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The successful design and construction of a floating cover molasses storage reservoir for the TSB Malelane Mill in South Africa

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ABSTRACT: Although the storage of molasses in floating cover reservoirs is cost-effective, a number of problems are associated with such storage, including gas generation, foaming, rainwater removal and cover drag. This paper describes the design and construction of a new 14 800m^3 floating cover molasses storage reservoir at the Transvaal Suiker Beperk Malelane Sugar Mill in South Africa, taking these design issues into consideration.
There were a number of challenges to the project, of which the most challenging were the time constraints on the project, the number of contractors involved, rainfall events during construction and design changes during the project. The floating cover molasses storage reservoir was commissioned within five months of appointing the consultants and meets design specifications. The reservoir is performing satisfactorily, and should continue to do so, provided that the reservoir is not overfilled, and foam generation is limited. This floating cover molasses storage reservoir is believed to be the largest of its kind in the southern hemisphere.

1 INTRODUCTION

The Transvaal Suiker Beperk (TSB) Malelane and Komati Sugar Mills are situated in the Lowveld of Mpumalanga, in the Republic of South Africa. Both Mills generate molasses as a by-product during the sugar cane crushing season, which is typically nine months. Molatek Animal Feeds, a division of TSB, uses the molasses generated by the mills as a raw material in the production of animal feeds, and requires molasses throughout the year in order to supply their markets. Storage of molasses during the crushing season for use during the off-season is therefore required.

Both mills are equipped with steel tanks for molasses storage, and a 5 000m^3 floating cover molasses storage reservoir was constructed at the Komati Mill in 1999. Insufficient molasses storage existed to provide for the molasses generated during the 2004 crushing season, and a number of alternative storage solutions were investigated, costed and compared by Molatek. The provision of a floating cover reservoir at the Malelane Mill proved the most cost-effective, based on the initial costing exercise. The Malelane Mill is situated about five kilometers from the Kruger National Park, across the Crocodile River. The surrounding environment is therefore important from a conservation perspective.

2 DESIGN BRIEF

The design brief set by Molatek Animal Feeds was to design a floating cover reservoir for the storage of 14 800m^3 of molasses. The design had to allow for possible gas generation from the stored molasses, as well as rainwater removal from the cover. Operational problems with these systems had been experienced at the Komati Mill floating cover molasses storage reservoir initially.

3 MOLASSES STORAGE ISSUES

In warm weather, and if stored for long periods, molasses can release gas. If not released from the storage facility, gas can build up under the cover, and form large bubbles or “hippos”. These can inhibit flow of incident rainfall to low points for removal, as well as be blown across the dam by winds.

Foam can be generated in the molasses, either as gas is generated within the molasses, or with the introduction of air when pumping. While a relatively thin layer of foam between the molasses and the cover is not problematic (such as 300mm or less), a thick layer of foam can cause serious problems. As the foam is less dense than the cover and water, instead of incident rainwater flowing to the lowest point, it tends to accumulate in pockets in the foam. This causes significant stresses in the cover, and can result in the cover pulling out of the anchor if severe.

Rainwater removal from floating cover reservoirs must be addressed for any product stored, which is complicated by the variable level of the cover. Because water is lighter than molasses, a low point must be created within the cover from which rainwater can be pumped. This is accomplished by placing weights on the cover. Where possible, the distance that rainwater has to travel on the cover should be minimized, so that this is not complicated by any gas bubbles.

Plate 1: Rainwater puddles on cover

Concrete is chemically degraded by molasses, resulting in the concrete failing. Design of molasses storage facilities must take this into account.

Molasses has a high viscosity, and flow beneath the cover can result in drag of the cover. This can result in the generation of significant stresses in the cover. The viscosity can, however, counteract uplift forces from wind.

4 RESERVOIR DESIGN

The reservoir was designed by Jarrod Ball & Associates cc (now part of Golder Associates Africa (Pty) Ltd), with input from the lining contractor, Aquatan (Pty) Ltd, as well as the client's project team.

The reservoir was designed to hold 14 800m^3, or approximately 20 000 tons, at a specific gravity of 1.35. A 300mm freeboard has been allowed for foam. The reservoir is rectangular, with a width of 40m and a length of 113m. Although a square would have been a more cost-effective shape, a maximum gas pathway of 20m was allowed for. Including the freeboard allowance, the reservoir is 4.6m deep. Approximately 3m of the dam is below ground.

The reservoir is lined with a GCL (Bentomat ST) and a 1.5mm thick HDPE geomembrane, while the cover comprises 1.14mm thick reinforced polypropylene (R-fPP). Given that the reservoir was constructed in weathered rock, it was necessary to place a 75mm thick imported clay layer to obtain the required finish for lining.

The liners and cover are anchored to a concrete anchor ring beam. The inlet to the dam is between the liner and the cover, so that no penetration of the liners was necessary for the inlet, limiting the risk of leakage. The reservoir is linked to a large sump, which is coated to protect concrete from attack by the molasses. The sump is used as the outlet, and molasses is pumped from it. The sump also acts as an additional inlet, as road tankers can discharge directly in to the sump.

A system of floats and weights was designed for gas and rainwater removal. The system is different from that traditionally used on floating cover reservoirs, as the floats, installed under the cover, run parallel across the width of the dam, allowing gas the shortest distance to escape. The pre-calculated weights are in place on the centre fold of the dam, to collect storm water to be removed by the storm water pump on the floating cover as well as assisting with gas removal. The gas removal system consists of a Hi-Drain (Cuspated HDPE sheet) strip installed along the perimeter of the wall to overlap with the floats underneath the cover and is connected to the atmosphere using Whirly bird extractors. The triangular space between the closely spaced floats edges below the R-fPP cover and the cover provides for gas flow to the Hi-Drain strip.

Pipes are usually installed in a herringbone system on a molasses reservoir floor, to allow for gradual, even filling of the reservoir, without stressing the cover. For this reservoir, such pipes were not included, due to cost and time constraints. A herringbone canal system was designed for the floor to spread the molasses uniformly between the HDPE liner and R-fPP cover first filling, minimising tensile stresses in the cover.

The design also considered aspects such as wind uplift, fire protection, and so forth.

5 CONSTRUCTION METHODOLOGY

The reservoir was constructed by four contractors. The bulk earthworks were undertaken first, and the imported clay protection layer was constructed by the same contractor.

Plate 2: Bulk earthworks

Plate 3: First installation of GCL on clay protection layer

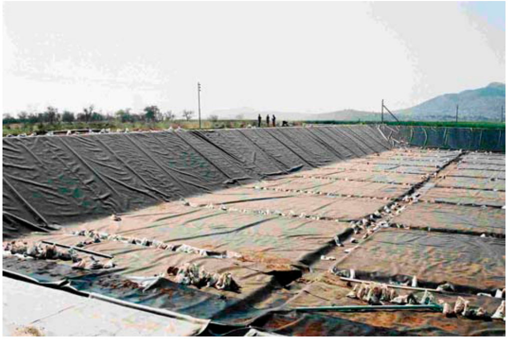

Plate 4: Installation of HDPE liner

The GCL and HDPE liners were laid as the earthworks were completed. The pipe work and structural work were programmed in so that the pipes were laid between the liners & cover, and so that the concrete anchor ring was completed in time to use as an anchor. The outlet sump was completed once the pipes were in place, and was backfilled to allow the liners and the cover placement to be completed.

Plate 5: Installation of fPP-R cover

Plate 6: The molasses reservoir during commissioning

First filling of the dam was undertaken slowly, to allow the trenches to be filled gradually, and for the molasses to spread across the floor and raise the cover evenly. This was undertaken in order to avoid generating tensile stresses in the cover. First filling required careful monitoring, but did not prove a problem at all.

6 CHALLENGES TO THE PROJECT

There were a number of challenges to the project which needed to be addressed:

- The client required the reservoir in a short space of time, to avoid the high costs of storing molasses in road or rail tankers during the cane crushing off-season. The reservoir was commissioned within five months of appointing the consultants.
- Despite the reservoir being constructed during the dry season, two unseasonal rainfall events occurred, causing a delay of

nine days, as well as damage to the clay layer underlying the GCL, which was repaired.

- Due to the short duration of the construction programme, four contractors worked on the small site simultaneously, which required good communication and planning. The contractors were responsible for earthworks, lining, piping and associated structures respectively.
- Design brief changes occurred late in the project, which had to be accommodated.
- The reservoir was constructed in weathered rock, making excavation relatively difficult and requiring the construction of a protective base layer with imported clay.

Plate 7: The reservoir in use

7 PERFORMANCE TO DATE

The reservoir has been in operation for just over a year at the time of writing, and is performing in accordance with design brief. Within two months of commissioning, the reservoir was filled to slightly above capacity, which was retained within the freeboard. This, however affected the gas removal system, as minor gas bubbles formed below the cover. These dissipated once the molasses level was lowered.

Issues of concern during the operation have included the breeding of mosquitoes in puddles on the cover, and frogs accessing the cover, and not being able to get off. The site is situated within a malaria area, so breeding of mosquitoes is a serious concern. These issues are being addressed by the client.

The project received the 2004 Geosynthetics Interest Group of South Africa (GIGSA) Award for Excellence in the use of Geosynthetics in Construction.

8 CONCLUSIONS

The Molatek floating cover molasses storage reservoir at the Transvaal Suiker Beperk Malelane Mill was completed within time and budget and meets design specifications. The reservoir is performing satisfactorily, and should continue to do so, provided that the reservoir is not overfilled, and foam generation is limited.

This floating cover molasses storage reservoir is believed to be the largest of its kind in the southern hemisphere (Maddocks & Associates, 2004).

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Jarrod Ball & Associates (JBA) (now part of Golder Associates Africa (Pty) Ltd) carried out the engineering and construction supervision, and Aquatan (Pty) Ltd was the main contractor and specialist lining contractor.

REFERENCES

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