sizing of steelwork.

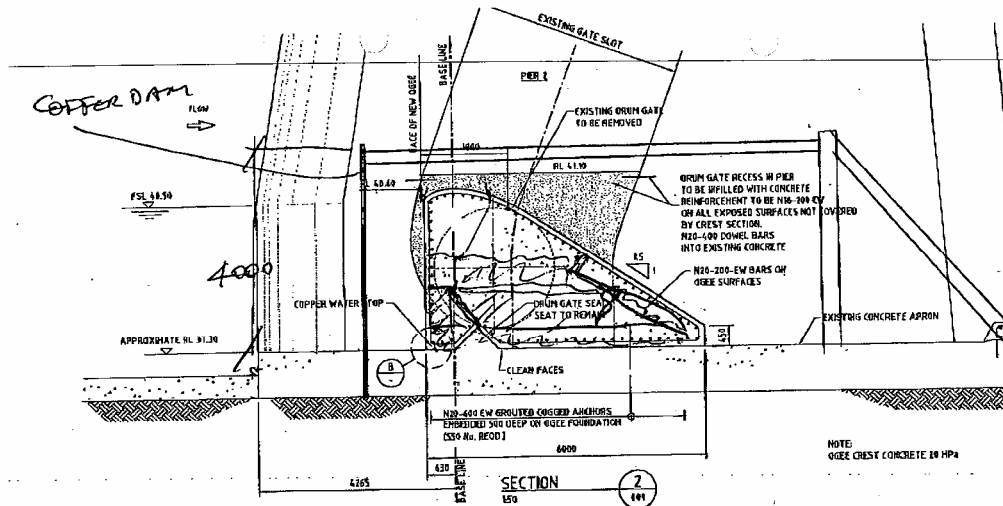


Figure 4 Sketch showing requirement for cofferdam

After contemplating the complexity and construction issues associated with anchoring the base of the cofferdam in the upstream water, the sketch shown at Figure 5 was offered as an alternative, and accepted by Geotechnical Engineering.

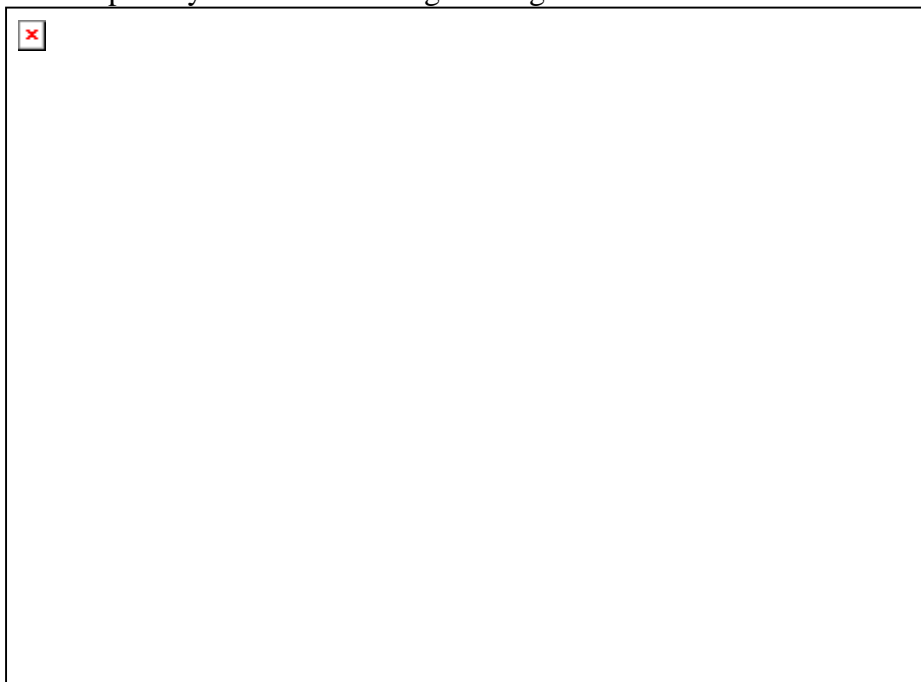


Figure 5 Concept of cofferdam submitted with tender

The concrete apron upstream of the drum gate had a substantial step about 4m upstream of the drum gate, which provided a ready structure to restrain the cofferdam against movement downstream. But this only addressed horizontal equilibrium, without considering the effects of overturning. With a vertical face, the toe would want to slide up the step. But by angling the front face downstream, the line of action of the pressure would be within the span of the horizontal joists sitting on the apron, as shown in Figure 5. This concept provided a structure which would require no fixings at least until the downstream side had been dewatered, eliminating the need for extensive work by divers. The sketch provided sufficient information to allow a rough estimate of the likely cost, but clearly there was more design required. It should be noted that the sketch assumed a freeboard of 300mm, not the 1m specified in the tender documents (of which the designer was unaware).

3.3 Final design

After award, the design concept was developed further, increasing the freeboard to the required 1m. End sections interfacing to the curved ends of the piers were detailed, and bracing provided to provide a positive restraint to the inclined struts and floor joists. It was decided that the cofferdam structure would be built in sections in the workshop with simple field-bolted seams between sections.



It gradually became apparent that the cofferdam would be overtopped in a design Maximum Probable Flood, and that there was a significant probability of minor overtopping in the construction period. Although the works were scheduled for summer months when flooding is less likely, Blue Rock Dam happened to be full, providing no buffer to slow the flow downstream.

The importance of the weir to the power station operators was emphasised in discussions. They were reliant upon the weir level remaining within 300mm of spillway crest, and would have to shut down Yallourn Power Station immediately if the cofferdam were breached. Further, the dam was also used to pump water to Loy Yang A and B Power Stations, and those would also have to close soon after. Hence, a significant fraction of Victoria's power supply was dependent on the integrity of one 26m wide cofferdam! At this point a decision was made to transfer responsibility for the design of the cofferdam from Keays Engineering and Geotechnical Engineering to Southern Rural Water, primarily because the consequences of a loss of the dam would not be insurable in their hands.

The design was reassessed assuming overtopping about 3m above the crest (2m above the cofferdam). The major change was to add another strut to support the cantilever end of the wall joists, which served to strengthen the joist, and provide guidance to any debris which might come over the top of dam. With the additional water pressure, the line of action shown on Figure 2 rose above the back of the floor joist, requiring tie-downs. However, it remained that the dam could be dewatered without these tie-downs, allowing them to be installed "in the dry".

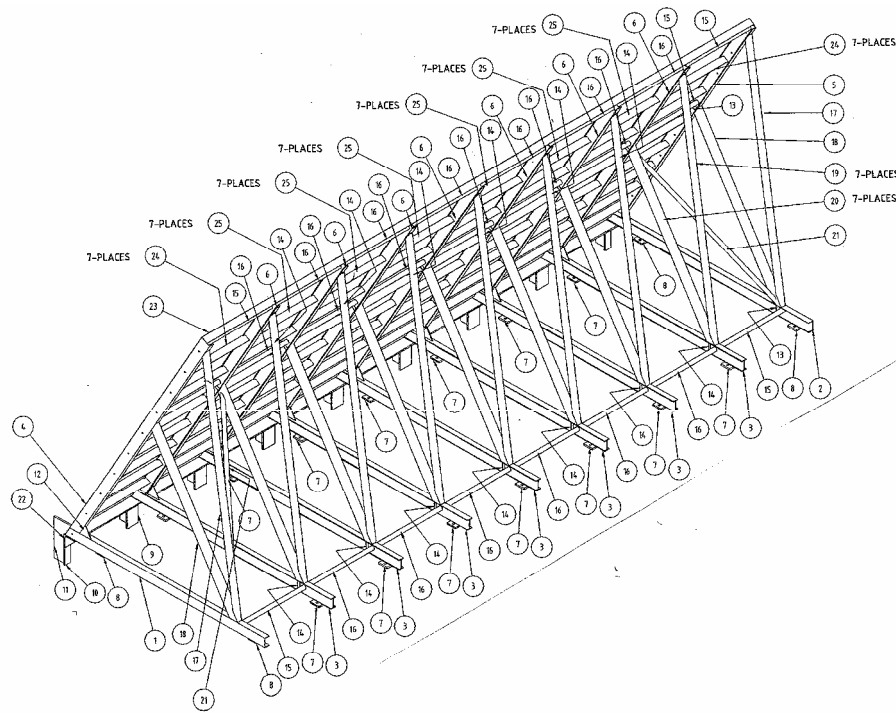


Figure 6 Isometric view of section of cofferdam

3.4 Construction

Construction was uneventful, with the structure behaving as expected. The step on the apron was similar to that shown on the drawings, and only a few modifications were required at the ends where the transition to the piers was different.

Given the concern about the possibility of flooding, there was perhaps some disappointment that the water level in the dam was never more than 300mm higher than the fixed crest height through the 9 month construction period.



There was just one cause for concern. Towards the end of the construction process, after the new main spillway had been installed, it was found that the few modifications at the end resulted in a clash between the temporary steelwork and the inlets to the new outlet structure at the western side. This clash was as a result of the modification mentioned above. To address this, the design was modified to allow removal of one set of struts, with the pressure loads transferred to the adjacent struts. When the load was transferred to the adjacent struts, one deformed more than one would expect. The cause was identified as the absence of one 50x5 flat web stiffener on the 150UB floor joist (and only on that one joist). This problem was rectified by welding in a new stiffener, and the structure served its remaining few weeks of service without distress.



4. Conclusions

The methods and outcomes on both these cofferdams are excellent examples of a contractor and designer working together to produce structures fit for the application, and able to be constructed with relative ease.

With respect to Tantangara, the assistance of the client, SnowyHydro, and their permanent works designer, Hydro Tasmania, must be acknowledged. They provided useful and timely comments on the design, and every assistance during construction. A word of thanks must also go to Andrew Jackson of Melbourne who checked the design of the temporary works.

On the Yallourn project, the client, Southern Rural Water, and their permanent works designer, SMEC Australia, must be acknowledged. The authors are particularly thankful that these two parties took design responsibility for the ultimate integrity of the temporary works.

(no references)