KTH ROYAL INSTITUTE
OF TECHNOLOGY

CFD MODELLING OF TWO-PHASE FLOWS AT SPILLWAY AERATORS

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Short Introduciton

Background

- **Issue: Caviataion Damages**

  For high-head dams, cavitation damages may occur in the chute spillways, which threaten the dams safety.

- **Solution: Aerators**

  Aerator flows can eliminate the cavitation damages.

- **What does my research focus on?**

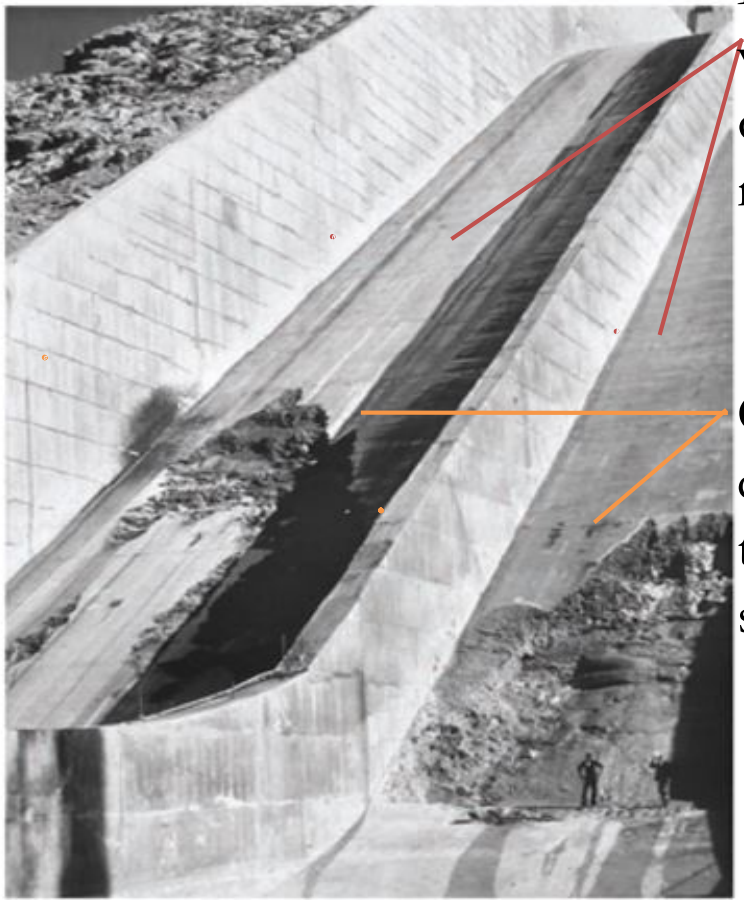
  My researches mainly focus on using **numerical methods** to gain a better understanding of **aerator flows**.

- What are cavitation damages in chute spillways?
- How does an aerator work?

Aerator Flows

Cavitation damages

- For high-head dams, the flow velocities in chute spillways are often in a range of 20-40 m/s.
- Local pressure in the chute bottom is below water vapour pressure.
- Vapour bubbles
- Bubble implosions erode the chute bottom.
- After some time, cavitation damages are generated.



Locations where cavitation may occur

Caviation damages in the chute spillway

Cavitation damages prevention

From experimental tests and prototype observations, if the air concentration near the wall boundary falls within 1.5–2.5%, the cavitation damages were obviously mitigated. If the concentration is between 7–8%, the damages disappear almost completely.

How to increase the air concentration of flows?

An aerator device is considered as a cost-effective means to entrain air.

Aerators

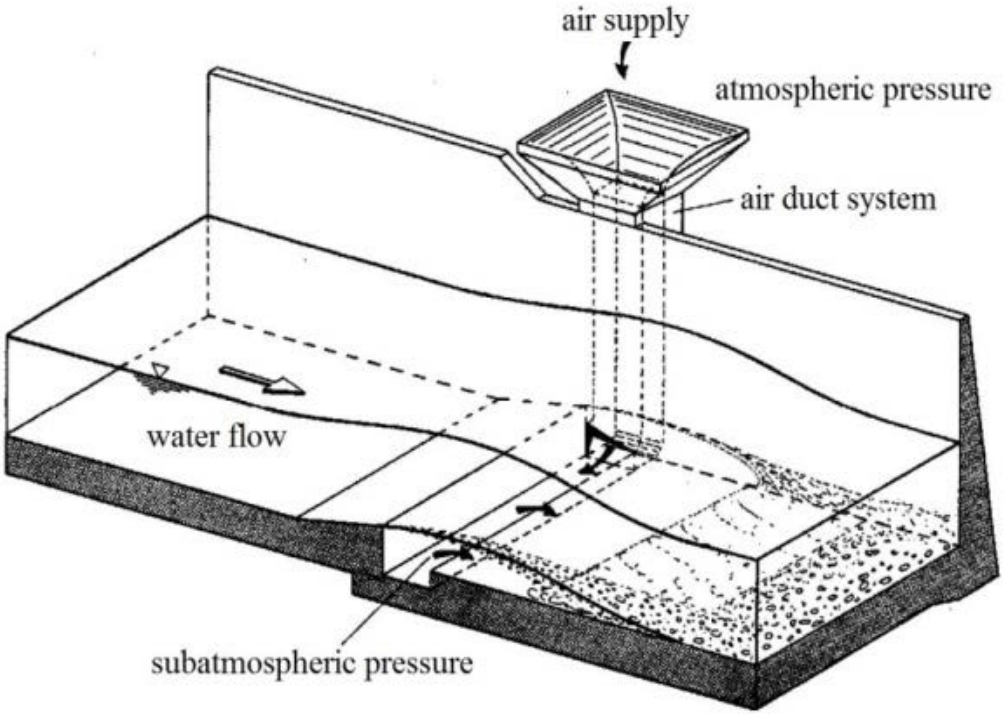
How does an aerator work?

↓ A jet is generated

↓ Air in the cavity is entrained by the jet

↓ Pressure difference in the duct system

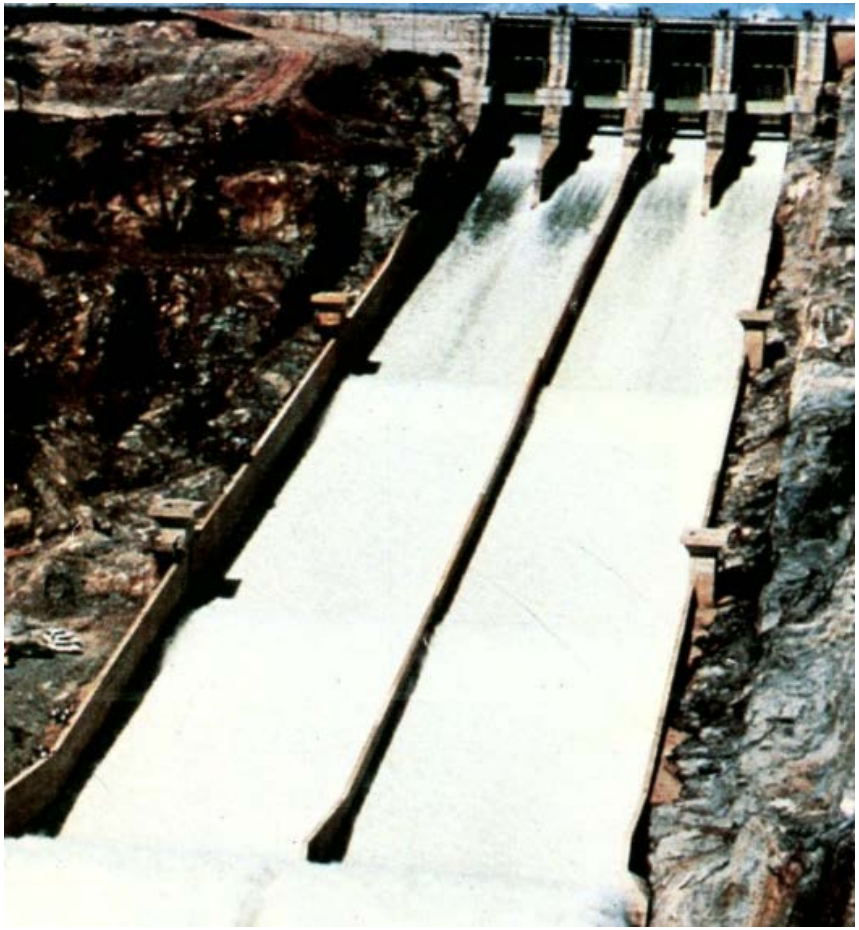
↓ Air is sucked



Principle of aerator device (Koschitzky 1987)

Aerator flows

- Air is entrained by a jet.
- A cavity is created below the jet.
- Air concentrations of the flow are increased downstream of an aerator.



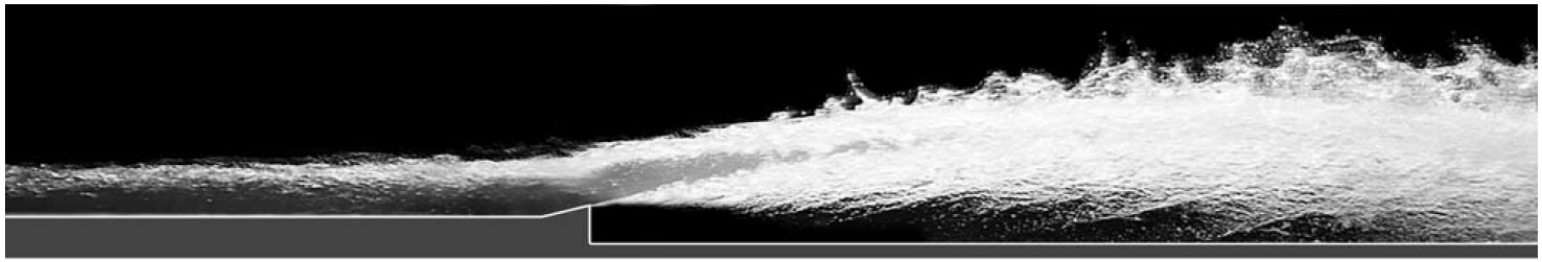
Foz do Areia in Brazil

How to study aerator flows?

Experiments and Numerical Methods

Numerical Methods

Aerator flows are typically two-phase flow.



Which multiphase flow models should be employed?

- **Volume-of-Fluid Model**
- **Two-Fluid Model**

Bergeforsen Dam

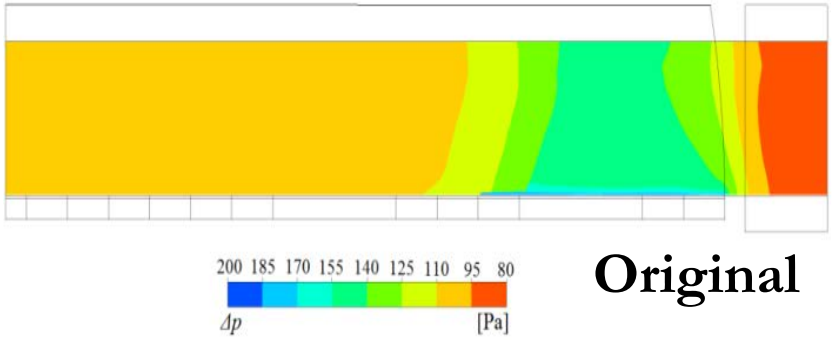
Background

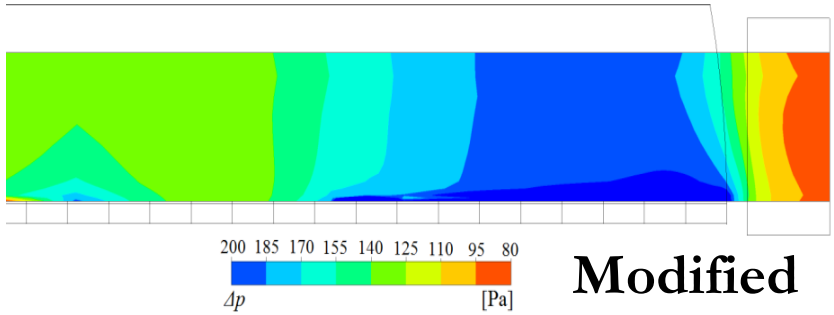
- An unconventionally wide chute aerator, with a width of 35 m.

- A non-negligible difference in the air pressure distribution within the duct.

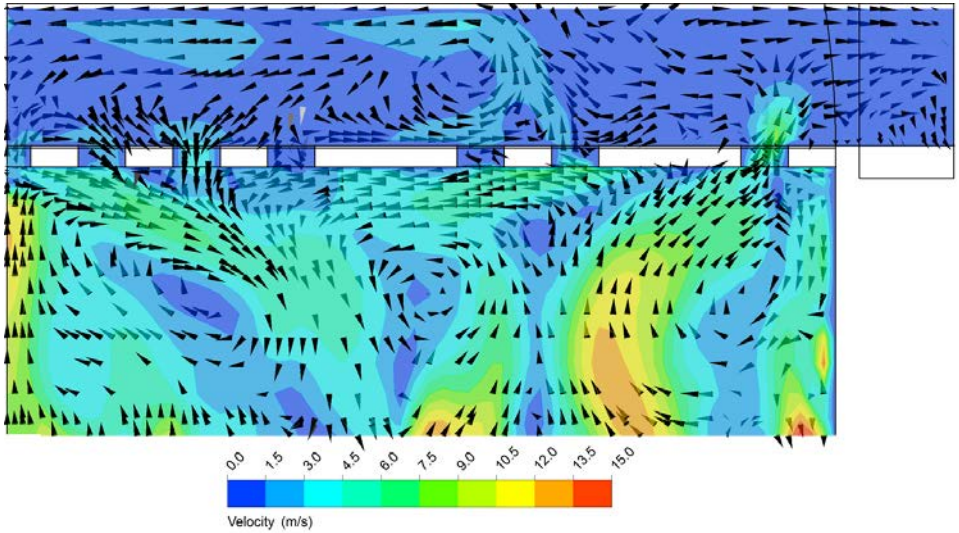
Numerical Model

- Volume of Fluid Model
- 3D Computational Domain
- A modified layout of air vent is studied

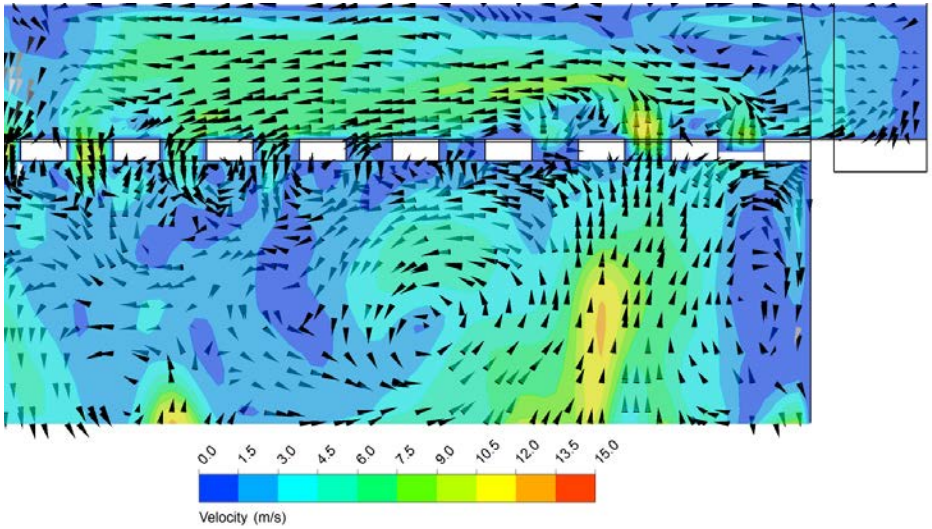




Teng, PH and Yang, J (2016). CFD modelling of two-phase flow of a spillway chute aerator of large width. Journal of Applied Water Engineering and Research.



Original layout



Modified layout

Results

- For the **large width** aerator, its performance is sensitive to **the air-vent layout**.
- An **improved** air flow field in the aerator leads to an increase in the air supply capacity.

Gallejaur Dam

Background

- Prototype observations and Physical model tests

A contradicting conclusion

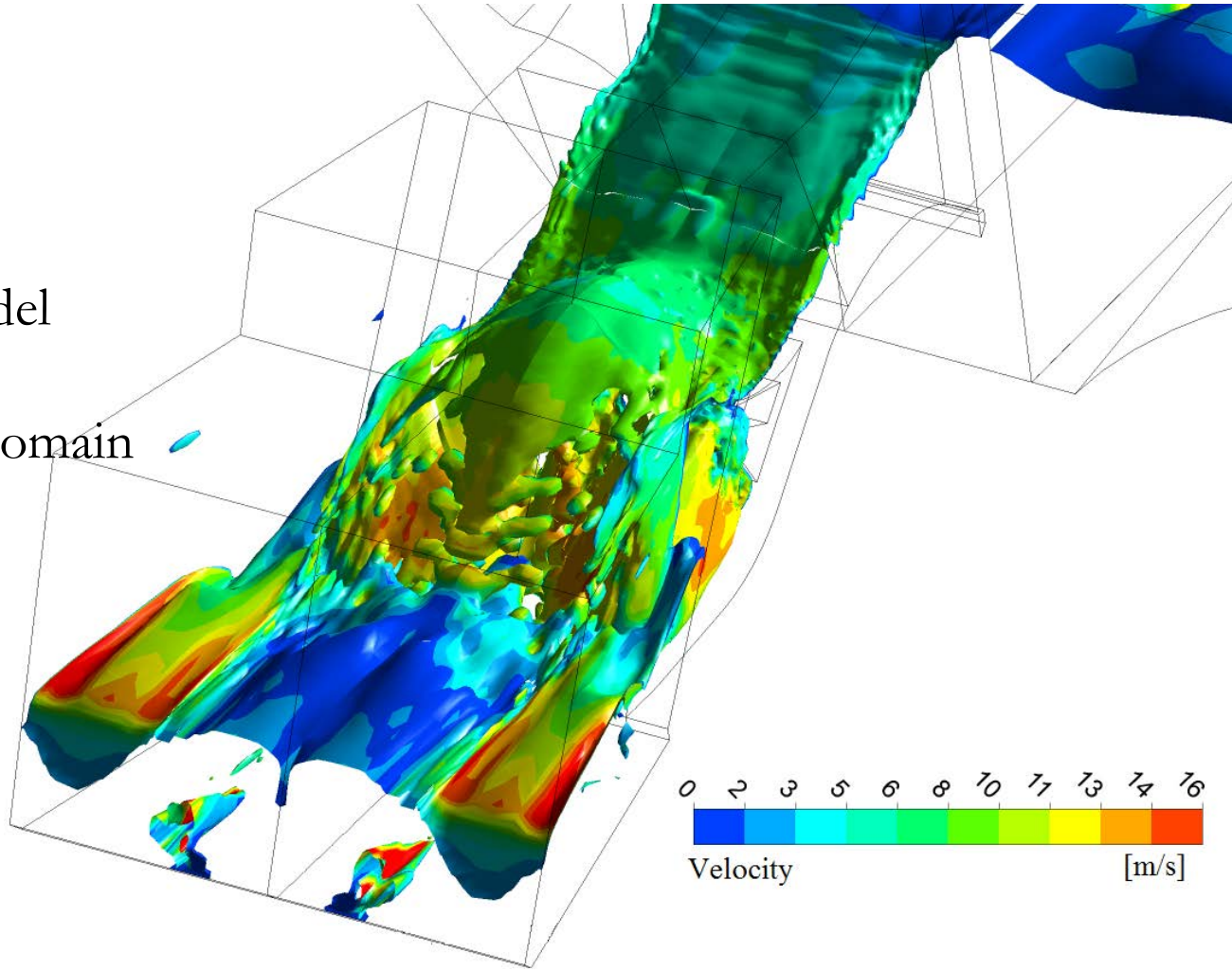
Prototype Observation

Physical Model Tests

- Numerical simulations are preformed to help seek the reason for the discrepancy.

Numerical Model

- Volume of Fluid Model
- 3D Computational Domain



Teng, PH and Yang, J. Flows over flip-bucket aerators,physical and CFD modeling with prototype tests. Submitted to Journal of Hydraulic Engineering, ASCE, for possible publication (under review).

Results

- The effects of surface tension play a non-negligable role in the physical model tests.

- In the experiments, the air flow and jet features cannot be correctly modeled by the Froude similarity law.

Comparison with experimental data

Background

- A set of reasonable experimental data.

- Aim to study the feasibility of the Two-Fluid Model for simulating aerator flows.

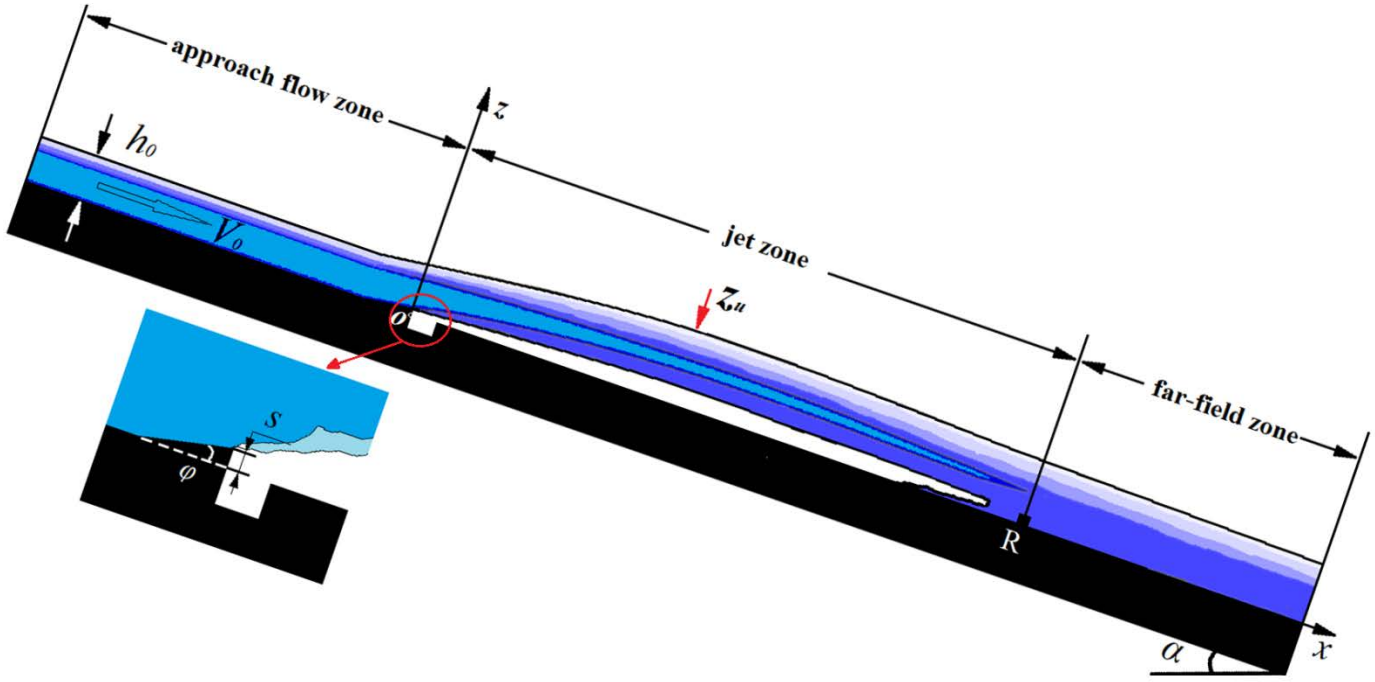
Challenge

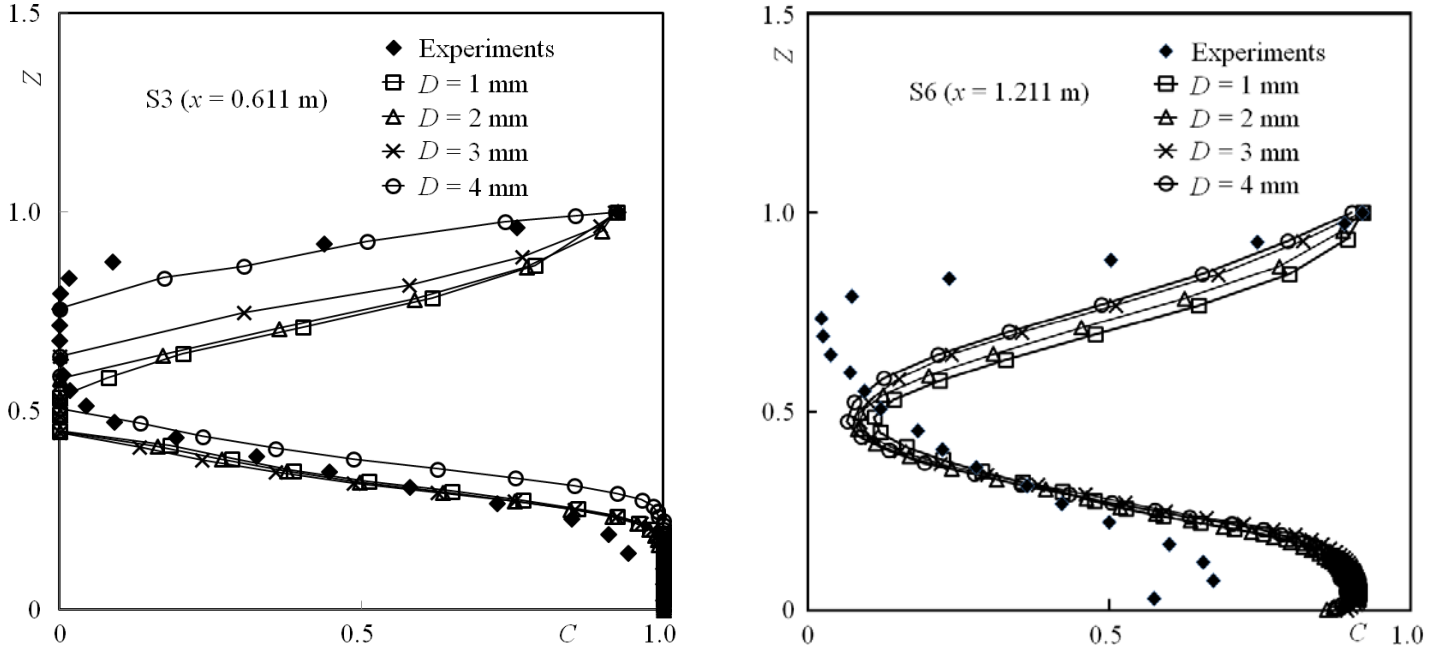
- Limited literature for the application of Two-Fluid model into aerator flows.

- A few parameters need be set in the model, including the air bubble diameter, the drag force, the lift force and other forces.

Numerical Model

- Two-Fluid Model
- 2D Computational Domain





Teng, PH, Yang, J and Pfister M (2016). Studies of two-phase flow at a chute aerator with experiments and CFD modelling. Modelling and Simulations in Engineering.

Results

- Depending on the **bubble size**, the results of Two-Fluid model gives relatively good agreement with experimental data in the cavity zone.
- In the far-field zone, the simulations **overestimate** the air concentration.

Concluding Remarks

- Air-vent layout should be considered in a unconventionally wide spillway.
- Models should be sufficently large to overcome surface tension effect.
- The use of Two-Fluid model has some limitations in aerator flow modeling.

Future work

- Detached Eddy Simulation
- New Experimental Data, PIV, BIV in Taiwan
- Population Balance Model
- …..

Thank you!