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WEST CUT TAILINGS DAM

G J HUNTER

D J DOUGLAS & PARTNERS PTY LTD, NEWCASTLE

ABSTRACT

This paper presents a chronicle of the West Cut Tailings Dam project specific to the main embankment for which the author had a major involvement as a geotechnical consultant. The project comprised initial investigation and stability assessment of the existing tailings dam embankment followed by design for remediation to increase the stability of the existing embankment against slope failure; design for augmentation to allow for additional tailings storage; supervision of construction; and further consultation at the onset of leakage problems consequent to the reintroduction of tailings.

INTRODUCTION

D J Douglas & Partners were commissioned to carry out geotechnical investigation of two tailings storage facilities to examine the existing stability of embankments and determine the feasibility of raising the current facilities for additional tailings storage. The West Cut Tailings Dam was one of the tailings storage facilities investigated.

The main embankment to the West Cut Tailings Dam is the topic of this paper.

BACKGROUND

The West Cut Tailings Dam is a coal tailings disposal dam located within a disused open cut area of an operating colliery in the Hunter Valley near Singleton. The open cut area is approximately 800 metres in length, 100 to 200 metres in width and up to 20 metres in depth.

The high wall of the open pit terminated on the eastern edge of a very broad, relatively flat-lying alluvial plain. Exposed on the high wall were about 3 to 5 metres of alluvial clayey sediments overlying interbedded siltstone and sandstone rock types of the Wittingham Coal Measures Formation (Permian age). The waste rock stockpiles extended to higher elevations further to the north and east of the disused open pit.

The main embankment to the tailings dam divided the disused open cut into a tailings disposal area to the north and water supply reservoir to the south as shown in Figure 1 below. At the time of initial consultation the embankment was about 150 metres in crest length and 12 metres in height at its deepest point, underlain by a further 8 metres of dumped waste to the open pit floor. The western abutment comprised the former high wall to the open pit and the eastern abutment stockpiled overburden/ interburden granular waste rock.

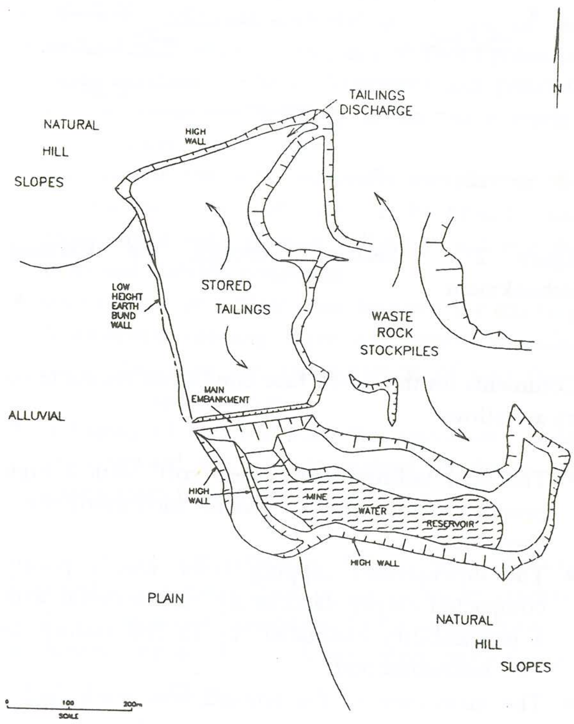

Figure 1: Site Layout

The embankment was understood to have been initially constructed by dumping granular waste rock through several metres of water and soft sediments. During earlier construction the embankment was reported to have continually slumped and following initial construction known to have leaked badly. It was not sure if the leakage comprised tailings slurry or clear run-off water.

A second stage of construction consisted of the placement of a 'clay' facing on the downstream shoulder to control the leakage. At this time a 2 metre thick capping was placed on the crest.

Construction of the embankment to this point had been carried out without the involvement of geotechnical consultation.

INVESTIGATION AND STABILITY ANALYSIS

The geotechnical investigation for the main embankment comprised the drilling of several bores within the embankment and some probing downstream of the embankment. Figure 2 is a section through the deepest point of the main embankment showing the measured geometry and interpolated subsurface conditions.

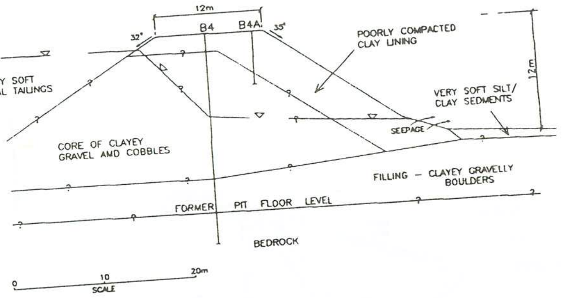

Figure 2: Section Through the Existing Embankment

Comments on the subsurface conditions encountered are as follows:

- The coal tailings were 'very soft' with a high proportion of highly plastic montmorillonitic clay fines.
- The downstream capping layer was a poorly compacted clayey sand/sandy clay material with a permeability estimated, by in situ testing, at 10^{-6} metres/second.
- The main core of the embankment comprised a poorly compacted granular material in a matrix of sand, silt and clay. The permeability of this stratum was considered to be relatively high as a result of water losses observed during drilling.
- Cobbles and boulders were encountered below 16 metres depth to the old pit floor level (20 metres).
- A layer of 'very soft' silt/clay sediments, 0.5 to 2 metres in thickness, underlain by boulders at the downstream toe within the deepest section of the embankment.

The phreatic water surface shown in Figure 2 was based on the following observations:

- Ponding of free water in large shallow ponds up against the main embankment on the surface of the flat lying tailings;
- Seepage of clear water at the toe of the embankment (at its deepest point) from several points estimated at a combined flow rate of 3 to 5 litres/minute;
- Standing groundwater levels measured in a standpipe installed in the deep bore through the embankment.

An open drain extended along the full length of the crest to the main embankment. This drain had a low point near to the deepest section of the embankment which was possibly settlement related. Severe erosion of the poorly compacted downstream lining near to the low point of the open drain was attributed to overflow of the drain in this region.

A stability analysis was carried out for the main embankment using the computer program XSLOPE; a two dimensional interactive slope stability program. The results of the analysis indicated that the existing embankment was marginally stable with the most likely failure mode being a slip failure in the downstream capping layer. An elevated phreatic surface in the embankment would most likely result in a slope failure.

It was recommended that the embankment be remediated as a result of its marginal stability and poor design.

TAILINGS DISPOSAL SYSTEM

Tailings from the washery plant was discharged via pipeline into the north-eastern point of the West Cut Tailings Dam as shown on Figure 1. The tailings had formed a very flat lying beach with only a relatively shallow change in height over the length of deposition. No segregation of size fractions was visually apparent between the discharge point and main embankment.

The tailings decant water was understood to have dissipated via cavities in the waste rock stockpiles and had therefore never ponded to any significant depth on top of the tailings. Presumably the decant water ended up in the mine water reservoir at the southern end of the open pit. As a result, the existing tailings dam had been constructed without a spillway.

The tailings itself was fine grained with a high proportion of silt and clay fines. The clay fraction comprised a montmorillonite mineralogy and was therefore highly plastic.

No significant crust had formed over the tailings at the time of the investigation and access onto the tailing surface by foot was not possible. Any rainwater would form in large shallow pools on the surface of the tailings in the southern region of the tailings dam. The dished surface of the tailings, formed as a result of greater consolidation settlement in the body of the tailings dam, would inhibit drainage of this shallow ponded water through the waste rock stockpiles. While water was ponded on the tailings no crust could form and therefore no increase in surface strength be attained.

As a result of its highly plastic clay content, the tailings would also have had a low solids content, high void ratio and relatively low permeability. Against the perimeter walls of the impoundment area, the tailings would also have developed, through consolidation, a denser layer with a lower. Thus, once covered in tailings the seepage potential through the retaining medium would be greatly diminished.

DESIGN FOR REMEDIATION

The purpose of the remediation of the existing embankment was aimed at the following:

- increasing the factor of safety against slope failure to an acceptable level (1.5 for long-term stability);
- addressing some of the inherently poor design features of the existing embankment;
- potential augmentation of the embankment for future additional tailings storage. A nominal crest level of 5 metres above the existing crest level was suggested for augmentation.

In assessing the available alternatives for remediation and potential future augmentation of the embankment the following aspects were considered:

- the type of tailings and their engineering characteristics;
- the existing site conditions;
- the available materials for embankment construction;
- control of the phreatic surface within the embankment;
- handling of the decant water;
- acceptance of the design by the regulatory authority, the Department of Mines.

It was considered that the very soft nature of the tailings and existing downstream stability problems precluded the use of the upstream construction method for raising the embankment. Therefore, the design for remediation and future augmentation suggested was by downstream construction. Figure 3 shows the proposed remediation design for the embankment.

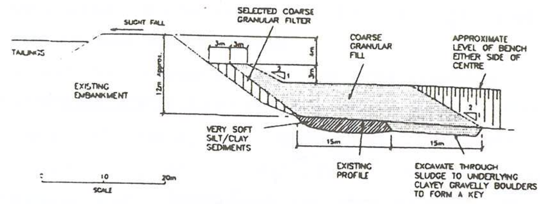

Figure 3: Proposed Remediation Design

Comments on the key aspects of the design are as follows:

- construction of a downstream berm consisting of granular waste rock filling won from the nearby stockpiles. The higher permeability of the granular filling in relation to the existing downstream clay capping layer would allow for control of the phreatic surface.
- the soft sediments directly at the toe of the embankment were left in place to avoid potential destabilisation of the embankment and possible risk to personnel working in this area during construction.
- removal of the soft sediments away from the downstream toe of the embankment and replacement with granular filling to achieve the proposed stability constraint.
- construction of a filter zone between the existing downstream capping layer and coarse granular fill to minimise the transportation of clay fines from the capping layer.
- reshaping of the crest such that rainwater would drain toward the tailings instead of down the downstream face of the embankment.

Placement of the granular filling was initially proposed in 0.5 metre thick layers rolled by tracked plant or compaction equipment to the satisfaction of the supervising engineer. A maximum particle size was set at 0.3 metres.

CONSTRUCTION OF THE EMBANKMENT REMEDIATION

Initially a starter wall (refer Figure 4) was constructed across the soft sediments by advancing out from the eastern abutment. The soft sediments were removed by excavator and then replaced immediately with granular filling. A filling layer of approximately 1 metre thickness was then placed over the soft sediments between the starter wall and the main embankment. This lift initially weaved substantially under the bulldozer (D8K Cat).

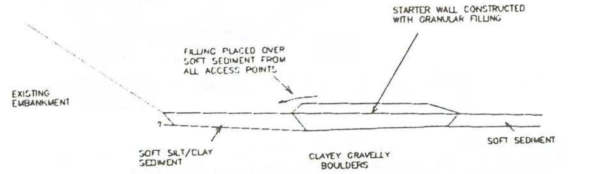

Figure 4: Construction of Starter Wall

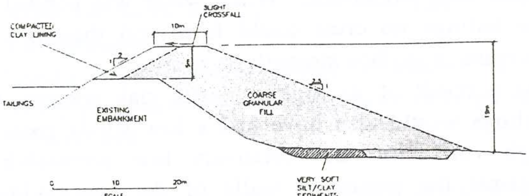

Figure 5: Augmented Embankment Design

Following observation of the weaving of the first lift over the soft sediments it was decided to stop work in this area to allow for some dissipation of pore pressures in the underlying soft sediments. After three days wet spots had appeared on the surface of the filling which were considered to be dissipated pore water from the soft sediments. The weaving under the bulldozer was overall substantially less after the time delay, with significant weaving confined to several localised areas.

It was noted that the coarse mine spoil being used as filling was easily broken down under the action of the dozer and later the padfoot roller, generating plastic fines. As a result, the stability of the embankment was reassessed and the batter slope flattened to 2.5H to 1V from the previous design of 2H to 1V. It was also decided that the filter zone was not necessary given the breakdown of the granular material.

Particularly soft and wet conditions were noted at the old embankment toe, which persisted for several metres above this level in the downstream capping layer.

AUGMENTATION

The design for augmentation of the embankment was carried out at the same time as the design for remediation taking into account the aforementioned aspects of the site conditions and design considerations. Changes to the earlier design were the flattening of the downstream batter slope and omission of the filter zone. The augmented embankment design proposed is shown on Figure 5 and comprised the following:

- raising of the crest level a height of 5 metres;
- a 5 metre wide compacted clay lining on the upstream shoulder constructed at a batter slope of 2H to 1V;
- a 10 metre wide crest as required by the client;
- bulk granular waste rock filling in the main body of the embankment.

A suitable clay source for the liner was won from an overburden stockpile some 500 metres from the embankment. The clay was of high plasticity and non dispersive when tested in the tailings decant water. It was also well dry of OMC (where OMC = optimum moisture content).

The specification for the clay lining required compaction in 200 to 250 mm thickness lifts to a minimum dry density ratio of 97% relative to standard compaction with the moisture content maintained within the range OMC -1% to OMC +3%.

In constructing the augmented embankment, the contractor initially had difficulty meeting the compaction and moisture specification for the clay lining. Eventually a sprinkler watering system was set up in the borrow area, which was then worked such that conditioned clay had at least 24 hours to cure.

On completion, the main embankment was about 200 metres in crest length with a height of 19 metres from crest level to toe level.

SPILLWAY CONSIDERATIONS

It was originally proposed that a spillway be incorporated into the embankment design. However, as previously discussed, throughout the history of tailings deposition the decant water had always dissipated through highly permeable zones in the waste rock abutment (eastern abutment). Therefore a decision on spillway construction was deferred pending observation of overall performance.

The eastern abutment of the embankment was constructed slightly lower than the remainder of the embankment to at least control the direction of overflow in the unlikely event of overtopping. In this area, the embankment height was only about 5 metres and any spillage would be over the coarse waste rock stockpiles with predicted minimal scour potential.

POST CONSTRUCTION

Several months following the reintroduction of tailings into the West Cut Tailings Dam it was observed that tailings was seeping out from the downstream toe of the embankment. On initial observation of the leakage, the mine personnel diverted the tailings to an alternate tailings dam.

It was understood that over this period of deposition the decant water continued to seep through permeable zones in the waste rock stockpiles and only shallow ponds of water were observed on the surface of the tailings.

On inspection of the reported tailings leakage the following observations were noted:

- Upstream of the embankment, tailings was flowing at a high rate into the waste rock at two locations near to the eastern abutment. Excavation in this area exposed a zone of large sandstone boulders with cavities (about 0.2 to 0.5 metres in size) through which the tailings flowed.
- Downstream of the embankment, tailings was observed to be seeping out of the waste rock at several locations over a length of approximately 60 metres along the toe of the embankment. The rate of flow was generally very low at most seepage points with a much higher rate observed at three specific locations.
- The seepage zones appeared to be located slightly downslope of the toe of the newly constructed embankment.
- A large wetted area encompassed the outflow seepage area, covering the downstream slope of the waste rock stockpiles and lower embankment slopes of the downstream shoulder.

It was decided to attempt to cap the highly permeable sandstone zone, where access was possible, using compacted siltstone-based waste rock from the waste rock stockpiles. The area proposed to be capped was a relatively flat bench about 50 by 50 metres in dimensions which was covered by up to about 0.5 m of tailings. Away from the bench the waste rock profile (from recollection prior to filling) sloped steeply down into deep deposits of tailings.

A bulldozer was used to initially push out a layer of waste rock over the bench area to raise it above the level of the tailing. This area was then compacted using a padfoot roller and another lift of waste rock placed. The exposed wall of the stockpiles above the bench was then capped with waste rock placed in thin compacted horizontal layers.

After two days the seepage at the downstream toe had slowed markedly. Seepage was only observed at two locations, one of which flowed clear water and the other with only a trace of tailings. It was considered probable that the tailings leakage problem had been resolved.

It was recommended that the area continue to be monitored for leakage of both water and/or tailings. Continued leakage of water was considered to potentially pose a stability problem for the embankment, depending on the location of the seepage points.

The tailings leakage was considered to have been sourced through highly permeable zones in the waste rock stockpiles underlying and surrounding the eastern abutment of the embankment, sourced through cavities on the upstream side of the embankment located at or slightly below the tailings surface level. Resolution of the leakage problem was therefore aimed at blocking off these major cavities, where access was possible. The use of a compacted granular capping layer would probable still have allowed some seepage, however, eventually a relatively impermeable layer of consolidated tailings would have formed over this capping layer.

Several months later some tailings seepage was observed at similar locations at the downstream toe. The rate of seepage was minimal in comparison with the earlier observed seepage.

The West Cut Tailing Dam is now full to capacity. Throughout its life the decant water continued to seep through the waste rock stockpiles with no further observation of tailings seepage at the downstream toe. The colliery now uses another storage facility for containment of its tailings.

Occasionally tailings is discharged into the West Cut Tailings Dam for short periods of time when required by the colliery. The ongoing consolidation of the tailings allows for additional storage.