Flood Control using the Automation Tops Spillway Gates: A case study of the Avis Dam, Namibia

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SYNOPSIS. The Windhoek City Council in Namibia required the maximum discharge from the Avis dam for the 1 in 100 year flood event to be limited to almost half the inflow peak to prevent undue flooding through the city.

The original dam spillway and basin could not achieve that. Further, electrically actuated gates were not a safe option considering the remoteness of the site, vandalism and the harsh environment.

The TOPS automatic spillway gate was selected as the only viable and safe option to achieve the performance criteria.

Two 3,5m high by 11m long TOPS gates were employed using a unique level control device to release water from the dam without an increase in water level up to the maximum flow required and thereafter the flood would be attenuated.

The gates are automatic and self actuating and provide a unique and interesting solution to this problem of flood control.

This paper presents a case study of the problem, solution, design, model study, fabrication and commissioning of the TOPS Spillway gates for this dam.

INTRODUCTION.

Namibia is situated on the West Coast of Southern Africa adjacent to a cold ocean current. It consequently has an average mean annual precipitation of less that 250mm per year. Although mostly dry, thunderstorms do occur during summer, sometimes resulting in flooding.

The German colonialists built the Avis dam on the outskirts of Windhoek as the city's water supply dam. The dam is an earth embankment dam with a concrete facing slab and a side channel spillway.

As the city grew, alternative water supply was provided and Avis dam reverted to a popular recreational dam.

THE PROBLEM

The watercourse downstream of the Avis dam runs through the city of Windhoek. With increasing development adjacent to the watercourse, the City Council needed to ensure that a maximum flow of 350m³/sec for a 1 in 100 year recurrence interval flood would not be exceeded.

The peak inflow rate into the dam was determined by the project consultants as 600m³/sec.

The dam with its uncontrolled rock spillway and its limited storage capacity, was not adequate to restrict the peak discharge to the required flow.

The initial solution to the problem was to excavate a 5m deep by 20m wide channel through the spillway to utilize the available storage to achieve the required peak outflow.

However this ran foul with the environmentalists and the public who could not accept a 5m drop in the FSL, particularly in such a dry country.

Electro-mechanical gates were not an option for many reasons including cost, environmentally adverse impact of power cables, gantries etc, as well as vandalism.

THE SOLUTION

The TOPS automatic spillway gate was selected by the project consultants as it could meet the performance requirements. The TOPS gates are automatic, self actuating, flexible in usage, reliable and safe. The gate was also ideally suited for the flat invert of the excavated spillway channel.

Two TOPS gates were employed, each 11m long and 3,5m high. The gates were modified to incorporate a level control valve to activate the gates' motion.

A further less obvious advantage provided by the TOPS gates was the provision of a walkway on the gates for pedestrians and horses, thereby eliminating the need for a relatively expensive and unsightly bridge over the spillway channel.

DESCRIPTION OF THE TOPS GATES

The Tops gate is so named because it is a top hung gate supported from two trunnions situated above the water level and up stream of the gate.

The gate consists of an upstream closure plate which seals against vertical sides and along the sill. The closure plate forms part of a ballast tank attached to the downstream side of the closure plate. The ballast tank is connected to the dam by four openings through the closure plate sothat the water levels in the dam and the ballast tank are in equilibrium.

The mass of water in the ballast tank creates a moment about the trunnion which is greater than the opening moment induced by the upstream water in the dam, and so the gate remains closed.

The gate remains closed to allow an overflow in the order of 300mm so that regular instream flows can be discharges without the gates opening.

For these particular TOPS gates, a telescopic arm connects the ballast tank to a float controlled discharge valve. When the water level rises above 300mm over the gate, the discharge valve will open automatically to release water from the ballast tank thereby reducing the closing moment which then causes the gate to open.

Telescopic arm connecting the ballast tank to the float controlled valve.

As the water level in the dam drops as a result of the discharge through the gates, the discharge valve closes automatically, water flows into the ballast tank through the 4 openings to the dam to add mass to the ballast tank thereby causing the gate to close.

The TOPS gate therefore opens and closes automatically in response to the water level in the dam.

Float controlled discharge valve discharging water from the ballast tank

The TOPS gate also incorporates other safety features such as an emergency discharge valve in the ballast tank as well as a manually controlled valve to ensure the gate opens in the unlikely event of the primary actuating system not working.

The TOPS gates are therefore failsafe to open and close to meet dam safety requirements.

DESIGN

The level controlled gate has a significant influence on the flood routing through the dam as indicated in the diagram below.

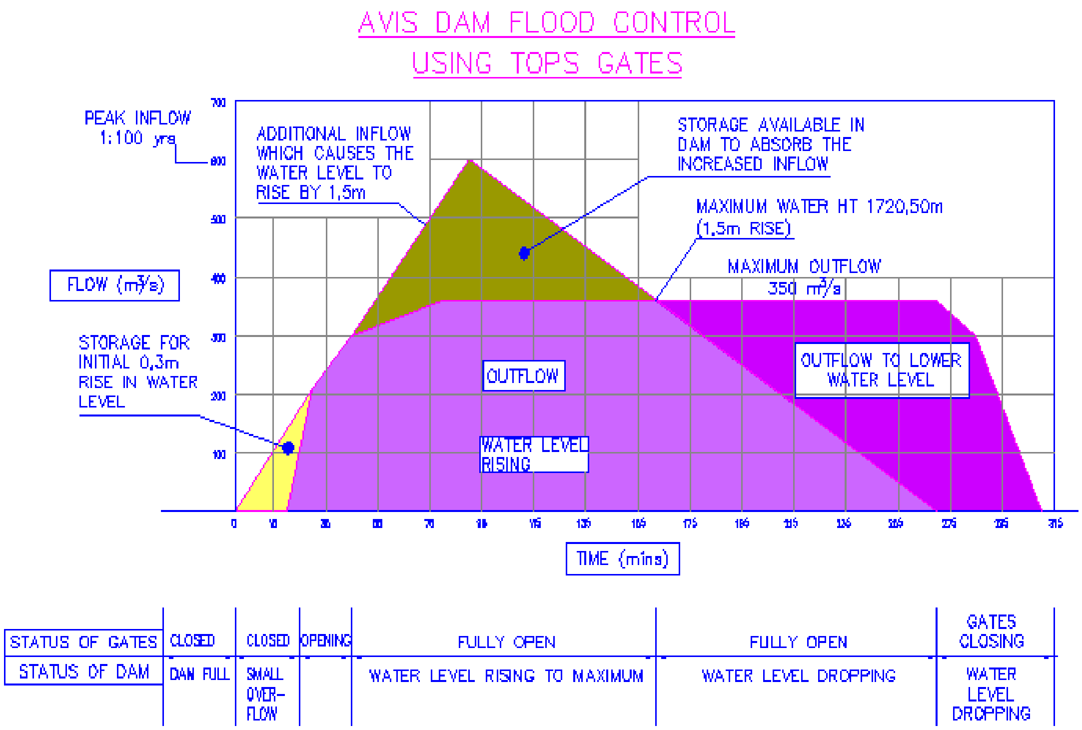
Once the water level reaches 300mm over the gate, the gate will open due to the discharge of water out of the ballast tank, and will close down as the water recedes. In effect the gate will maintain a constant water level in the dam within a 30mm variation.

There will therefore be no increase in storage in the dam and the inflow and outflow will essentially be the same for the initial part of the rising limb of the inflow hydrograph.

The gates are set with a 50mm incremental level difference so that one gate will operate before the other. The gates are restricted from opening more than 2,6m under the gate to give a total discharge of 305m³/sec at the water level at which the gates open.

Thereafter the water level in the dam will rise with increasing inflow, thereby using the available storage in the dam to attenuate the peak inflow. In this case an additional 1,5m rise in water level is required.

In this way the two TOPS gates are able to restrict the discharge to the required maximum of 350³/sec while attenuating the peak in flow of 600m³/sec.



Further it satisfies the environmental aspects in that

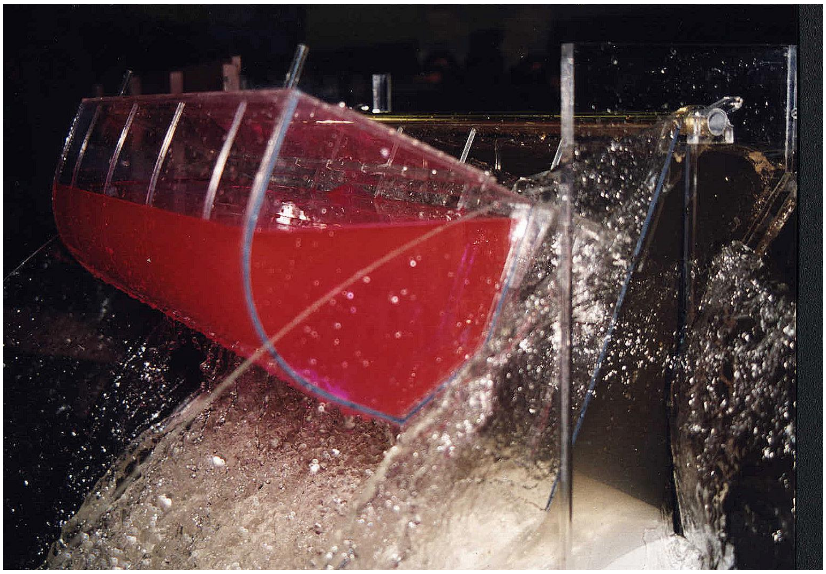
- It achieves the highest possible water level in the dam
- It is aesthetically pleasing
- No H.T. cables or dangerous mechanisms are required
- It provides a safe walkway over the spillway channel

From a structural aspect, the large ballast tank provides a large moment of inertia which results in low stresses and deflections.

MODEL STUDY
A 1 in 20 scale perspex model was built of the gate and spillway. It was tested in the Stellenbosch University Hydraulics laboratories by independent researchers.

The angular displacement of the gate was measured for different upstream water levels and flows and the discharge characteristics of the prototype determined.

It was determined that the gates would rotate to 55° to the horizontal to pass the required flow.



It was also noted that the gates could open considerably more to pass larger flows but in this case the movement of the gate was stopped at 55° rotation to give the required discharge.

The model was also tested with large debris and floating logs and found to have no adverse effect.

FABRICATION
The gates were fabricated by Concor Engineering, a member of the Hochtief group.

Normal workshop practice for low pressure vessels was adopted. The gate is manufactured out of carbon steel. The trunnion shaft as well as the seal plates are stainless steel grade 304L.

The seals are double stem bulb seals which are hydraulically pressurized to assist sealing.

The front upstream closure plate was fitted with studs to receive a 80mm thick nylon fibre reinforced concrete facing on site. This is to provide both effective corrosion protection to the closure plate as well as impact resistance.

The corrosion protection to the remainder of the gate consisted of
500 microns inside the ballast tank and 200 microns external twin pack polyamine system and a 35 micron external coat of twin pack polyurethane weather resistant final coat.

The gates were transported from Johannesburg to Windhoek, a distance of almost 1500km.

INSTALLATION

The gates were loaded from the transporters and placed on tressles where the trunnion arms and seals fitted.

The gates were then lifted into position by a 35 tonne crane and placed over holding down bolts to locate and secure the trunnion brackets.

The gates were then rotated down into position where the seal plates were adjusted to ensure a 2mm pre-compression on the seals. The gate was tracked up and down to ensure a free movement.

Second stage concreting to the seal plates and trunnions was the final operation together with casting the concrete skin to the closure plates.

Gate lifted complete into position

Gates installed ,one partially open

COMMISSIONING

An earth coffer dam was constructed 20m upstream and water then pumped in behind the gates over two days to reach the final depth of 3,5m above sill level. The gates did not show any sign of distress.

Gates retaining full 3,5m water

The various components such as the level control discharge valve and the manual butterfly valve were wet tested.

Gates ready for wet commissioning

With 60 interested observers and dignitaries in attendance the float controlled valve and manual valves were opened to release water from the ballast tank. At a drop of water level in the order 0,9m in the ballast tank, one gate opened and then the other.

One gate opening

Unfortunately here was insufficient volume of water behind the gates to maintain an almost constant water level which is required to open the gates fully. The first gate opened partially which rapidly drew the water level down behind the gates so that full opening could not be achieved.

The gate was closed down and the water level restored behind the gates by pumping. The second gate was then opened in the same manner.

Despite not being able to open the gates fully, wet commissioning was nevertheless successfully achieved.

CONCLUSION

This installation demonstrated the effectiveness and flexibility of operation of the TOPS spillway gates to maximize available storage in a dam to reduce flooding downstream as well as providing additional safe storage above the spillway level.