



Horseshoe Bend – Innovations in Roller Compacted Concrete

The Horseshoe Bend dam project, completed in April 1999 – was the first significant use of roller compacted concrete (RCC) in New Zealand.

The potential for a dam at the site – on the Teviot River in Central Otago – had been realised for many years. When planning for the project began, the options of a concrete-faced rockfill and roller compacted concrete (RCC) dam were looked at. The feasibility studies revealed very similar costs, but RCC had the distinct advantage of being less prone to damage if over-topping was to occur during construction.

Roller compacted concrete essentially combines concrete technology with that of mass earthworks. Aggregates with a grading similar to M4 basecourse have cement added to produce a lean mix which is placed using conventional compacting equipment. The mix will usually just paste up (compact) under vigorous vibration.

The challenges

The Horseshoe Bend project provided the project team with several challenges. Although RCC is relatively commonly used overseas, the conditions for its use at the proposed dam site were quite unique.

The dam was constructed as a design-build lump-sum project with the project managers and contractors Fulton Hogan Ltd, designers Opus International Consultants, and client Pioneer Generation (formally Central Electric Ltd). The total cost of the project was \$2.32 million.

The challenges faced and resolved by the team included:

Batching

While comprising over 5,000m³ of RCC,

this is considerably smaller than international experience. Innovative batching and placing techniques needed to be developed to ensure that the set-up costs did not become prohibitive.

Remote location

The site is in a remote mountainous area. Transportation of materials (including cement) had to be carefully considered. For example, wet weather could prevent use of access tracks.

Weather conditions

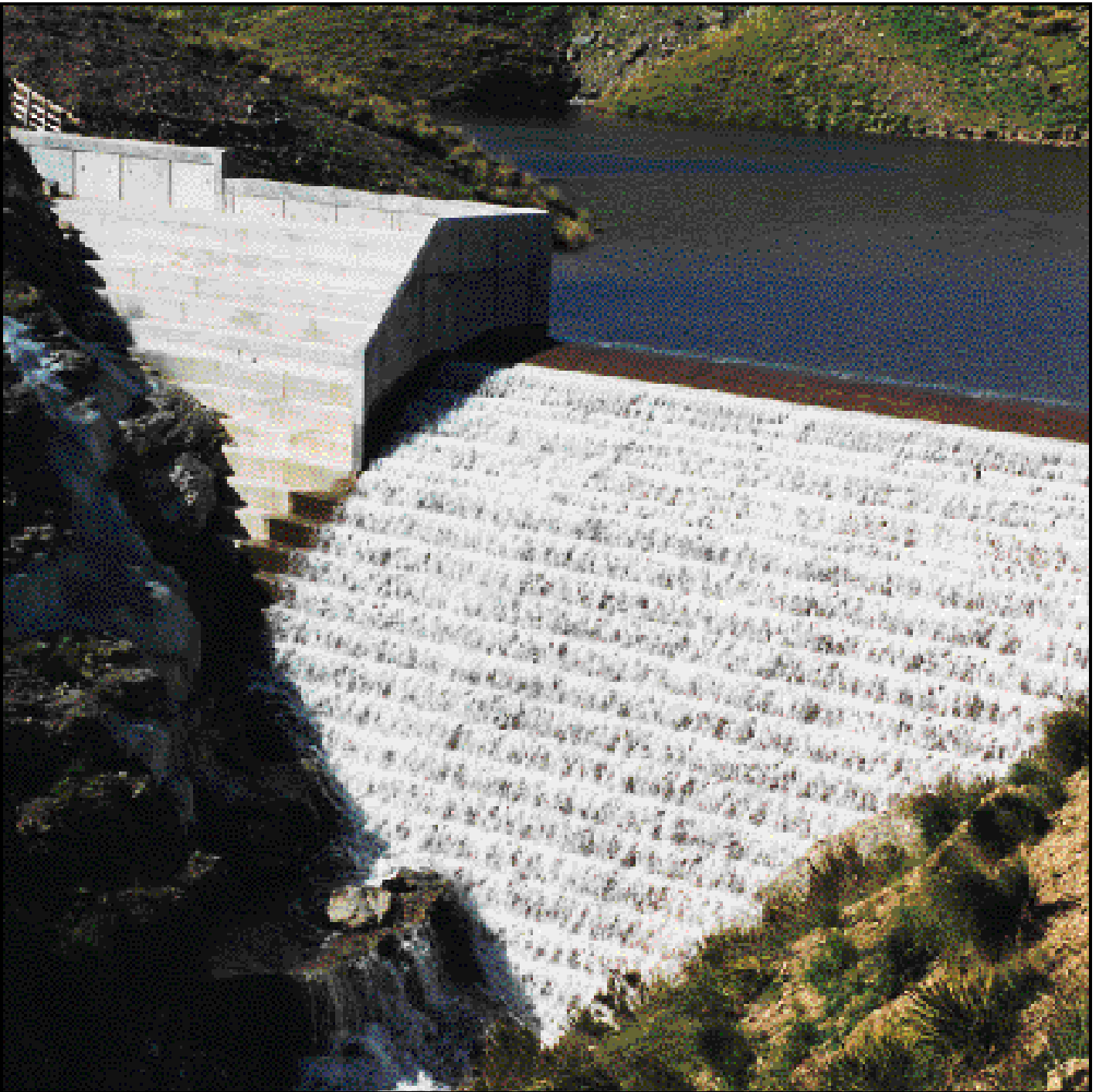
The area is prone to freezing temperatures in winter and hot dry weather in summer. The mix design on exposed faces required air entrainment to ensure appropriate durability. Heat build-up during hydration needed to be controlled carefully as well.

Scarce aggregates

The aggregates available for RCC production were obtained from quarried schist. This material is considerably softer than those which have typically been used overseas. There is no local low-cost source of fly ash, which is often used overseas both to improve durability and reduce unit costs.

Design considerations

The small size of the project, by international standards, called for careful consideration of the relative merits of formed and unformed construction. The size meant that a 'think big' mentality was not appropriate, and fit-for-purpose placement and quality assurance were



required. To achieve the desired strength and workability with the available aggregates, higher cement contents than traditionally used in RCC were needed.

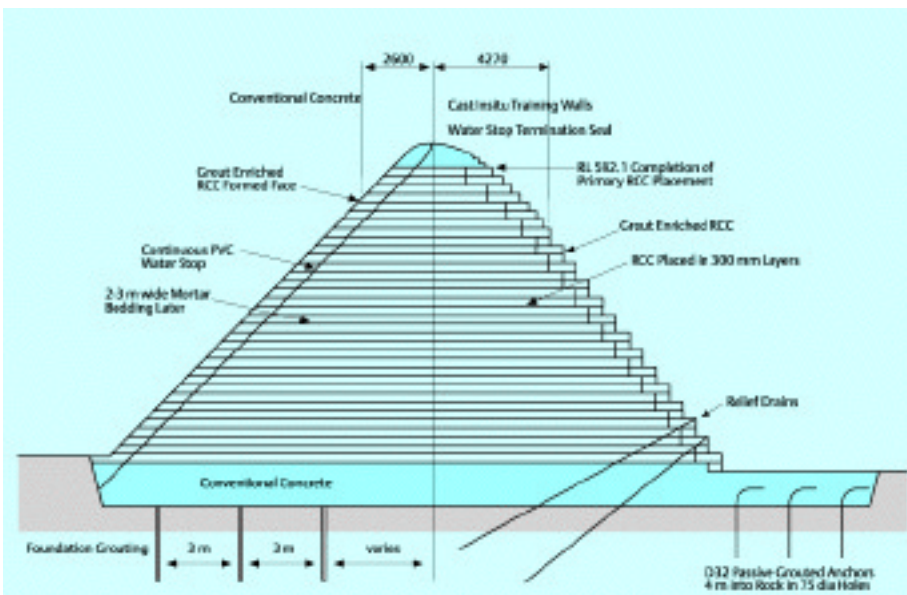
Design of the dam involved a collaborative approach between designers and contractors. The upstream face was constructed at a 1H:1V batter to avoid the use of formwork. Analysis showed that the cost of providing an additional volume of RCC was less than that of providing formwork and a more vertical upstream

profile. The added advantage was that the larger 'footprint' provided a bigger working platform, an issue which can become important when construction traffic movements over the dam are considered.

The downstream face, being exposed to the elements, incorporated 5 percent air entrainment as a protection against freeze-thaw cycles. Initially, grout enriched air-entrained RCC was trialled. Useful data was obtained from the trials, however difficulty was experienced in getting repetition of

results. The decision was therefore made to use a conventional concrete mix for the outer 600 mm of the dam. This 25 MPa concrete mix was batched on site and delivered by ready-mix trucks. The concrete was placed concurrently with the RCC to ensure that a monolithic construction was achieved. Pencil vibrators were used to ensure adequate compaction, and curing was achieved using continuous mist spraying.

To control cracking, and therefore



Horseshoe Dam Cross-Section

leakage, continuous vertical contraction joints were provided at approximately 14 m centres. Water stops were provided on the upstream face of these joints. Grout-enriched RCC (GE RCC) was used around the 300 mm wide PVC water stops provided at each vertical contraction joint.

For a diameter of approximately 1 m around the water stop, a measured volume of grout was vibrated into the RCC mixture to provide a dense low-permeability mix, very similar in appearance to conventional concrete. This process proved to be very successful and produces a desirable fuzzy interface between the RCC and GE RCC.

Construction

Aggregates for the RCC mix were obtained from an on-site schist quarry located close to the right abutment. Some 8,000 m³ of material was drilled, blasted and processed, and placed into three separate sized stockpiles, which because of the limited space were established on three separate levels. The pre-separation of aggregates provided the ability to accurately control the RCC batching process.

On completion of excavation, all loose rock was removed by an excavator fitted with a ripper, and then a level working area was created using mass concrete vibrated into all of the crevices. Upon the completion of a level base using conventionally batched concrete, the site was ready for the

commencement of RCC placement. The RCC mix was designed as a low heat mix using a ground granulated slag blended cement.

RCC is essentially a zero slump material, so a Vebe test was used to monitor workability. Batching used a four-bin process, continuously computer monitored and feeding into a pugmill. Material was deposited into a dispatching bin. Care was taken throughout the process to prevent segregation. RCC was transported to the dam using large loaders. The RCC was spread using a small bulldozer and compacted using a vibrating roller.

Quality control

Throughout the process, all stages were carefully monitored to ensure quality standards were maintained.

Eight compression test cylinders were taken each day. Two being tested at 18 hours, and 7, 28, and 90 days.

The pre-compaction temperature was continually monitored and work was suspended when the temperature of the mix exceeded 20° C.

The placement and location of various loads were logged.

Vebe tests were conducted to test for workability (8 to 20 tests per day depending on how continuous the batching operation was).

Plateau tests were conducted to determine compaction characteristics and the compaction was monitored using non-destructive testing.


In any mass concreting project, careful consideration needs to be given to temperature build-up during the hydration process. Thermal modelling was undertaken to determine simple criteria that could be used to minimise the possibility of unacceptable levels of thermal cracking. With consideration of placement rates and cement and aggregate types, a simple criteria of ensuring that the temperature was no greater than 20° C prior to compaction was developed. To achieve these criteria, the aggregate piles were constantly mist sprayed, and typically, on a hot day RCC production had to be suspended by approximately 3:30pm.

RCC placement continued at two 300 mm lifts per day, meaning that RCC placement was 95 percent complete within 19 working days. At the completion of each lift the surface was moist cured using sprinklers. If the next lift was commenced within 24 hours, no special preparation of the surface of the previous lift was required other than applying a grout tie coat to the upstream 3 m of the exposed face. If the break between lifts exceed 24 hours, or the surface dried out, the lifts were tied together with a cement grout which was squeegied into the surface.

The dam was topped off with precast panels manufactured off site and sized to accommodate the lifting restrictions on site.

The proof of the product

The successful construction of the Horseshoe dam demonstrated that RCC can be used with low-strength aggregates and in relatively small production runs. In this particular situation, RCC was used for the construction of a dam. However, the process leads itself to many other applications, such as roads, gravity retaining walls, or hardstand areas.

Further technical information on RCC construction is available from the CCANZ Library, email: library@cca.org.nz. 

Project team

Project Manager: Andrew Holmes, Fulton Hogan Ltd

Client Engineer: Peter Mulvihill, Pioneer Generation Ltd

Design Engineer: Ian Walsh, Opus International Consultants Ltd



Air entrained conventional concrete is placed against D/Sshutters.

SPECIFICATIONS

Tech Spec

Height of dam: approximately 13 m

Volume of conventionally batched concrete (for precast work, rock dental, base levelling, and downstream facing): 2,000 m³

Volume of Roller Compacted Concrete: 5,000 m³

Tonnes of silica fume enriched cement: 800 t

Number of grout holes: 147

Tonnes of cement used for pressure grout: 25 t

Square metres of Shotcrete: 150 m²

Upstream shoulder: Unformed 1:1 slope

Downstream shoulder: Air-entrained concrete steps (0.8H:1V equivalent slope)

Target compressive strength of RCC (90 day): 12 MPa

Maximum aggregate size of RCC: 40 mm

Additives to RCC: high range water reducing agent

Method of RCC spreading: bulldozer

Compacting equipment: vibrating roller

Maximum lift height: 300 mm

Maximum horizontal spacing between contraction joints: 14 m

Peak use of cement: 82 tonnes in one day

Batching process: pugmill