RECLAMATION
Managing Water in the West

U.S. Department of the Interior
Bureau of Reclamation

Hydrodynamic Forces on High-Head Gates

Evaluation during unbalanced closure

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This study involved laboratory experiments to evaluate hydrodynamic forces during unbalanced closure of a high-head gate. The results indicate that downpull forces are strongly dependent on intake geometry and downstream radial gate position. Furthermore, in the absence of air venting, large load fluctuations occur as the leaf gate passes through the transition zones for specific operating conditions. Generalization of these findings is expected to provide improved design guidance for future installations of this type.

Mission Issue

This research supports infrastructure reliability through an expanded understanding of performance to support improved design and operation of high-head gates.

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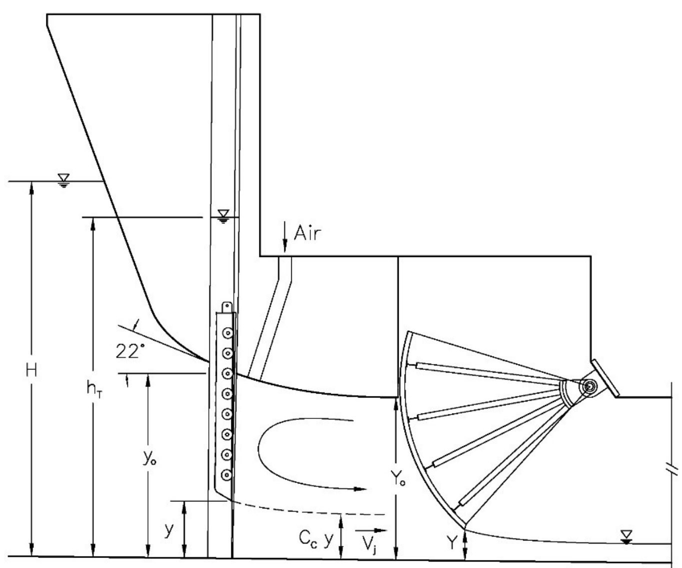
Problem

Hydraulic downpull is a critical consideration in the design of high-head gates. Over the past several decades, numerous investigations have been conducted in the pursuit of practical methods for predicting downpull forces acting on vertical leaf gates subjected to unbalanced operation. Most notably the work of Naudascher, et al. (1964, 1986, 1991) has identified the key physical mechanisms necessary for the development and advancement of generalized methods to predict downpull with broad applicability. Others have considered various aspects including the work of Colgate (1958) describing results from physical model studies and field testing, Dodge (1963) who investigated downpull characteristics for a specific spillway gate design, Murray & Simmons (1966) in an effort to generalize what was, at the time, the state of knowledge regarding downpull forces on large gates, and Hampton & Lesleighter (1980) who investigated the effects of gate bottom shape on downpull via physical model studies. More recently Aydin, et al. (2006) compared experimental results obtained from a physical model with a one-dimensional mathematical model.

The physical processes associated with downpull involve the piezometric head differential between the top (due to head in the gate slot or gate well) and bottom surfaces (due to reduced pressure resulting from high velocity flow) of the gate. However, an improved understanding of the effects of intake geometry and air venting will further provide needed information for future design and operation of high-head gates, particularly for situations where they are closely coupled with a downstream gate.

Solution

Laboratory experiments were performed to directly measure downpull forces on a high-head vertical leaf gate arrangement representing somewhat of a departure from conventional situations studied in the past. For these experiments, a vertical leaf gate is located in the gate well of a rectangular conduit just downstream of the entrance and just upstream of a radial gate. The wheel-mounted upstream gate rides in slots and is equipped with seals on the downstream side that engage when the gate nears closure. The seal arrangement allows for flow over and around the gate for positions greater than approximately 5-percent open. The gate bottom geometry is comprised of a curved to angled section leading to a relatively small gate lip and bottom seal.



Schematic of high-head gate arrangement for laboratory experiments showing the relevant physical parameters.

Collaborators

Reclamation
Mid-Pacific Region
Central California Area Office

U.S. Army Corps of Engineers
Sacramento District

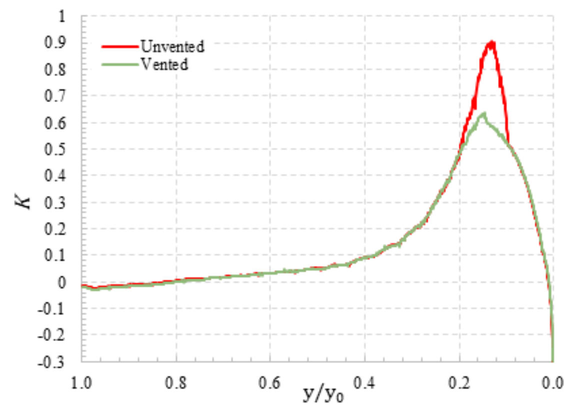
More Information

https://www.usbr.gov/research/projects/detail.cfm?id=1892

Application and Results

The results indicate that the maximum downpull on the leaf gate occurs in the transition zones where control shifts from the downstream radial gate to the upstream leaf gate. Operation in the transition zone is also accompanied by large downpull fluctuations. Furthermore, the findings confirm the presence of significant uplift during the initial moments of closure which increases with upstream head and local velocity due to increased initial discharges. Air venting to the chamber between the gates was found to have a significant influence on leaf gate operation during unbalanced closure. The two primary effects of venting include relief for reduced pressures that otherwise develop in the chamber between the radial and vertical leaf gates and suppression of fluctuations for smooth operation as the gate passes through the transition zone. The former has a marked influence on downpull while the latter mainly concerns downpull fluctuations and gate vibration.

As an example, the figure below shows a comparison of leaf gate downpull coefficients (K) during unbalanced closures with and without venting for a downstream radial gate position of 20-percent open. In this case, downpull forces in the transition zone are significantly larger without venting. The dominant mechanism is associated with reduced pressures in the chamber between the gates which acts on the leaf gate resulting in additional downpull. As the leaf gate passed through the transition zone, the downstream head decreases. At some point a free surface forms in the gate chamber which reduces pressures below atmospheric as the water surface drops. Observations during testing without an air vent also indicated that, during this stage of closure, intermittent venting from downstream of the radial gate occurs when pressures in the gate chamber become sufficiently small which contributes to the fluctuations in downpull. Generalization of these results is expected to provide an important extension of previous work for improved future design and operation of high head gates.



Comparison of hydraulic downpull coefficients as a function of leaf gate opening (y/y0) during unbalanced closures for vented and unvented gate chamber.

Future Plans

Future plans include refinements in generalization of the results and publication of this work.