Construction of the Plastic Concrete Cut-off Wall at Hinze Dam

Steve O'Brien[1], Christopher Dann[2], Gavan Hunter[3], Mike Schwermer[4]

[1] *Associate Civil Engineer, URS, Melbourne*
[2] *Senior Principal, URS, Brisbane*
[3] *Principal Geotechnical Engineer, URS, Melbourne*
[4] *Project Manager, BAUER Foundations Australia, Brisbane*

One of the principal geotechnical issues identified for the Hinze Dam Stage 3 project was the potential for internal erosion and piping within the extremely complex geology at the right abutment. A plastic concrete cut-off wall was selected as the best solution to reduce the risk of piping to acceptable levels and careful planning of this work was required to manage a range of key project risks that included complex technical challenges, potential risks to dam safety, the environment, the surrounding community as well as delivering the works on a tight construction schedule to an agreed budget value. Construction of the 220m long and up to 53m deep cut-off wall, the largest wall of this type constructed to date within Australia, was undertaken by Bauer Foundations Australia and completed in January 2009. A major key to the success of the project was the planning and risk reduction measures that were undertaken during both the design and construction phases, a summary of which is presented in this paper.

Keywords: *Cutoff Wall, Plastic Concrete, Hinze Dam.*

Background

Hinze Dam is a zoned earth and rock fill embankment located on the Nerang River some 30 km west of Gold Coast. Stage 1 of the dam was constructed in the mid 1970's with a maximum embankment height of 47.5m and Stage 2 works raised the dam by 16m in the late 1980's. Stage 3 works are currently being undertaken to raise the dam by a further 15m.

The right abutment at Hinze Dam is a geologically complex region of the foundation. The mid to lower slopes on which the embankment is founded are underlain by extremely weathered greywacke (up to 25 m deep). The mid to upper slopes of the right abutment around to the saddle dam are within greenstone. The greenstone is deeply weathered (up to 30 to 40 m depth) and below this generally grades to slightly weathered and then to fresh over a short depth.

The upper deeply weathered zone within the greenstone comprises extremely to highly weathered greenstone with layers of chert and silicified greenstone. An extremely weathered rind of greenstone is present around the chert and silicified bodies. These chert and silicified greenstone inclusions are typically highly fractured, highly permeable and of very high to extremely high strength. Further details of the geology of the right abutment are provided in Chamberlain *et al* (2008).

Grouting works undertaken during Stage 2 construction were not successful in grouting the foundation, particularly in the highly permeable chert and silicified greenstone bodies. Post construction monitoring confirmed that the grout curtain was not effective and areas of high permeability were still present within the grouted zone.

Possible leakage through the right abutment foundation presented several issues for the Stage 3 embankment operation and dam safety risk profile including:

- Seepage paths along which internal erosion and piping could initiate in erodible soils;
- High piezometric conditions within the foundation, impacting on embankment stability; and
- Uncontrolled seepage out of the foundation emanating downstream of the embankment. These seepage areas would be unsightly and elevated groundwater conditions present potential local instability issues.

A number of remedial options were investigated including grouting, cut-off walls, filter buttresses, re-alignment of the embankment and blanketing options. However the construction of a cutoff wall was selected as the "best for project" solution providing the best technical solution and the lowest delivery risk.

Plastic Concrete Cut Off Wall

Construction of the 220m long and up to 53m deep Cut Off Wall (COW) was commenced by Bauer Foundations Australia (BFA) in May 2008 and was completed in January 2009 approximately six weeks ahead of schedule. The wall was excavated from ground level using a combination of "clamshell" grab and hydraulic trench cutter. When higher rock strengths were encountered, a chisel was used to assist in breaking the rock for excavation. A general view of the excavation operation is shown in Plate 1 and a view of the trench cutter is shown in Plate 2.

Plate 1 – General View of COW Operation

The 830 mm thick wall was constructed in an alternating sequence of primary and secondary panels. Primary panels consisted of 3 bites for a combined total of 7m length. Secondary panels were excavated once the adjacent primary panels were complete. The secondary panels were 2.8m long and were overcut into the plastic concrete of the adjacent primary panels. During excavation, the sides of the excavated trench were supported by a bentonite slurry. Upon completion of excavation of a panel, low strength plastic concrete was poured into the trench using the tremie method. As the concrete level in the trench rises during placement, excess bentonite is drawn off and pumped to the plant station for treatment and re-use.

Plate 2 – General View of Cutter

Key successes achieved during this work included:

- Excavation through the core of the embankment while under full reservoir conditions.
- Excavation through zones of silicified greenstone with estimated unconfined compressive strengths of up to 160MPa.
- Achieving the target founding criteria into slightly weathered to fresh greywacke and greenstone.
- Meeting the requirements that verify the integrity of the constructed wall including panel verticality and panel joint construction requirements.
- Meeting acceptable strength, ductility and permeability requirements for the plastic concrete.
- Delivering the works ahead of schedule and under budget.

This paper outlines the key risks that were identified during the design development and construction processes, together with the mitigation strategies that were developed to manage these risks.

Design Development

During the early studies to develop a scope of work to address the risk of piping at the right abutment, concerns were raised by the Independent Peer Review Panel that it may not be physically possible to construct the wall and the risks associated with constructing the wall may actually be greater than leaving the abutment in its natural state. A significant amount of work was undertaken during the design phase to identify and manage these risks which included:

1. The complex geological conditions.
2. The ability to construct a cut off wall.
3. Certainty in delivering the work to an agreed budget and timeline.

These risks and the measures undertaken to address these risks are discussed further below.

Geological Conditions

Understanding the geological conditions at the right abutment was key to evaluating the foundation requirements for the Stage 3 works and extensive geotechnical investigations were undertaken. The Stage 2 investigation data and construction records were reviewed prior to scoping the Stage 3 geotechnical investigations. Key issues that drove the scope of the Stage 3 investigations at the right abutment included:

1. Surface mapping of exposures at the right abutment showed a series of inclined, irregular shaped chert bodies and zones of extremely to highly weathered greenstone that were potentially highly erodible .
2. The Stage 2 grouting programme blew out from an initial 13 week programme to a 52 week programme and closure had not been achieved in the right abutment when a decision was made to stop the grouting work.

These key issues also led to the concerns regarding the possible high volume seepage paths and potential piping issues at the right abutment.

The site investigation drilling program was subsequently revised to include the drilling of 10 deep, angled boreholes to depths of up to 75 m with borehole water pressure testing. Eight of these boreholes were “imaged” using geophysical equipment. These boreholes supplemented the existing borehole data from Stage 2 (6 boreholes were available close to the final COW alignment). Key outcomes from the site investigation included:

1. Detailed geological sections based on the 16 borehole dataset (and numerous test trenches) provided a high level of confidence in the complex geological conditions within the right abutment.
2. The extent of irregular shaped chert bodies was defined – an average borehole spacing of about 15m was achieved along the COW alignment. The investigations also confirmed that these chert bodies comprised zones of extremely high permeability.

3. The highly weathered and potentially erodible greenstone with the chert bodies extended to depth.
4. Fresh greenstone was encountered at depth and this material would provide a base to cut off the potentially erodible weathered greenstone material.

Specialist Contractor

Hinze Dam Stage 3 was delivered under an Alliance framework and a key to success in the design and construction of the wall was the engagement of a specialist contractor early within the design phase of the project. An Expression of Interest was issued to specialist foundation contractors for a plastic concrete cut-off wall solution to the right abutment works. Bauer Foundations Australia (BFA) was selected as the preferred contractor based on their specialist capabilities and extensive COW experience.

A specialist team from BFA worked with the Hinze Dam Alliance (HDA) during the design phase to develop the preliminary design of the COW. The COW layout, design requirements and foundation conditions were presented to BFA who then determined how the wall would be constructed including selecting the equipment and plant required, agreeing the estimated time for construction of the works, in particular coordinating with other activities at the site and developing a detailed cost estimate.

Following selection of the COW as the preferred solution to address piping risks at the right abutment, BFA was engaged as a sub-Alliance partner to undertake the construction of the plastic concrete cut-off wall.

Key outcomes from the early involvement of BFA in the development of the COW solution included:

1. A high level of confidence that the COW could be constructed, in particular through the very high strength chert bodies.
2. Certainty in the timeframe and cost to deliver the COW.
3. A clear understanding of the key risks associated with the COW construction and a transparent framework to manage financial impacts associated with these risks.

Construction Cost and Schedule

BFA was initially selected when there was limited definition of the scope of the COW works and was initially engaged to work with the Alliance only to develop a detailed cost estimate and construction schedule. The Alliance had selected two possible foundation treatment options at the right abutment:

- A plastic concrete cut off wall.
- Realignment of the main embankment and blanketing of the upstream area of the right abutment with compacted clay.

Evaluation of these two options was undertaken in parallel to assess the technical feasibility of each option and to maintain a competitive pricing environment. A key concern at this time was that one of the proposed solutions may not actually meet the design criteria or have an unacceptably high construction risk. The construction cost for each of the options was developed with a transparent "open book" approach considering:

1. The direct project costs associated with the works.
2. A probabilistic risk cost for each option. For the COW option this included an agreement on where the certain risks would be allocated. For example, the Alliance accepted the risks of variation in geological conditions, in particular the extent of hard chert materials and BFA accepted the risk of achieving the target production rates in each material type.
3. A risk/reward framework that was focussed on ensuring that BFA mobilised to site by an agreed date and then completed the works by an agreed date.

Key outcomes from the cost development approach include those described in the section that discusses the benefits of the early involvement of BFA as well as satisfying the project owner that the cost of the works represented value for money for the project.

Construction Planning

There were a number of significant risks associated with the construction of the COW which included:

1. Selecting appropriate equipment to construct the COW, in particular to be able to excavate through the extremely high strength chert and silicified greenstone.
2. Piping induced by the head of bentonite slurry on a defect within the dam or the foundation.
3. Loss of bentonite within a trench panel leading to collapse of the trench
4. The integrity of the wall joints including panel alignment, overlap and concrete joint integrity
5. Integrity of the wall itself with groundwater flows under high head possibly impacting concrete placement.
6. Financial risks associated with the uncertainties of the geotechnical model.

A more detailed discussion of each of the risks identified is provided as follows:

Equipment Selection

Selection of equipment that had the capability to construct the COW was a key risk to the project, in particular the ability to excavate through the extremely high strength chert and silicified greenstone. The consequences of mobilising equipment to the site that could not complete the works would have significant impacts on the project costs and delivery schedule.

BFA mobilised an equipment specialist from their head office to work with the Alliance team to select the best equipment to undertake the works. Key information that was considered in the selection of equipment included:

- The results of the site investigation work, in particular inspection of the core recovered from the boreholes.
- Review of previous BFA experience in similar strength materials.
- The design requirements for the COW.

The cutter machine was specifically developed for the Hinze Dam project. A Bauer BC40 cutting frame was used together with Bauer BC50 gearboxes to achieve the following specific properties:

- Minimising the wall width to 830mm (a BC50 frame requires a minimum width of 1.2m);
- Gain more weight for better cutting performance;
- BC 50 gearboxes maximise the power which is delivered to the cutting teeth.

Piping

The COW was constructed from a platform level of EL95.0m and bentonite slurry would be placed to this level during the construction of each panel, which is approximately 13m above the Stage 2 full supply level. This increased the hydraulic gradient and potentially the risk of piping during construction of each panel of the wall.

Key factors that were considered in assessing the piping risk during construction included the highly permeable zones that are adjacent to potentially highly erodible materials, potential defects within the foundation, in particular at the greenstone/greywacke contact and a "window" in the Stage 2 filters that was located close to this geological contact.

A piping incident would be a serious event that had the potential to impact the integrity and safety of the dam.

The risk of inducing piping during construction of the COW was managed by careful design of the bentonite slurry and the development of a bentonite management plan and backfill procedures as detailed later in this paper.

Bentonite Losses

During excavation of the panels the open trench is stabilised with a bentonite-water suspension. A rapid loss of this bentonite suspension can lead to collapse of the panel and potentially impact the integrity of the dam. The factors that can lead to a rapid loss include high permeability zones, defects within the foundation or a piping incident as described above.

The consequences of a large bentonite loss were significant and had the potential to fail the dam or cause damage that would require significant remedial works. This potential was also increased due to the wall being constructed under full reservoir conditions.

An effective management strategy to deal with the risk was implemented, including appropriate management of the bentonite, provision for emergency backfill procedures and development of a suitable panel excavation sequence.

To manage the bentonite suspension the levels within the panels were continuously supervised during the excavation. During the night and on the weekends the bentonite levels were checked by security at the site every four hours. If the loss was more than 1.2m over any period then the level would be topped up by Bauer staff. This occurred twice during construction of the wall.

An emergency plan was in place to deal with large bentonite losses included:

- If the loss was detected between 0.3m to 2m per hour then the viscosity of the bentonite would be increased.
- If the bentonite losses continued or if the loss was greater than 2m per hour then the trench would be backfilled with sand.
- Should the bentonite loss continue then the trench would be backfilled with a concrete mix.

An emergency stockpile of 30m^3 of sand was kept adjacent to the excavation works to enable an immediate backfilling of the trench if required. At no stage during the works did any sudden large bentonite losses or trench collapse occur.

During construction of the COW a maximum of three panels were allowed to be open at a single time. This was based on having sufficient bentonite quantities available to deal with bentonite losses and to reduce the risk of bentonite losses in multiple panels. The possibility of having communication between panels also meant that adjacent primary panels were not opened at the same time.

Silicified Greenstone Bodies

The silicified greenstone and chert bodies comprised very high to extremely high strength material with unconfined compressive strengths of up to 160MPa and the difficulty of excavating through this material was a key risk to the delivery of the COW solution. In addition the high strength chert bodies were surrounded by relatively low strength weathered greenstone which posed significant risks to maintaining alignment of the wall panels. The nature and extent of the silicified greenstone and chert bodies were also key risks to the cost and time to construct the COW.

BFA was able to demonstrate that equipment to similar that proposed for Hinze Dam Stage 3 had successfully excavated through rock material of similar high strength. Bauer also provided a range of teeth to the cutter that included "rock" teeth that were proposed as the primary method for excavation through the high strength rock. Bauer also had access to cutter wheels with "roller bit" devices that could excavate material with greater than 160MPa UCS. However this equipment was not mobilised to the site initially. The COW works commenced where the highest strength rock was expected to see if the "rock" teeth could excavate the material. This would allow the works to proceed in other areas if the roller bit equipment had to be mobilised to the site, if required. Fortunately the rock teeth were able to excavate the high strength material and the additional cost of mobilising the roller bit was not incurred.

The various cutting options considered by BFA are shown in Plates 3 and 4.

Plate 3 – Cutter Wheels with Rock Teeth

Plate 4 – Cutter Wheels with Roller Bits

Wall Joints

The wall was constructed in an alternating sequence of primary and secondary panels. When excavating secondary panels, a bentonite cake forms on the plastic concrete of the adjacent primary panels, it is required that this is cleaned prior to the concreting of the secondary panels to ensure a continuous plastic concrete wall is achieved.
The cleaning was conducted using the following method:

- After completion of excavation of the panel, the majority of the working bentonite within the trench is replaced with a more viscous bentonite.
- The sides of the adjacent primary panels are cleaned using the brush shown in Plate 5. This device is slightly wider than the cutter so that the brushes scrape down the side of the panel. The brush is also pulled across by the crane to the side being cleaned to ensure the brushes are bearing on the side of the panel.
- The trench cutter is then sent back down the secondary panel to clean any material from the base of the panel and to replace the bentonite with concreting bentonite. The panel is then ready to be concreted

This method proved to be very successful. A number of joints were exposed following completion of the wall, the quality of the joints meant that it was typically difficult to detect where the joint actually was.

Plate 5 – Cleaning Brush for Joints

Integrity of Wall

The cut-off wall was required to be a continuous plastic concrete wall with a design thickness of 830mm. A risk associated with constructing the wall through variable geology was possible misalignment of panels which could leave a defect in the wall allowing piping to occur. Therefore, careful control of the verticality of each panel was required to meet the required overlap between adjacent panels.
In order to control and guide the trench cutter or grab during the initial excavation of each panel, and to ensure the position, alignment and verticality of the cut-off wall, guide walls were constructed. The guide wall was constructed as a continuous cast-in-situ reinforced concrete element that was to be removed following completion of the cut-off wall.
During cutter excavation, the verticality is controlled by an inbuilt electronic inclinometer (B-Tronic) which measures the cutter's vertical deviation in two directions. The deviations are continuously displayed on the computer monitor mounted inside the operator's cabin and the cutter can be "steered" to compensate for any drift in verticality.
A "Koden" measuring device was used to verify the verticality of each panel after excavation was finished. This is an ultrasonic measuring device which uses a cable suspended ultrasonic probe that is lowered into the trench. The device is capable of measuring the verticality of the panel of both directions.
The combination of the guidewall, B-Tronic and Koden devices allowed careful control of the verticality. All records were thoroughly reviewed to ensure the appropriate overlap and overcut requirements were achieved. This process led to a successful alignment being achieved for all panels.

Construction

The following details some of the investigations conducted during the construction phase including issues that arose and how these were resolved.

Plastic Concrete

Prior to mobilising to site, laboratory trials were conducted to determine the design plastic concrete mix. The mix had to meet the following requirements:

- Sufficient workability of the fresh concrete to be placed by the tremie method, the concrete had to displace the bentonite-water suspension and it had to be ensured the concrete was self levelling and self compacting.
- A stable mix of the fresh plastic concrete with respect to bleeding and segregation.
- Sufficient strength to ensure resistance against earth-pressure and erosion.
- Ductile to accommodate the deformations and stresses imposed by the subsequent embankment construction.

The technical requirements for the plastic concrete were as follows.

- A 28 day unconfined compressive strength between 2MPa and 4MPa.
- Ductile stress-strain properties to accommodate differential stresses and deformation without cracking (Axial strain at maximum compressive strength of greater than 0.6% and 50% of peak strength at 7% strain)
- Low permeability (< 1 * 10-9 m/s.)

In total, 13 different trial mixes were batched with variations in aggregate proportions, maximum size of aggregates, aggregate volume, water-cement ratio, bentonite dosage and binder. The final mix quantities that were adopted are listed in Table1, these were based on the required performance criteria, site conditions and materials available.

Table 1 – Mix Design Quantities

Material	Quantity (per m^3)	Unit
5 to 10mm aggregate	437.4	kg
0 to 5mm aggregate	1013.0	kg
GP Cement	154.5	kg
Bentonite Suspension	0.239	m^3
Water	0.172	m^3

Field trials were also conducted prior to construction of the COW to confirm the following:

- The most efficient batching procedure for the design mix
- The selected laboratory trial mix could be produced under site conditions
- The field mixes show similar behaviour and properties to the small scale lab mixes
- The fresh properties of the plastic concrete are suitable for the pouring of the panel using the "tremie" system.
- Uniformity of the mix throughout each agitator truck with negligible balling.

A concrete mix was produced with sufficient workability so that it could be placed over a maximum 10 hour pour.

The main issue that was observed during the field trials was ensuring a homogeneous product. A number of the trials produced inconsistent concrete from one end of the truck to the other, with the last cubic metre in the truck often being poorly mixed. The batching procedure was modified and trialled a number of times to ensure that an appropriate procedure and mixing time was adopted to produce a homogeneous mix.

The concrete was discharged directly from the truck mixer into the hopper of the tremie pipe string as shown in Plate 6. It was required that the base of the tremie be kept continuously immersed in the fresh concrete for a minimum embedment depth of 3 metres. As the concrete level in the panel rose, sections of the tremie pipe were periodically removed whilst always maintaining a 3 metre embedment into fresh concrete.

For the primary panels either 2 or 3 tremie pipes were used depending upon the height differential of the base of each of the 3 bites. Where there was a differential greater than 1m between each of the bites a 3 tremie arrangement was used, but this was only required on 1 occasion. Otherwise two tremies were used for the primary panels. For secondary panels only a single tremie pipe was required.

Where two or three tremies pipes were used, each pipe was charged independently, but concurrently, by separate concrete trucks. The level of the concrete at each tremie location was checked following each truck in order to ensure that the level of the rising concrete surface in the panel was as close to horizontal as possible to avoid inclusions in the panel.

The concrete was over-cast at ground level to ensure that all contaminated concrete (in contact with the bentonite) had been removed.

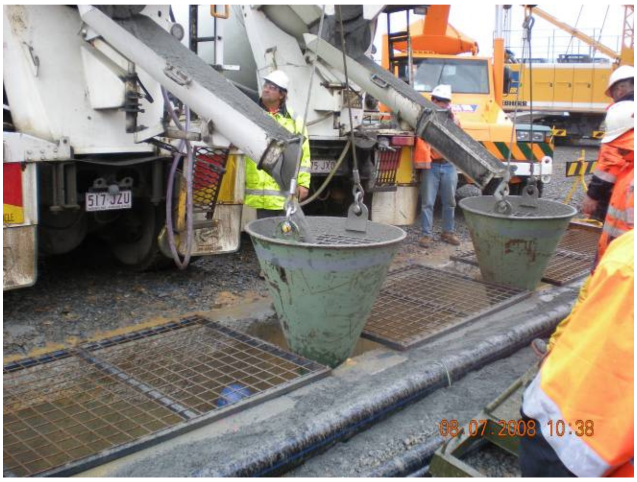

Plate 6 – Concreting of Primary Panels

The main issue that arose with the concrete during construction of the wall was that at one stage the batch plant operator noticed that less cement was being used than predicted. This was picked up by the quantities that were being loaded into the cement silo. The batch plant calibration was checked and it was found to be incorrectly measuring the weight of the cement for a number of panels, some with up to 20% less cement than required, some with up to 20% more cement. The electrical system was replaced and production continued. The testing of the cylinders from these panels found that all of the associated panels still met the permeability and ductility requirements. One panel was found to have a slightly lower compressive strength (1.7MPa) than the specified 2MPa at 28 days. Three panels were also found to have a higher strength than the specified 4MPa with a maximum value of 4.4MPa.

The higher strength panels were accepted as the permeability and ductility requirements were met and the extra strength did not affect the integrity of the wall. For the lower strength panel further testing was conducted that included hole erosion tests of the available samples. No erosion of the samples occurred under the expected differential hydrostatic pressures that would be applied to the wall. The combination of permeability and ductility results led to the panel being accepted and re-excavation of the panel was not required.

Cohesive Plastic Concrete

During the pouring of the initial primary panels, it was observed that the concrete at the top of the panel appeared cohesive, see Plate 7, and was extruded up between the guidewalls. At times this meant the concrete could not be pushed out of the top of the panel or pushed out over the full width of the panel. Investigations and testing into the reasons for the cohesive concrete included the following:

- Tests on the concrete for water loss, thixotropic effect and setting of concrete.
- Introduction of red dye (iron oxide) into the initial 10 trucks of two of the panel concrete pours to determine if it was the initial concrete in the pour coming to the surface.
- Laboratory trials incorporating a retarder into the mix.

Plate 7 – Panel 25 Concrete Pour

It was determined that it was the concrete from the initial trucks that gets pushed to the surface of the panel. This effect can be seen in Plate 8 where the red dyed concrete from the initial trucks is clearly apparent above the later non dyed concrete.

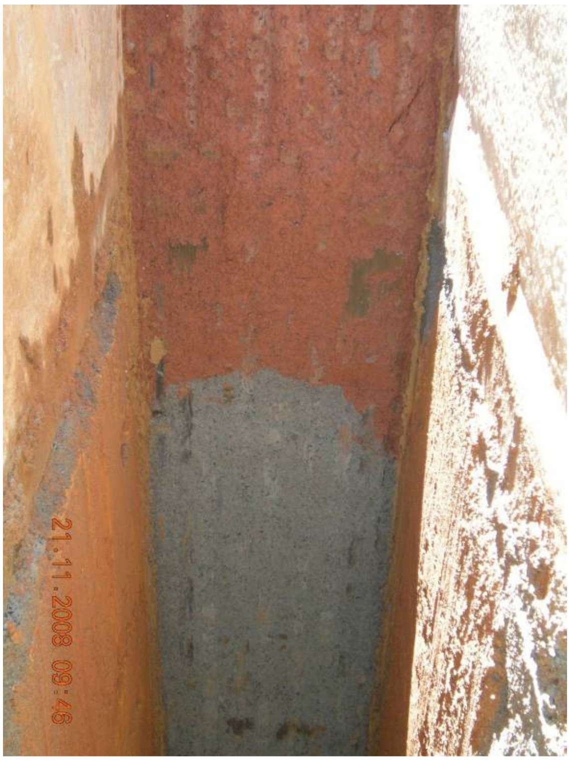

Plate 8 – Dye testing of concrete

From further investigations it was determined that over the time it takes to pour an entire primary panel, typically 6 to 8 hours, the concrete was going through its initial set and therefore appeared to be cohesive/stiff at the surface of the panel. The testing of the cohesive concrete and observations made gave no suggestions that there were any adverse effects to the concrete. The main concern was that the concrete extends to the full width and length of the panel to fill in any voids, particularly for the secondary panels.

To prevent the early setting of the concrete during pouring on future primary panels and for all secondary panels, a retarder was included into the mix. The amount of retarder was 2.5% by weight of cement and was included for the first 8 trucks for a primary panel and first 4 trucks for a secondary panel. For the majority of the panels poured after the retarder was introduced the concrete came up reasonably fresh. However there were still occasions, particularly in the primary panels, where there was some initial set to the concrete. It was decided not to increase the amount of retarder in the mix as it was towards the upper limit of the recommended percentage by weight of cement.

To ensure that there were no joints or defects in the cohesive concrete, the top 5 to 6m of each of the secondary panels was excavated by the grab without the use of bentonite. This meant that the sides of each of the primary panels could be visually inspected. A couple of minor joint defects were found in the top portion of two of the panels. However as the top 1.5m of the wall was to be removed prior to construction of the overlying embankment, the defects would be removed.

Once construction of the COW was completed, the guidewalls were removed and the top 1.5m of the plastic concrete was excavated. This allowed a detailed inspection of the joints within the wall. It was typically difficult to detect the position of the joint which indicated that the cleaning process was effective in removing any excess bentonite. The quality of the joints can be seen in Plate 9 which shows the joint between a panel with dyed concrete and a panel without.

Plate 9 – View of joint between primary and secondary panels

Founding Depths

A critical aspect of the construction of the COW was ensuring that the base of the wall was sufficiently socketed into slightly weathered to fresh greenstone or greywacke to ensure no seepage paths could develop beneath the wall. The arrangement of the desanding plant was such that samples could be taken by placing an excavator bucket beneath the discharge point for the larger cuttings. This gave large high quality samples for assessment as shown in Plate 10. Once the samples were observed by the HDA geologist to have none or minimal traces of weathering in the rock then the excavation would continue for an additional 0.5m to ensure the panel was socketed into rock.

Plate 10 – Typical sample in slightly weathered to fresh greenstone

Communication between Primary Panels

On two occasions, plastic concrete was observed within the desander cuttings when excavating a primary panel. The distance between adjacent panels is typically approximately 2m. The communications occurred at depths between 30 and 35m within the foundation. The finding of this plastic concrete in cutting samples indicates that plastic concrete was moving through voids or infilled defects in the foundation at least up to 2m in length. In one of the panels the plastic concrete detected had 10mm aggregate in it which suggests that the voids/defects in the foundation were relatively large.

Base of COW at Saddle Dam End

The key design conclusions for the saddle dam end of the wall were as follows:

- The depth of potentially erodible materials was shallow (approx 12m deep) compared with the rest of the COW.
- The moderately weathered greenstone below the erodible material in this area was assessed to generally have a low permeability and could be grouted with a single line grout curtain prior to construction of the COW.

Therefore, the design was for a shallow wall terminating in the non-erodible MW greenstone. The MW greenstone was to be grouted to fresh greenstone prior to construction of the COW. During the grouting of this area, very high grout takes were identified.

Based on the additional information obtained from the grouting programme it was evident that the foundation conditions in the high grout take areas were different from those assumed during the original design, in particular the permeability, and that a review of the extent of the COW was warranted.

The options available were to move to a triple line grout curtain or to deepen the COW in this area to cutoff the high permeability zones. The key concerns with the triple line grout curtain option were as follows:

- This would have had an impact on grouting resources, which may have delayed grouting works being undertaken on the saddle dam.
- Although a triple line grout curtain was successfully implemented in areas beyond the COW, there was no guarantee that closure would be achieved.
- The grouting would have impacted the program for the construction of the COW.

Given the above, and the certainty of outcome achieved with the deepening of the COW, it was decided to deepen the COW in this area, with a 0.5m socket into slightly weathered to fresh greenstone.

Conclusion

The potential for internal erosion and piping of the right abutment of Hinze Dam was a critical issue in the development of the Hinze Dam Stage 3 project. The Hinze Dam Alliance in conjunction with Bauer Foundations Australia developed an innovative cutoff wall design that provided a positive cut-off of the seepage that could not be achieved during Stage 2. The COW was successfully constructed and met all the key criteria with a major key to the success being the planning and risk reduction measures that were undertaken during both the design and construction phases.

References

Chamberlain, C., Macfarlane, D. and Eades, G. 2008. Hinze Dam Stage 3 – Development of the geological model and the implications for design. ANCOLD Conference Proceedings.

Hunter, G. Chamberlin, C. Foster, M. 2009. Innovative solution to foundation piping on the right abutment. ANCOLD Conference Proceedings.