PUMPED CO-DISPOSAL OF BLACK COAL WASHERY WASTES IN AUSTRALIA[1]

by

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Abstract. The washing of black coal results in the production of coarse reject and tailings wastes, which historically have been disposed of separately. Loose-dumped coarse reject is highly porous, with largely air-filled voids. Tailings, disposed of as an aqueous slurry, have a high porosity with water-filled voids. By co-disposing coarse reject and tailings, the voids between the coarse reject particles can be filled with tailings. The mixture settles, drains, and gains strength and stiffness rapidly. It occupies less volume than the two waste products disposed of separately, potentially increasing the water return, and also facilitating rehabilitation. This paper briefly describes various co-disposal methods, detailing the behaviour, advantages, disadvantages, and cost implications of the co-disposal of coarse reject and tailings by combined pumping.

Additional Key Words: beaching, coarse reject, costs, tailings.

Introduction

Prior to mining and mineral processing, ore bodies comprise a heterogeneous mixture of different sized particles of different mineralogies. The mining and processing of the ore involves the separation of materials according to their particle size and mineralogy, and results in coarse and fine grained waste materials, which historically have been disposed of separately.

The washing of black coal to meet market specifications results in granular coarse reject (up to 100 mm [4 in] in size) and fine grained tailings (typically silt-sized). The coarse reject is conventionally loose-dumped, while the tailings are conventionally pumped as an aqueous slurry to a storage impoundment. The coarse reject disposed of alone has a high porosity (about 45 %), with largely air-filled voids. The tailings disposed of alone have an even higher porosity (about 55 % after they have settled), with water-filled voids. When coarse reject and tailings are co-disposed, the coarse reject tends to settle in loose contact, with tailings filling the voids between the coarse particles. Co-disposed washery wastes settle, drain, and gain strength and stiffness rapidly. They occupy less volume than the two waste products disposed of separately, potentially increase the water return, and can progressively and more readily be rehabilitated to a high level of future land use.

There are several methods of co-disposing of black coal washery wastes. This paper discusses these briefly, before concentrating on the method most often adopted in Australia, which involves the combined pumping of coarse

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reject and tailings. Beyond the coal mining industry, the co-disposal of overburden waste rock and tailings is being considered at a number of gold mines in Australia.

Methods of Co-Disposal of Coal Mine Washery Wastes

The co-disposal of coal mine washery wastes can be achieved by the following methods.

1. Co-disposal of dewatered tailings filter cake, produced by a belt press filter, and coarse reject is employed at many mines worldwide, including Mount Thorley in the Hunter Valley Coalfields of New South Wales, Australia. The dewatering of the tailings avoids the necessity to recover water after disposal, and facilitates the handling and rehabilitation of the combined wastes. However, the capital and operating costs are high (McKee 1992; in Williams 1992). The main operating costs are attributable to a high flocculant dose (up to 0.5 % by mass of dry tailings; up to 10 times that required for conventional thickening) and labor to maintain the operation of the belt press filters.
2. Combined pumping of a coarse reject/tailings mixture is employed at many coal mines worldwide (several in the USA, three in Queensland, one in New South Wales, and two in Indonesia), and is proposed at numerous existing and future mines. This method is described in detail later in the paper.
3. Pushing coarse reject into uncrusted, wet tailings has been successfully trialed at Ulan Coal Mines in New South Wales, Australia (Williams 1992). There is an optimum time after tailings disposal at which the coarse reject should be added to achieve good mixing. In the field, this optimum time is between one and two days. If the coarse reject is added immediately after tailings disposal, the coarse reject particles will reach the base of the storage before the tailings, and form a segregated layer. If the delay before the addition of coarse reject is too long, the tailings will have settled to the base of the storage, forming a segregated layer. If the tailings are allowed to settle and their surface allowed to desiccate and crust, the coarse reject will be supported by the tailings crust until sufficient coarse reject builds up to punch through it, resulting in bow-wave failure. Operationally, coarse reject must be added continuously, trailing behind the tailings discharge pipe as it is moved around the perimeter of the storage. A stable, trafficable deposit is formed as coarse reject emerges above the tailings surface. Operationally, this method requires a high management/labor input, to move the tailings discharge pipe and to ensure good mixing of the coarse reject. A stable/trafficable surface is possible only if there is sufficient coarse reject for it to rise above the tailings surface (a coarse reject to tailings ratio in excess of about 3 to 1 by dry mass).
4. Pouring tailings slurry over thin (about 0.3 m [1 ft] thick) layers of uncompacted coarse reject has been successfully trialed in South Africa (van Rooyen 1992). This method is effective in sealing coarse reject against possible spontaneous combustion, which is a feature of conventionally loose-dumped South African coarse reject. However, it requires a high management/labor input to place the coarse reject in thin layers and to move the tailings distribution pipes and is suited to only a narrow range of coarse reject to tailings ratios. It is unsuitable for coarse reject to tailings mass ratios of less than about 3 to 1.
5. The co-disposal of thickened tailings (using high-compression or paste thickening) and coarse reject

has been proposed. High-compression thickeners can achieve up to 65 % solids by mass and paste thickening can achieve 65 to 70 % solids, approaching that achieved by belt press filters. This should remove the need to recover water after disposal. The mixing of the thickened tailings and coarse reject could be facilitated by gravity, conveyor, pumping, or truck delivery of the thickened tailings. This method is yet to be trialed, but is being considered by a number of coal and gold mines. In the latter case, overburden waste rock would be co-disposed with thickened tailings.

Co-Disposal by Combined Pumping

Co-disposal by the combined pumping of a mixture of coarse reject and tailings is technically feasible from a pumping point of view, but operational refinements are required.

Pumping Characteristics

The conveyored coarse reject, conventionally thickened tailings (at about 30 % solids by mass), and make-up water are combined in a simple hopper. The wastes are then pumped by a high pressure (up to 3,000 kPa [435 psi]), large bore (approaching the internal diameter of the pipeline), centrifugal gravel pump at about 30 % solids, and at high velocity (2.5 to 4 m/s [8 to 13 ft/s]), to reduce the potential for the pipeline blocking. Pipeline blockages are usually readily cleared by increasing the line pressure. As a result of the relatively low solids concentration, a huge volume of water is required for pumped co-disposal, necessitating efficient water recovery. Particle sizes of up to 100 mm [4 in] (usually limited to about 50 mm [2 in]) can be pumped in a 200 mm [8 in] diameter pipeline, although the pipeline internal diameter should ideally be 4 or 5 times the maximum particle size. Pumping distances in Australia currently vary between 0.3 km [0.2 miles] and 2.5 km [1.6 miles]. Pumping distances greater than about 5 km [3 miles] may well make combined pumping uneconomic on the basis of pipeline capital and operating costs. Pumping heads currently range up to about 10 m [33 ft]. To maintain stable pumping conditions, some fines are required. Coarse reject to tailings mass ratios of between 1:1 and 6:1 have been successfully pumped. Pump and pipeline wear is high.

Beaching Behaviour

Co-disposed wastes beach at a slope of up to 1 (vertical) in 10 (horizontal), compared with a tailings only beach slope of about 1 in 100, and co-disposed wastes can be pushed up to slope angles approaching the angle of repose of the coarse reject material. On co-disposal, hydraulic sorting of the particles occurs, according to their particle size and specific gravity. These two effects may counteract, with the result that there may be little change in particle size down the co-disposal beach, with high specific gravity particles settling close to the discharge point and low specific gravity (coal-rich) particles settling at the far end of the co-disposal beach (Williams 1992).

Some wash out of fines (up to two-thirds of the tailings, the proportion increasing with decreasing particle size) is inevitable on pumped co-disposal. This results, in part, from the relatively low solids concentration and high velocity at which the washery wastes are pumped to limit the potential for pipeline blockages. Fines wash out increases with the inevitable gap-grading between the coarse reject and tailings, and with increasing plateness of the coarse particles. Crushing of the coarse reject, which would reduce the gap-grading and plateness of the particles, may be of benefit, provided that it does not substantially increase the proportion of fines in the mixture. For coarse reject to tailings ratios of less than 3:1, a mixture with a ratio of about 3:1 will form on the co-disposal beach, with the residual fines washing out to form a tailings-like beach. To minimise the impact of fines wash out, co-disposal directed upslope is preferable to downslope co-disposal. Upslope co-disposal retards the flow of fines, allows them to be covered by later co-disposal, and avoids the construction of a major downstream containment. Water return of 75 to 90 % is possible, the percentage decreasing with increasing initial solids concentration.

The co-disposal mixture has a permeability (typically about 0.0001 m/s [0.0003 ft/s]; Williams and Kuganathan 1993) mid-way between that of coarse reject only and tailings only, at about 1,000 times that of the silt-sized tailings alone. Drainage paths exist around the coarse reject particles in loose contact, against which the angular tailings particles form a loose packing. The flow on the co-disposal beach is about 100 mm [4 in] deep, making the surface almost immediately trafficable. The co-disposed mixture rapidly achieves a dry density of up to 1.5 tonne/cubic m [94 lb/cubic ft], at a gravimetric moisture content as low as 15 % and a porosity as low as 30 %. The overall physical characteristics of coarse reject disposed alone, tailings disposed alone, and co-disposed wastes are compared in Table 1.

Table 1: Overall dry density, moisture content and porosity of coarse reject only, tailings only, and co-disposed wastes.

MATERIAL	DRY DENSITY (t/m^3) [pcf]	MOISTURE CONTENT (%)	POROSITY (%)
Coarse reject only	1.2 [75]	5-10	45
Tailings only	0.8 [50]	70	55
Co-disposed	1.5 [94]	35-40	35-40

Relative Ease of Pumped Co-Disposal

The relative ease of pumped co-disposal depends on the following parameters.

1. Coarse reject to tailings mass ratio: Generally, the higher the ratio the better, since it reduces the total fines wash-out and results in a steeper co-disposal beach.
2. Particle size distribution of mixture: There is, inevitably, little overlap between the coarse reject and tailings sizes. The more pronounced the gap, the less efficient is the trapping of fines.
3. Coarse reject particle shape: Rounded particles are more readily transported and pack and trap fines better than platey particles, but give a flatter beach slope.
4. % solids: Provided pipeline blockages are avoided, the higher the solids concentration the better. This results in a steeper beach slope and a reduced volume of water in circulation.
5. Flow velocity: Provided pipeline blockages are avoided, the lower the flow velocity the better. This results in a reduced wash out of fines.
6. Geometry of deposition: A steep initial beach slope results from burial of the discharge, until a blow-out occurs.
7. Level of decant pond: This affects water clarity and discharge into water will slow the segregated fines.
8. Direction of discharge: Upslope pumped co-disposal is far preferable to downslope, preventing the segregated fines from running and allowing them to be progressively covered. However, it requires more management/labor input.

Potential Problems with Pumped Co-Disposal

The potential problems with pumped co-disposal include the following.

1. Excessive pump wear: This can be largely overcome by using a larger pump bore, several times the size of the largest particle and similar to that of the pipe.
2. Excessive pipe wear: Pipe wear will be highest where the line pressure is greatest (near the pump). High density polyethylene (HDPE) and mild steel pipes wear excessively, but may be appropriate for short pumping distances (< 0.5 km [0.3 miles]). Ceramic- and polyurethane-lined pipes perform well, at a higher capital cost, while the more brittle basalt-lined pipes perform less well. A 10 mm thick lining may be optimal.
3. Pipeline blockages: High pressure (3,000 kPa [435 psi]) pumps largely overcome pipeline blockages.
4. Long pumping distances: As a rule-of-thumb, an additional pump should be added (preferably along the line, although this necessitates remote power) for every km length of pipeline.
5. Variable coarse reject/tailings feed: High pressure pumps provide a robust system, capable of handling variations in the coarse reject/tailings feed.
6. Moving discharge point(s): Moving the discharge point or points is recommended to minimise rehandling of the mixture and for better control. It can be done by dragging the pipeline or, preferably, by using a number of discharges in rotation and adding lengths of pipe as required. The optimum number of discharges is dependent on the storage geometry.
7. Water recovery and recirculation: Efficient water recovery for recirculation is vital, requiring substantial management/labour input. The clarity of the return water is relatively unimportant.

Co-Disposal Storages

New mines will likely co-dispose above-ground, either upslope or into paddocks, while existing mines may have dis-used ramps or pits available. Upslope co-disposal above-ground offers the potential to store up to five times the volume of washery wastes stored by downslope co-disposal, for the same height of downstream containment. Co-disposal offers a more efficient use of available in-pit storage volume than the separate disposal of coarse reject and tailings. Co-disposal into ramps should preferably be upslope, to maximise the available storage volume, reduce the impact of fines segregation, and increase the stability of the embankment separating the ramp from the pit.

Water Recovery from Pumped Co-Disposal

Co-disposal by combined pumping requires the recovery and circulation of large volumes of water. It is therefore vital that water recovery be efficient. Water clarity is less important, since the water will be recirculated with the co-disposed wastes. Various methods have been or can be used to recover and recirculate water from the co-disposed wastes. For in-pit and downslope co-disposal, pumping from a conventional decant pond is appropriate. For upslope co-disposal, underdrainage is required in addition to pumping from an upslope decant pond.

Costs of Pumped Co-Disposal

The costs of pumped co-disposal are offset by the elimination of tailings dams and coarse reject dumps. Jeebropilly Colliery, in the Ipswich Coalfields of south eastern Queensland, Australia, operates pumped co-disposal for about 15 % of the cost of the previous separate disposal of tailings to a dis-used pit and coarse reject to a dump. However, Jeebropilly has dis-used pits available for co-disposal, and experienced difficulties with the dumping of their highly degradable, clay-rich coarse reject. As a guide, pumped co-disposal should cost of the order of half the cost of conventional separate disposal, depending on a range

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Cost items associated with conventional coarse reject dumps include the following.

- Coarse reject hopper.
- Truck capital, operating, maintenance, and replacement costs.
- Land cost.
- Construction and maintenance of haul roads.
- Collection of seepage from the dump, and treatment if necessary.
- Rehabilitation costs. To reshape and cover a coarse reject dump costs up to $A 75,000/ha [$US 22,500/acre], but the costs can be greatly reduced by progressive reshaping and rehabilitation.

Cost items associated with conventional tailings dams include the following.

- Thickener capital, operating, and maintenance costs.
- Tailings dam construction and raising.
- Land cost.
- Capital, operating, and maintenance costs of pumps and pipeline(s).
- Water recovery and return.
- Rehabilitation costs. To cover crusted tailings costs in the range from $A 40,000 to $A 80,000/ha [$US 12,000 to $US 24,000/acre].
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Cost items associated with pumped co-disposal include the following.

- Tailings thickener capital, operating, and maintenance costs. Where pumped co-disposal has been adopted, a conventional tailings thickener has been retained. There is scope for some of the tailings to by-pass the thickener, avoiding the need to add make-up water, with consequent cost savings.
- Construction of a hopper for combining the coarse reject, thickened tailings, and any make-up water. This can be a modest, low-cost facility.
- Land cost. This will be less than that required for the separate disposal of coarse reject and tailings, because of the reduced storage volume occupied by co-disposal.
- Capital, operating, and maintenance costs of pumps and pipeline(s). These will be substantially higher than the corresponding costs for tailings only, and may be the largest cost item. A low-cost pipeline may be adopted for emergency purposes. Instrumentation should be installed to warn of possible pipeline blockages.
- Operating costs associated with moving the co-disposal discharge.
- Costs of recovery and recirculation of water, preferably involving a separate water storage dam.
- Operating costs associated with re-shaping the co-disposal deposit.
- Rehabilitation costs. These will be far lower than those for separate coarse reject dumps and tailings dams. A nominal cover after progressive re-shaping may be all that is required.

For existing mines, a number of situations offer opportunities to switch from conventional separate disposal to pumped co-disposal. These include an exhausted coarse reject dump and/or tailings dam, coarse reject haul truck(s) requiring replacement, and expansion of the mine, and mining voids becoming available. For new mines, pumped co-disposal can take advantage of not being locked into existing plant and methods, a comprehensive cost-benefit analysis, flexibility in the siting of waste handling plant and waste storages, and rehabilitation requirements.

Rehabilitation of Pumped Co-Disposal

Pumped co-disposal offers the potential for progressive, ready rehabilitation to a high level of future use. The co-disposal discharge should be shifted to build up the desired final land form, by regularly moving a single discharge, or using a number of discharges in rotation, extending out over the deposit as it builds up. Upslope co-disposal lends itself to progressive rehabilitation, since it minimises the impact of fines segregation, maximises the use of hydraulic placement, and allows the downstream slope to be built up, using co-disposed material, to the desired final slope angle.

Concluding Comments

There are several different approaches for the disposal of black coal mine washery wastes. The pumped co-disposal of the combined coarse reject and tailings is an economical alternative to the conventional separate disposal of the two waste products, which has been adopted at many coal mines worldwide and is being considered at numerous other mines. It will find application at existing and new mines where its potential benefits are recognised and can be realised. Pumped co-disposal has a number of problems including pipe wear and the segregation of fines on the beach. However, an appreciation of these problems in the design and operation of pumped co-disposal will minimise their impacts.

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