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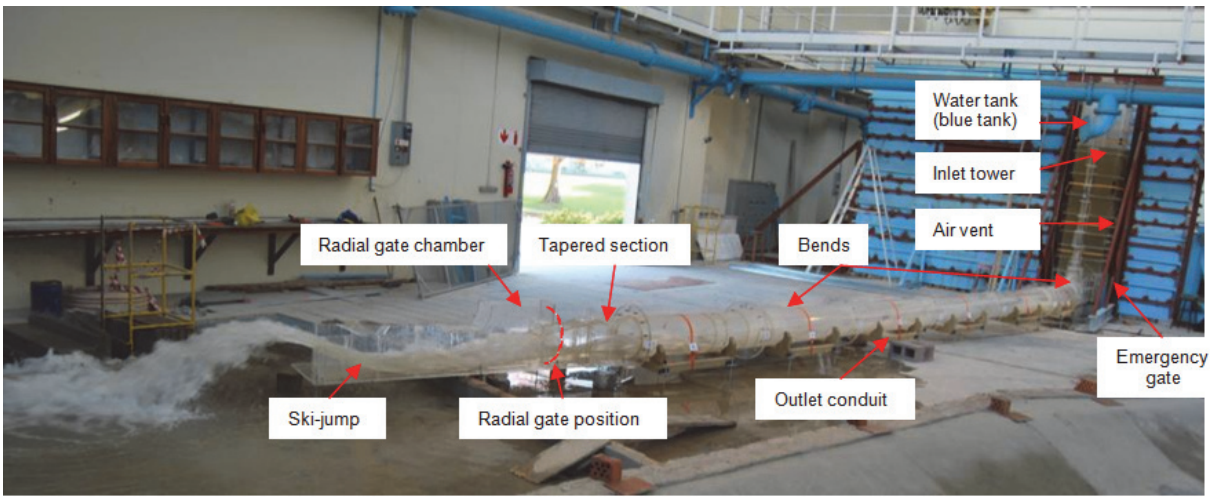
The WRC operates in terms of the Water Research Act (Act 34 of 1971) and its mandate is to support water research and development as well as the building of a sustainable water research capacity in South Africa.

TECHNICAL BRIEF

Hydrology

Investigation of unsteady flow conditions at dam bottom outlet works

A WRC-funded study investigated operational deficiencies experienced at the bottom outlet works of the Berg River Dam, in the Western Cape.



The physical model.

Provision of service and quality

The Berg Water Project (BWP) is the result of a 14-year strategic integrated planning process carried out by the Department of Water Affairs (DWA) to identify suitable measures to address the increasing water demand in the Greater Cape Town region. The Berg River Dam is equipped with the first multi-level draw off environmental flood release outlet in South Africa and can release flows of up to 200 m^3/s.

The outlet is controlled by a radial gate and is protected by a vertical emergency gate. Commissioning tests of the emergency gate in 2008 found that large volumes of air were expelled from the air supply shaft designed to reduce expected negative pressures in the conduit during emergency gate closure.

In 2009, Stellenbosch University was first commissioned by the WRC to investigate this phenomenon. The 2009 study, comprising of tests on a 1:40 scale physical model and a two-dimensional numerical computational fluid dynamics (CFD) analysis, was inconclusive on the cause of the large air releases. This subsequent study used a 1:14.066 scale physical model.

The main objectives of the study were to:

- Determine the reasons for the release of very large volumes and fluctuating positive and negative air flow from the air vent shaft, as observed during the commissioning test closure; and
- Provide a solution to mitigate the excessive airflow.

Air entrainment phenomenon

The investigation of the air entrainment phenomenon at dam bottom outlet works of the Berg River Dam consisted of two interrelated components:

- The first component comprised of tests on a 1:40 scale **physical model** and a two-dimensional numerical computational fluid dynamics (CFD) analysis, was

inconclusive on the cause of the large air releases. Subsequently, a 1:14.066 scale physical model was used, and the results are covered in ***Volume I*** of the report;
- The second component consisted of a study using three-dimensional CFD analyses, and the results are reported in ***Volume II***.

Physical model

Simulations of continuous gate closure on the as-built physical model of the Berg River Dam outlet showed predominant inflow of air into the airshaft during emergency gate closure with short high speed air releases while the emergency gate was between 35% and 25% open. The problem was determined to be one of air blowback in the air shaft rather than continuous air release.

The cause of the blowback was found to be the constriction of flow at the radial gate chamber. A number of modified model configurations were tested and recommendations were made for future design. The most crucial of these is that flow in high headed outlets should not be constricted.

The emergency gate was opened too quickly during the simulations, which increased the pressure on the radial gate chamber. This caused the radial gate chamber to fail. Given this failure, it is advised that the radial gate and emergency gate should never be operated simultaneously when the outlet conduit of the Berg River Dam has to be filled or drained.

Implications for future designs

The following recommendations should be adhered to for the prevention of air flow reversal problems in future designs:

- Large-scale (preferably greater than 1:20) hydraulic models should be used in the design process, and tests should include emergency gate closure procedures.
- Bottom outlets should be designed for free-surface flow conditions in the outlet conduit for all foreseeable flow conditions and the formation of hydraulic jumps should be avoided.
- The slope of the tailrace conduit in bottom outlets should be kept as flat as possible to prevent upstream movement of air and possible blowback problems due to buoyancy forces.
- Air entrapment at all changes in cross section should be avoided by matching tunnel ceiling heights rather than inverts.
- The flow in outlet conduits should not be restricted for all foreseeable flow conditions.
- The case of a radial gate failing in a partially closed position is a particular scenario which would cause a constriction which may cause a severe restriction of the flow, possibly leading to dangerous air blowback during emergency gate closure.
- Where ski-jumps are used the crest height should not be so high that it could cause submergence of the conduit under low flow conditions.

Further reading:
To obtain the reports, ***Investigation of Unsteady Flow Conditions at Dam Bottom Outlet Works due to Air Entrainment During Gate Closure, Volume I: Physical Modelling*** **(Reports No. TT 528/12)** and ***Volume II: Computational Modelling*** **(Report No. TT 529/12)** contact Publications at Tel: (012) 330-0340; Fax: (012) 331-2565; e-mail: orders@wrc.org.za or Visit: www.wrc.org.za to download a free copy.