The use of a floating raft and walkway to replace the conventional timber walkway and penstock on tailings dams

Rui Couto
Semane Consulting Civil Engineers (Pty) Ltd, 1st Floor Samancor House, 88 Marshall Street, Johannesburg
PO Box 61950, Marshalltown, South Africa, 2107
E-mail: rcouto@semane.co.za

1. ABSTRACT

Water is the earth's most distinctive constituent and the quantity is limited. It sets the stage for the evolution of life and is an essential ingredient of all life today and is the most precious resource the earth provides to humankind. Plants and tailings dams in the mining industry are the largest users of water. A large amount of this water is wasted (by evaporation, seepage into the ground or locked up in the interstices of the tailings).

The conventional tailings dam includes a penstock with a buried gravity fed pipeline leading into a return water dam. The penstock is generally situated far from the dam bank and therefore an access walkway is required.

Over the years as the tailings dam increases in height, so must the height of the penstock be increased and the walkway replaced. This becomes a tedious and expensive process for the life of the mine. In addition penstocks with their buried pipelines are problematic (e.g. water seepage, penstock towers falling over and accessibility).

Safety in the mining industry is of paramount importance and conventional walkways become a safety hazard for personnel operating the dam.

This paper provides a brief description of a walkway with floating barges designed to replace the conventional timber walkway & pipe penstock. An example is given of where the design was successfully installed at a mine in Africa. In addition, because of its flexibility, water can be returned efficiently and easily to the plant or return water dam.

2. KEY WORDS: return water, penstock, walkway, tailings dam.

3. INTRODUCTION

Water is arguably the most precious and limited resource the world has to offer and its proper management in all spheres of activities is imperative. In the mining industry where a primary consumptive use of water is in the tailings dams and associated return water, a large amount of this water is wasted (by evaporation, seepage into the ground or locked up in the interstices of the tailings).Optimization of penstock designs is critical to ensure that water is efficiently returned to the plant and evaporation and seepage is kept to a minimum.

The first design of the “jet float” raft system (as a floating penstock) in the mining industry was developed for a Gold Mine situated in Mali – North-western Africa. Semane Consulting Engineers, with advice from Jetfloat-Africa, developed a floating decant barge with pumps, a floating catwalk and a floating electrical mini-sub as an emergency decant system. Since the successful installation of these rafts, similar installations have been carried out on a Gold Mine in South-West Africa and replacement of a failed system on a mine in KwaZulu Natal, South Africa.

This paper provides a brief description of a walkway with floating barges designed to replace the conventional timber walkway & pipe penstock with an example of where the design was successfully installed. In addition, because of its flexibility, water can be returned efficiently and easily to the concentrator plant or return water dam.

Controlling of water is undoubtedly the most important aspect of rehabilitation

4. THE CONVENTIONAL PENSTOCK

For safe operating conditions, and to optimise water return, it is necessary to ensure that all free water is removed from the impoundment with a minimum of delay. In the conventional tailings dam system, water is removed with penstocks. Penstocks are designed to decant all free water from the tailings deposition operation and the 1 in 100 year storm of 24 hour duration, within an acceptable period.

These criteria are used to determine the number and size of the penstock pipes, the number of penstock inlets and their fixed positions in the tailings dam.

Thick walled reinforced concrete pipes are commonly used as penstock outfall pipes. The vertical sections of the penstocks are often constructed with nesting pre-cast concrete rings. Rings are added as the level of the tailings rises thus providing for an “adjustable” intake level. Removal and replacement of rings is the only control available when decanting water.

Access to the penstock intakes is often by constructing a pool wall and a gantry or “catwalk” from the edge of the pool wall to the intake. In some cases access to the penstock intake is by catwalk gantry only.

In older tailings dams, wooden walkways and inlet towers were used. These often collapse under load, rotted or are used for firewood. Recently, floating penstocks (barges) are being used. However they are found to have a relatively short life span due to their designs e.g. the use of drums (steel and plastic) to float the raft. Once one of the drums is punctured the raft will sink or leaks as a result of rust occurring below the water line.

One of the key observational procedures required in tailings dams is to check on the operation of the penstocks, which includes penstock tower construction, catwalk safety facilities, and methods of decanting to minimise the transportation of solids out of the system to return water.

5. THE FLOATING PENSTOCK

In order to describe the design in a simplified manner the first design of the “jet float” raft system (as a floating penstock) in the mining industry developed for the Gold Mine situated in Mali – Northern-western Africa has been used as a case study.

The barge was urgently required to replace the existing conventional penstock that was in the process of falling over and threatening to bring the mining operation to a stand-still.

The criteria for the design of the decant barge was as follows:

- The barge must be sized such that if the existing penstock should fall, it will completely replace it.
- The maximum volume of water that could accumulate in the pool on the dam that must be decanted should be determined from the sum of normal process water, plus the maximum build up of water on the dam over three months due to rainfall, plus an extreme 1 in 100 year return storm of 24 hour duration.
- A very large but shallow pool depth needs to be de-watered.
- A cost-effective solution.

A total of 600l/s of water needed to be removed based on the above conditions to ensure that there would be minimal risk of overtopping the dam wall. The pool size could be reduced to an acceptable size after 4 days of continuous pumping.

A number of pump, pipeline, walkway and barge types and configurations were considered, and through an interactive process between the client, Semane and Jetfloat, the final arrangement was selected. The design process is briefly described below starting with the pumps.

5.1. PUMP DESIGN

To decant a flow of 600l/s required either few very large pumps or many small pumps. The pumps ability to draw water down to a minimum of 300mm and have good suction characteristics was important, ensuring that solids were not pumped and cavitation did not take place. The pump design had to take into account a variable head, starting at 24m maximum static head, and reducing to 2m at the end of the tailings dam life. To do this, a number of pumps were considered, such as:

- Transverse pumps with a suction pipe over the edge of the barge
- Vertical spindle pumps with its suction in an opening within the barge
- Submersible pumps where the pump will sit in an opening in the barge

In all cases two, four or six pumps were considered to assess the flexibility and practicality of each system as well as its effect on the barge size, buoyancy and power requirements. The preference was to have lighter pumps to decrease the load on the barge as well as for maintenance reasons. This will mean more pumps and the objective was to keep the number of pumps to as few as practically possible while keeping the weight to a minimum.

5.2. BARGE DESIGN

The design proceeded based on the four submersible pumps. The barge was to be constructed using plastic cubical units supplied by Jetfloat International. The modular floating system is simple to install, is made of high strength HDPE which is UV resistant, has a 20 year life and can be easily dismantled and re-used elsewhere. Due to the urgency and importance of the barge, it was decided not to design a conventional steel or drum-type barge. It was accepted that though the cost might be greater due to import of the jetfloat, the risks would be reduced.

A steel frame was fixed on top of the floats to stiffen it and on which the pumps, electrical distribution board and pumps were mounted. The steel frame assisted in the spread of the load. Aluminium decking protected the plastic surface. Square openings of 1,5m by 1,5m were provided within the barge for the pump suctions. An A-frame gantry system was provided on the barge for lifting the pumps for maintenance and for keeping the pumps in position. Excess buoyancy was designed into the barges to ensure that the barge will lift free in the event that it came to rest on the slime. To minimise the chance of the barge resting on slime, it was strategically positioned.

Single and separate options for barges were looked at. Single and double layer float units were considered to take the pump loadings but it was decided to use single layer and keep the area larger for greater stability and working area. The barge was designed to float 0,2m above the pool level and would be anchored in one position, but could be winched or driven (using onboard motor) to shore should pump or barge maintenance be required.

For the construction of the barges, a small excavation near the edge of the pool was created as a “dry dock”. Once complete, the barge was launched out slowly into the dam by means of a winch.

5.3. PIPELINE DESIGN

A number of pipeline systems were considered including: -

- Marine and dredging type floating pipelines.
- HDPE pipelines which have some floatation.
- Pipelines mounted along a floating walkway.

In addition, the number and diameter of pipelines was considered taking into account the flexibility of each and effect on pumping. The pipelines needed to be 500m in total length from the barge to the stilling chamber where it discharges into a solution trench.

5.4. WALKWAY DESIGN

Having committed to using the float cells for the barge, it was logical to make use of them along the walkway. The cost was compared to that of the typical floating drum walkway and timber catwalk. There was no significant saving, and fabrication would be more difficult. Jetfloat international provided a number of options. A 1,5m by 86m long walkway was selected, made entirely of float units. The buoyancy, stability and strapping requirements for the pipelines were included. The walkway was anchored (to prevent wind action from moving it around the pool) using stainless steel chains fixed to anchors.

The walkway was designed with a Jetfloat single layer platform of 12 square meters at every 3 meter interval. Each platform has brackets to hold secure the 4 pipelines (1 per pump – 2 pipes each side of the walkway). The inter-joining walkway was manufactured out of aluminium.

5.5. ELECTRICAL DESIGN

Since the barge was no longer a temporary facility, the preferred supply of power was by means of an overhead powerline as opposed to a generator.

The original intention was to install a sub-station that would supply 400V power by cable to the pumps. Four cables would run along the ground and on the walkways to the four pumps on the barge. The cable length was 500m thus increasing the costs excessively and resulting in an increased cable size from the increased voltage drop.

An option to supply a sub-station mounted on a barge, which would distribute power to motor control panels (also on a barge) and have short cables to each pump. The total weight of the sub-station and MCC was 10 tons.

It was felt that in the event of a power failure, the dam had been designed to hold water.

5.6. CONTROL AND INSTRUMENTATION DESIGN

Due to the importance of the decant system, it was considered necessary for the switching of the pumps to be remotely controlled from the plant and made part of their PLC system. By means of a radio link in the plant to a station adjacent to the stilling chamber (situated at the end of the return water rising main), the pumps could be remotely controlled. The operating philosophy was such that one pump would start at a time to reduce the surge of power, with a short delay before the next pump started. Any number of pumps in any order could be started, stopped or operated at any one time.

To ensure that solids were not pumped, a sensitive density meter was installed on each pipeline. The pumps would be switched off if dirty water is being decanted.

6. DISCUSSION

6.1. DESIGN PHASE

Pump Design – The following summarises the findings for the three types of pumps assessed:-

- Transverse pumps with a suction pipe over the edge of the barge – was rejected because of its high mass and potentially poor suction (required small priming pump). Four 90kW motor pumps (3,5ton each) would be required to deliver 600l/s and they are heavy.
- Vertical spindle pump has an excellent suction characteristic and can be easily modified to cope with the decreasing head, however it is heavy (2,6ton each) which is a disadvantage. The cost of the pumps was comparatively acceptable. Four 90kW pumps would be required. The pump would require a minimum of 600mm of water depth from which to pump, which would be a disadvantage in terms of minimising the pool size on the slimes dam.
- Submersible pump can cope with changes in head and will deliver greater flows as the head decreases. Four 85kW pumps weighing 1,6 ton each would be required to deliver the full flow. These pumps could draw water down to 300mm depth and therefore fulfilled the requirements and were considerably lighter than the vertical spindle pumps but more expensive.

After consultation with the client, a decision was taken to select the third option of submersible pumps.

Electrical Design – It was found that significant electrical cost savings could be made by having the sub-station on a barge. This would increase the barge costs but would still be cheaper overall.

6.2. GENERAL

Flooding of the timber walkways and penstock can easily occur due to abnormal floods and cause extensive damage. (See photographs No.1)

Photograph No.1
Typical Conventional Penstock Failure
Flooding

The conventional penstock and walkway can become a safety hazard and need to be re-constructed as the level of the dam increases.

Photograph No. 2
Conventional Timber Walkway and Penstock
Safety Hazard

Sink holes can also create problems for the penstock and outfall pipeline. Leakages in the system are difficult to repair especially whilst the tailings dam is operational. (See photographs No.'s 3 and 4)

Photograph No.3
Conventional Penstock Failure – Sink Hole

Photograph No. 4
Conventional Penstock Failure

The conventional penstock is often difficult to maintain perfectly vertical as the level of the dam increases and/or the tailings is of soft constitution. This results in the penstock "tower" falling over.

Photograph No. 5
Typical Conventional Penstock Rings

The advantages of replacing the conventional penstock with the floating barge and walkway are:-

- Tailings dam pool can be easily managed and controlled due to the flexibility in moving or relocating the walkway and barge.
- Return water pipelines are on surface allowing for easy access for repairs if required.
- The barge and walkway always keep afloat at the dam water level.
- It is a much safer system due to the material and the standard associated products such as hand railing etc.
- With the assistance of instrumentation, the water level at the dam can be controlled from the plant.
- In the event of abnormal floods the dam can be dewatered more quickly.
- The pool can be drawn down to very low levels thus allowing for water to be returned to the plant efficiently reducing evaporation and an improved water balance.
- An onboard motor can be fitted to the barge to assist in docking the pumps for maintenance if required.
- The problem of buoyancy can also be addressed by allowing water into each float to the required level.
- Rust and corrosion would not be a problem as it cannot affect HDPE products.

The disadvantages of replacing the conventional penstock with the floating barge and walkway are:-

- Pumping is required. (RWD requires it in any event)
- Electrical power is required. (However the return water dam requires power any way)
- Slightly higher on capital cost due to the import cost of Jetfloat. (These costs should be offset against the cost of the RWD, the Penstock & Outfall pipeline and the Return Water pumping system)

Photograph No. 6
Typical "Jetfloat" Walkway

Photograph No. 7
"Jetfloat' Walkway and Pump Barge under construction on site

7. CONCLUSION

Water has become an expensive commodity and its cost per cubic meter is on the increase. Therefore the preservation of water by the mining industry is crucial. The effective re-cycling of water plays an important role in sustainability. The “Jetfloat” Floating Barge offers a neat and effective engineering solution to the Tailings Dam return water system. By implementing this system, it has been found that water can be quickly and effectively returned to the plant thus minimizing water loss by evaporation and seepage.

Based on the advantages and disadvantages discussed above, the advantages of installing a floating barge in lieu of the conventional penstock, far outweighs the disadvantages.

The system consists of maintenance free, guaranteed floating structure, capable of withstanding over 100 kph winds, resistant to cyanide and UV with a life expectancy exceeding 20 years. In addition to this, the system can be easily dismantled and moved to another location if need be.

Considering what has been used in the past, as well as the value and importance of the pumps remaining operational in remote locations, the “total value for money” over the 20 year period is justified.

8. ACKNOWLEDGEMENTS:

Work was performed by J.T. Araujo from Semane Consulting Engineers (Pty) Ltd, Malcom Harrison from Jetfloat-Africa and Andrew Copeland from Anglo American – ATD.