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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

Dam engineering

Improving the design of straight ogee spillways

A newly-completed Water Research Commission (WRC) study investigated additional parameters for the design of straight ogee spillways.

Background

The design of Ogee spillways are based on the relationships which were derived from two-dimensional flow considerations.

In 2011, it was postulated that, based on the observations made from the physical modelling of the Neckertal Dam, three-dimensional flow conditions should be incorporated to ensure an effective ogee spillway design.

It was hypothesised that the following parameters will influence the relationship used for the successful numerical quantification of the required form of the Ogee spillway:

- The 'symmetricity parameter' of the upstream approach channel quantified by the cross-sectional details reflecting the asymmetricity of the upstream channel;
- The radius/curvature of the dam wall and spillway; and
- Quantification of the discharge coefficient for three-dimensional flow.

Neglecting the effect of three-dimensional flow upstream of a spillway may contribute to the separation of the lower nappe of water flowing over the spillway. This will induce sub-atmospheric pressure on the surface of the spillway, which may contribute to cavitation formation and spillway erosion.

Catastrophic failure of the structure may occur during high flood events if these three-dimensional flow parameters are not considered during design of the spillway.

Research objectives

Due to budget constraints, only the following parameters were reviewed in this research project:

- The influence of asymmetricity of the upstream approach channel
- The relative orientation of the spillway compared to the flow in the approach channel.

The final report reflects the research undertaken to investigate the three-dimensional flow parameters to facilitate the inclusion of the upstream asymmmetricity as well as the orientation of the spillway relative to the direction of flow for the design of Ogee spillways.

Experimental tests were conducted on a sharp-crested weir for which the bottom profile was measured, known as the Ogee profile. The measured profiles were compared with the calculated profiles computed by various relationships.

With the objective to compare a number of different layouts, the Ogee profile was modelled numerically using Next Limit's XFlow and CD-Adapco's STAR-CCM+ Computational Fluid Dynamics (CFD) software.

Main results

At first the results of the CFD modelling were compared with the results obtained from the physical model study. With the needed numerical refinements and mesh independence studies, the CFD modelled Ogee profile results were compatible with the measurements conducted on the physical model.

The findings of the research can be summarised as follows:

- For symmetrical approach channels, with contraction the original design head had to be increased by up to 17% to prevent separation of the lower nappe;
- For asymmetrical approach channels, with contraction the original design head had to be increased by up to 14% to prevent separation of the lower nappe; and
- For symmetrical approach channels, orientated at a skew angle, without contraction, the original design head had to be increased by up to 18% to prevent separation of the lower nappe.

In addition to the above findings, the reference group requested the review of the asymmetric upstream conditions and the orientation of the spillway in relationship with the discharge coefficient. This assessment indicated that the discharge coefficient decreased, resulting in a reduction in discharge for the same energy head.

Asymmetrical approach channels with flow oblique to the spillway structure tend to be the worst case scenario.

Conclusions

The findings indicate the necessity to include three-dimensional flow parameters for the numerical approximation of the Ogee profile and reflect the shortcomings of the current mathematical relationships used for the design of Ogee spillways. In addition, this underlines the need to review all three-dimensional flow parameters which were excluded from the current research project.

It is therefore recommended, that as a matter of urgency, the research should be continued to include:

- The effect of curvature/radius of the spillway;
- The orientation of the curved spillway relative to the approach channel;
- The upstream asymmetricity of the approach channel for a curved spillway; and
- Quantification of the discharge coefficient for three-dimensional flow.

The findings also indicated that it is essential that when these parameters are present on existing dam structures, the discharge coefficient should be reassessed.

Further reading:
To order the report, *Additional parameters for the design of straight ogee spillways* (**WRC Report No. 2253/1/15**), contact Publications at Tel: (012) 330-0340;
Fax: (012) 331-2565; Email: orders@wrc.org.za or
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