Comparative analysis of the energy dissipation on a stepped spillway downstream of a Piano Key Weir

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2nd Int. Work. on Labyrinth and Piano Key weirs – PKW 2013
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PKW can be placed on the top of gravity dams

L'Etroit dam - France

Saint Marc dam - France

Introduction

PKW can be placed on the top of gravity dams
Recent projects considered PKW and stepped spillway

Ouldjet Mellegue - Algeria

Dakmi 2 - Vietnam

Introduction

PKW can be placed on the top of gravity dams
Recent projects considered PKW and stepped spillway
PKW toe → 3D interacting jets, aeration

Ogee crested weir

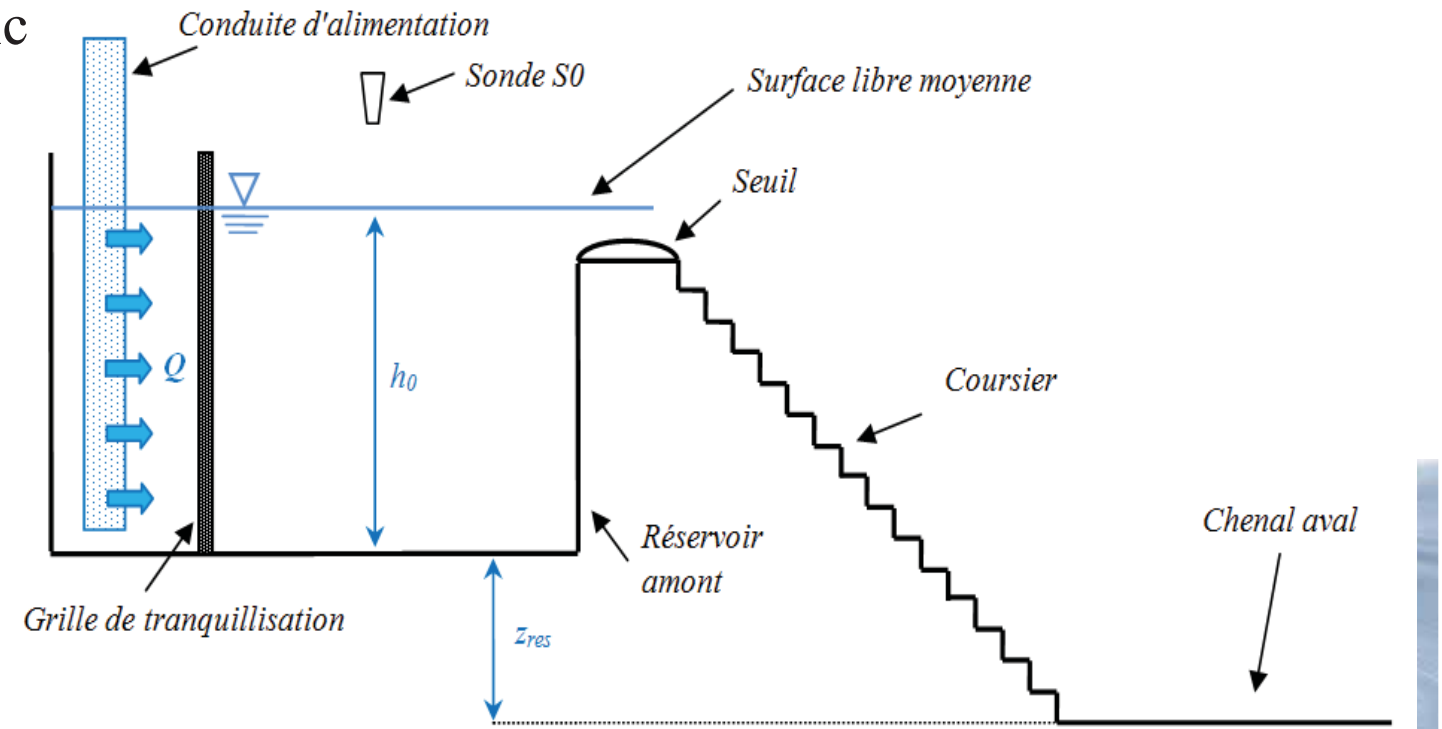
PKW1

PKW2

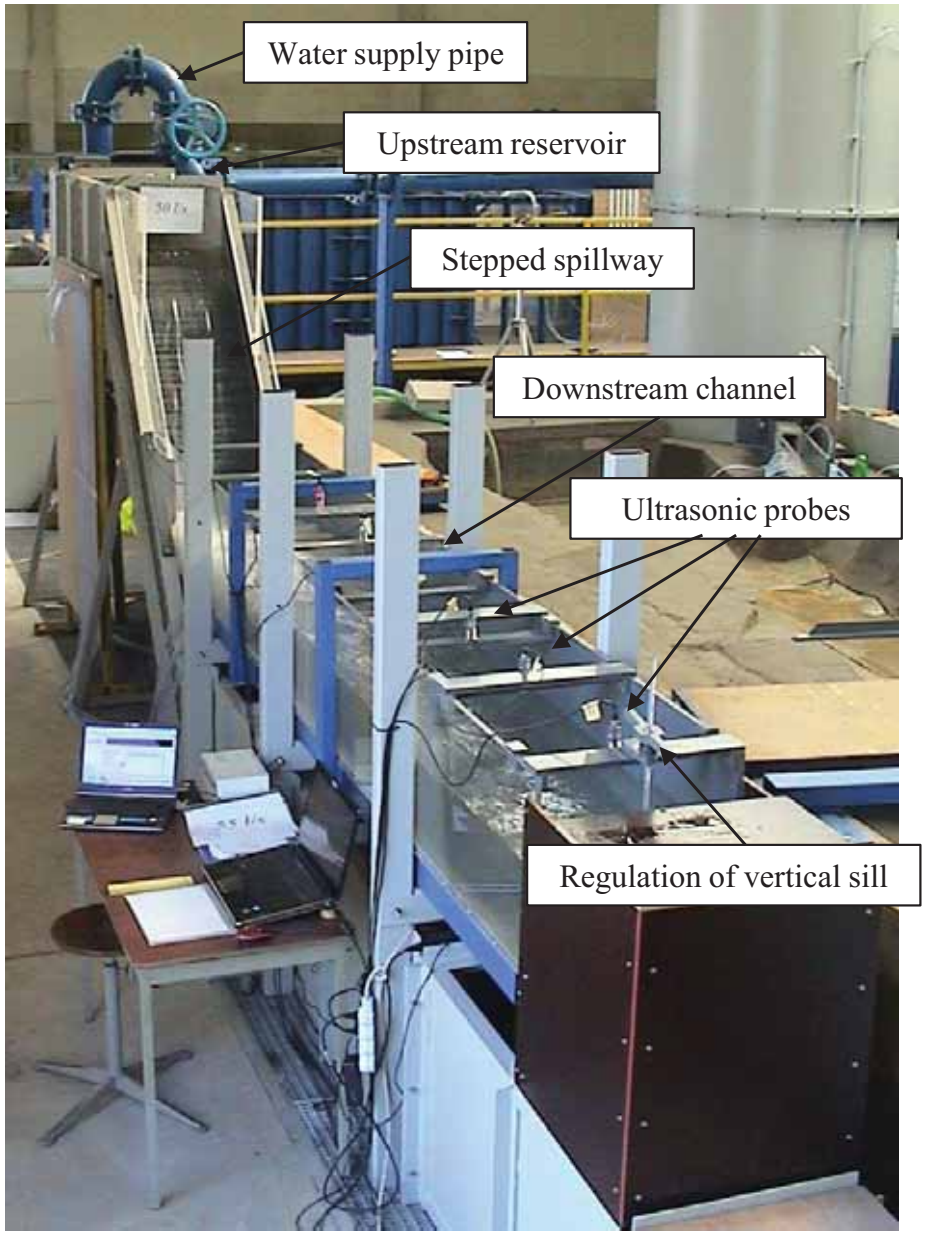
→ **? spillway length needed to reach uniform flow conditions ?**
Comparison with an ogee crested weir on the same spillway

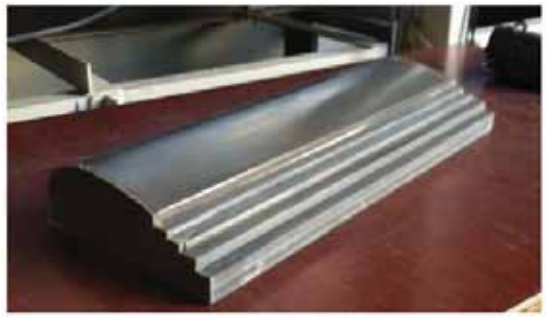
Experimental facility

- Upstream reservoir, regulated pump, electromagnetic discharge meter
- 0.494 m wide stepped spillway, 52° slope
- Regular steps 2.4 cm long and 3 cm high
- Variable spillway length: 0.64, 1.07, 1.29 & 1.71 m
- Downstream horizontal channel, 4.2 m long, with end vertical gate
- Ultrasonic probes
- Steel, PVC, Acrylic



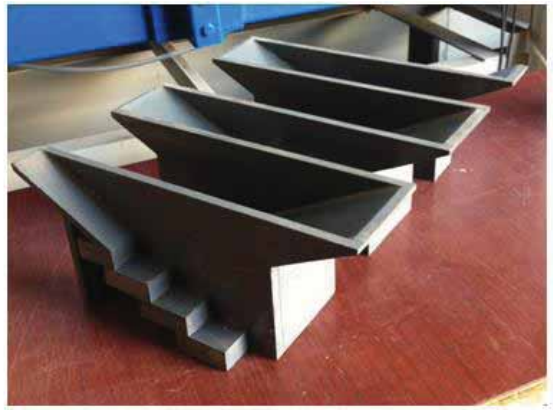
Experimental facility





Ogee crested weir (OCW)

PKW1

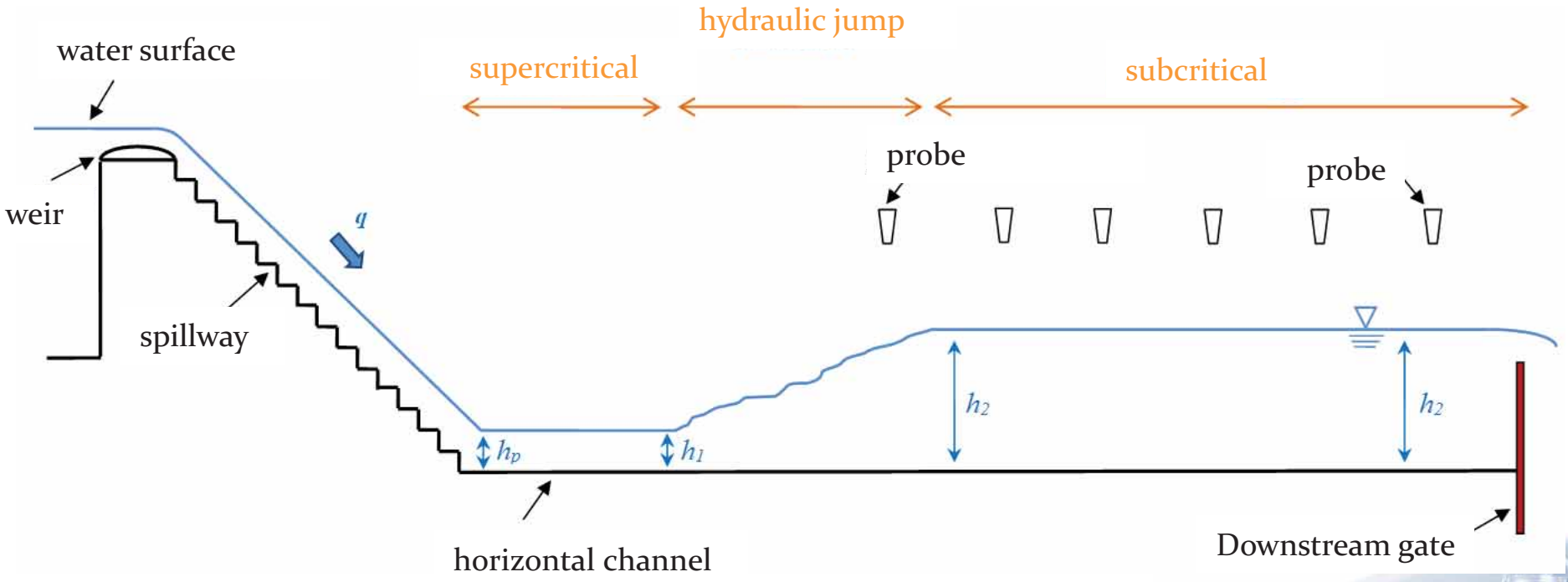


PKW2

Methodology

Goal: to compare residual energy at the spillway toe E_t for constant discharges and varied spillway lengths and weirs

→ Indirect method to compute E_t from water depth measurements in the horizontal channel (Shvainshtein 1999, Matos & Quintela 2004)



$$E_t = h_t + \frac{(q/h_t)^2}{2g}$$

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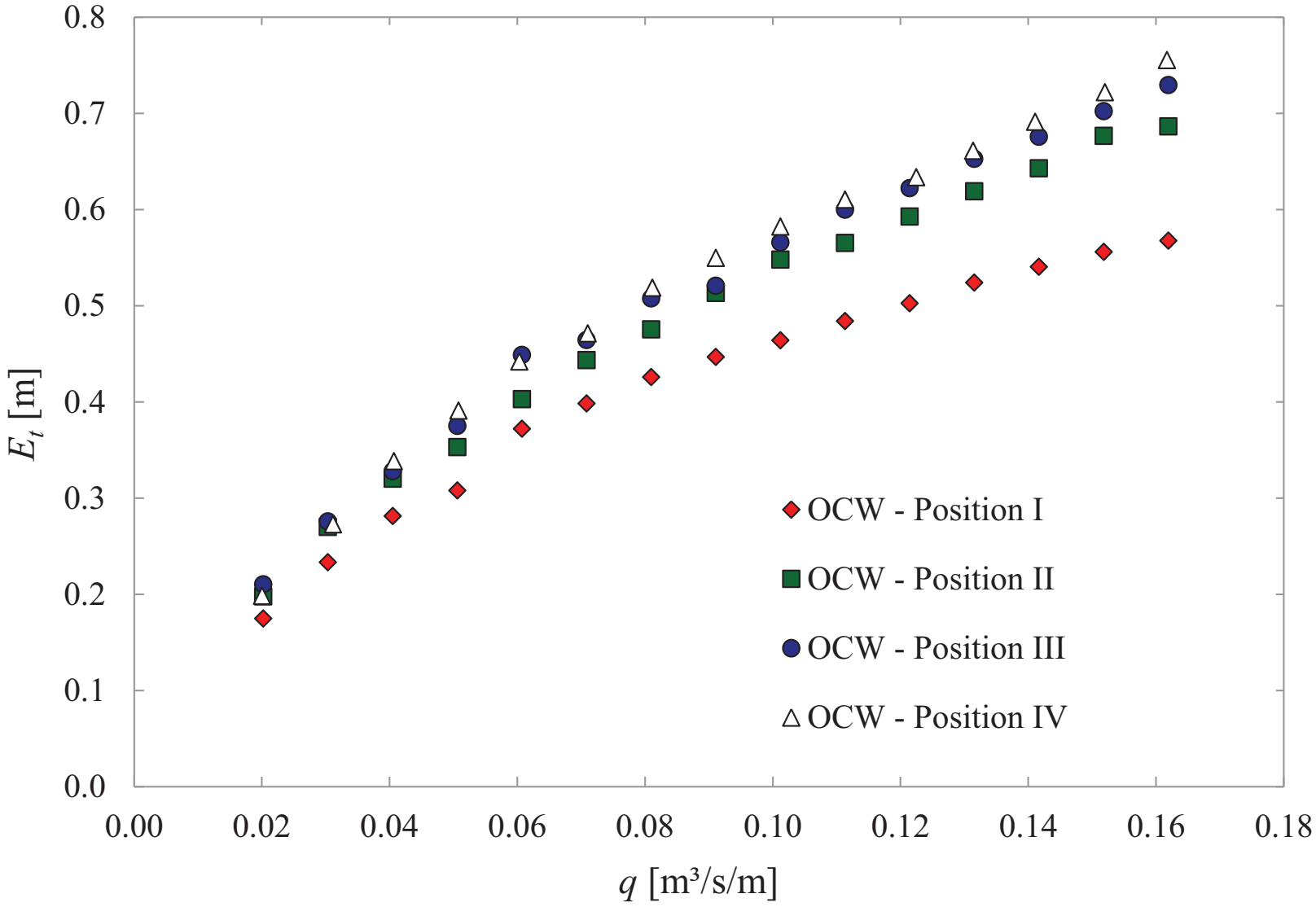
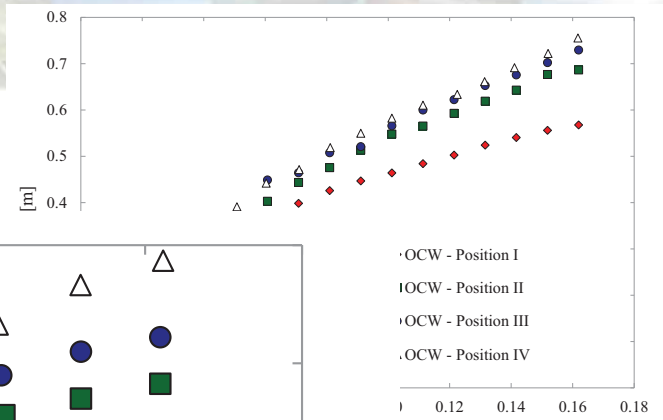
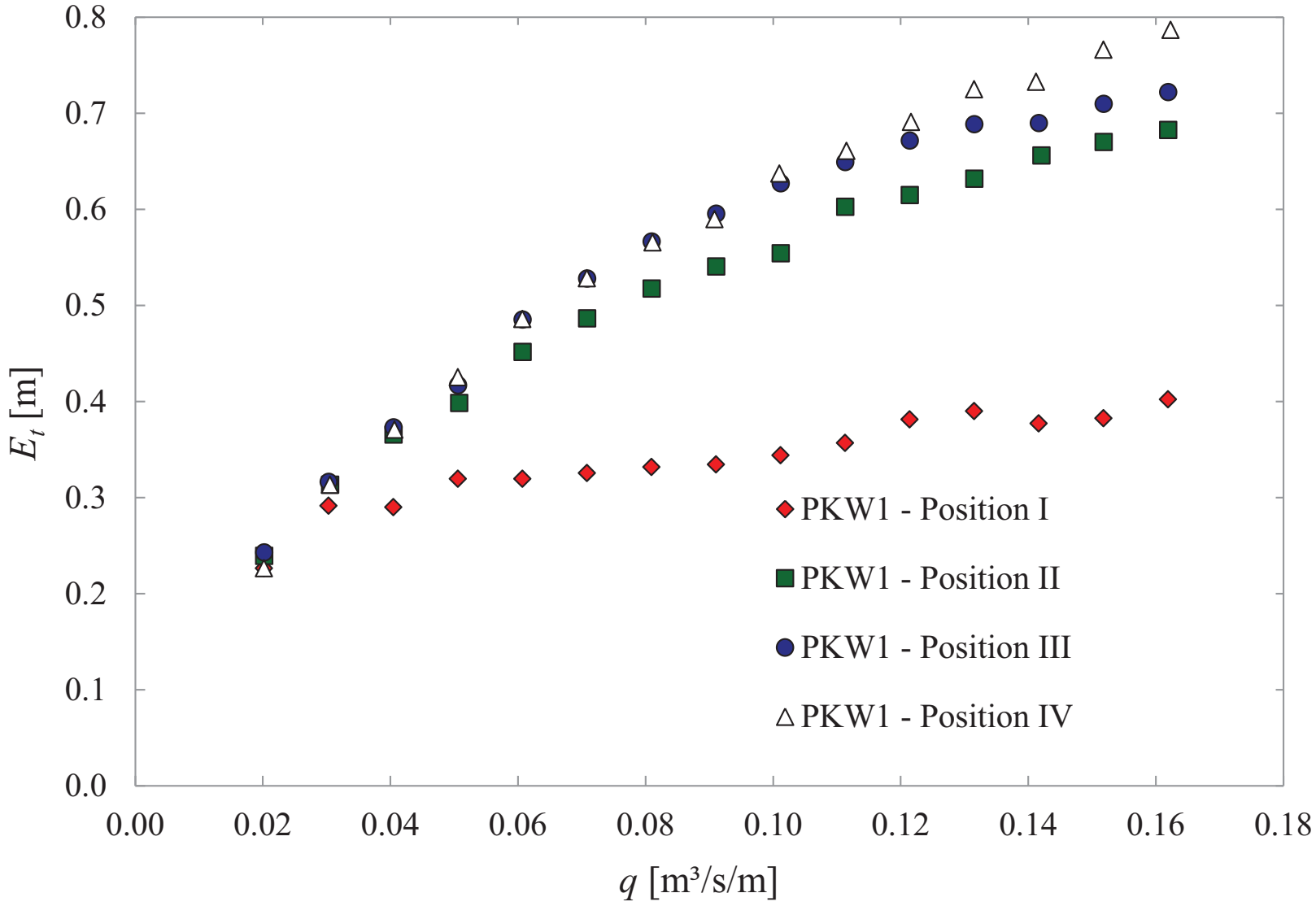
Residual flow energy at the spillway toe



Results and discussion

Residual flow energy at the spillway toe





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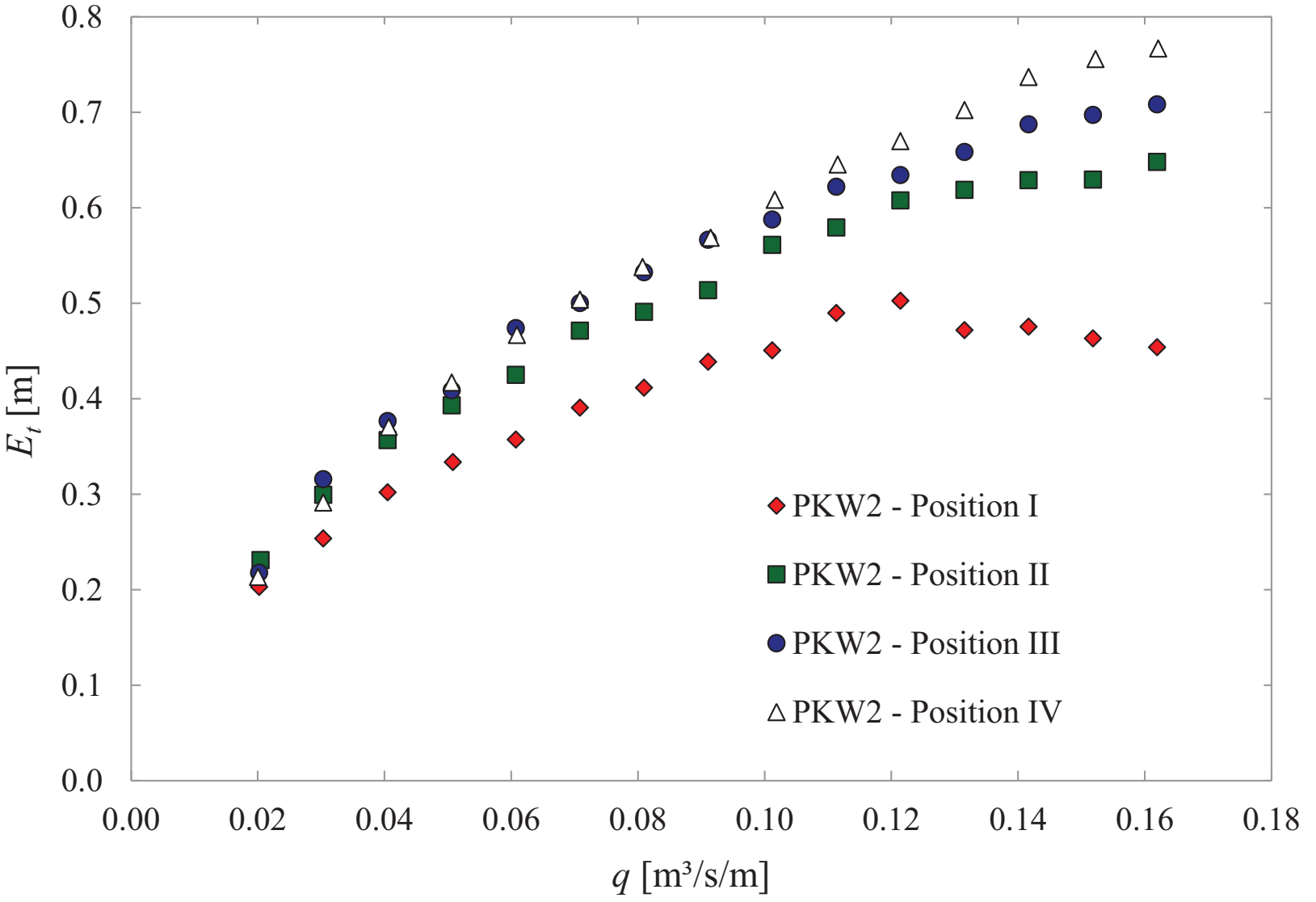
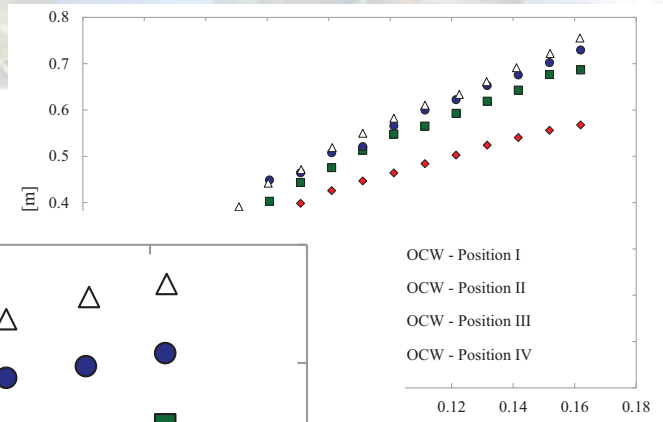
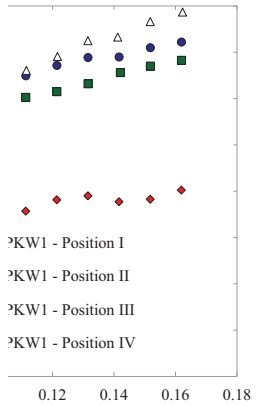
Results and discussion

Residual flow energy at the spillway toe







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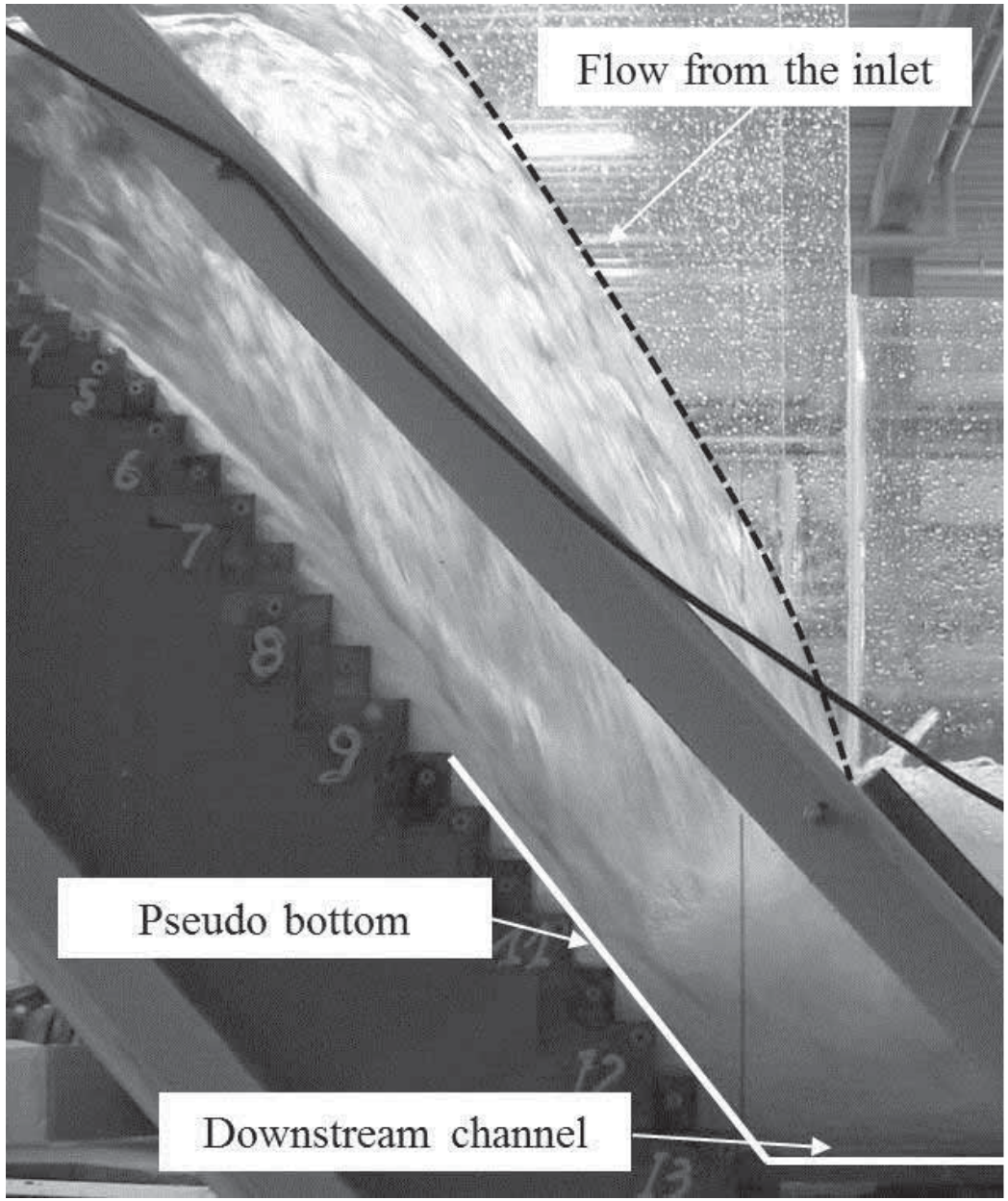
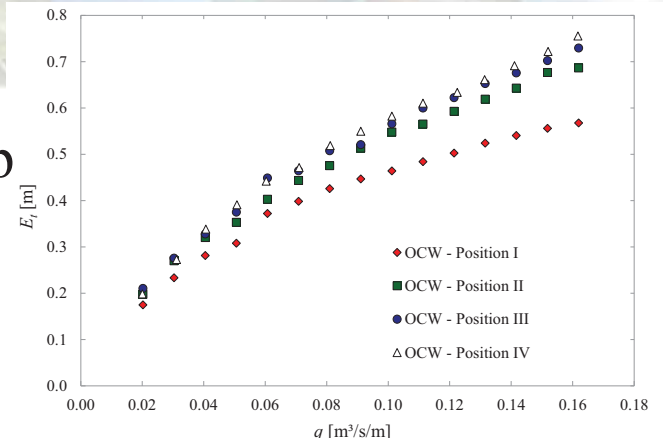
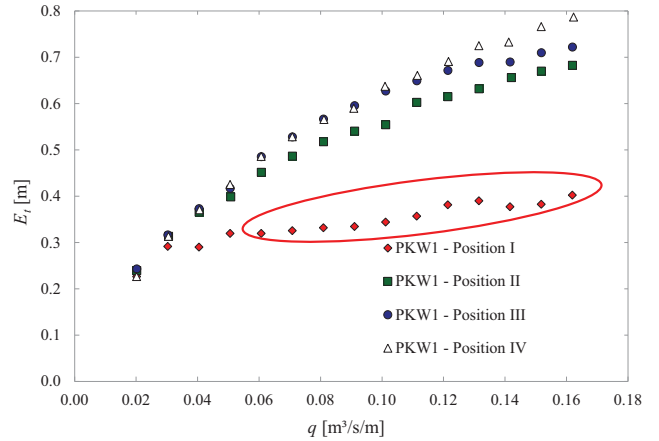
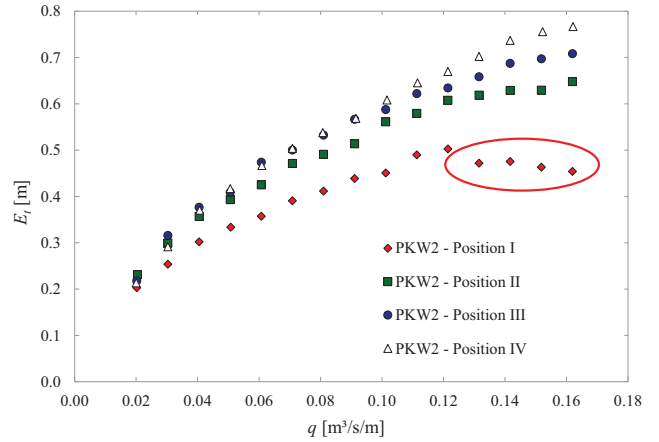
Results and discussion

Shortest spillway: inlet flow enters the hydraulic jump

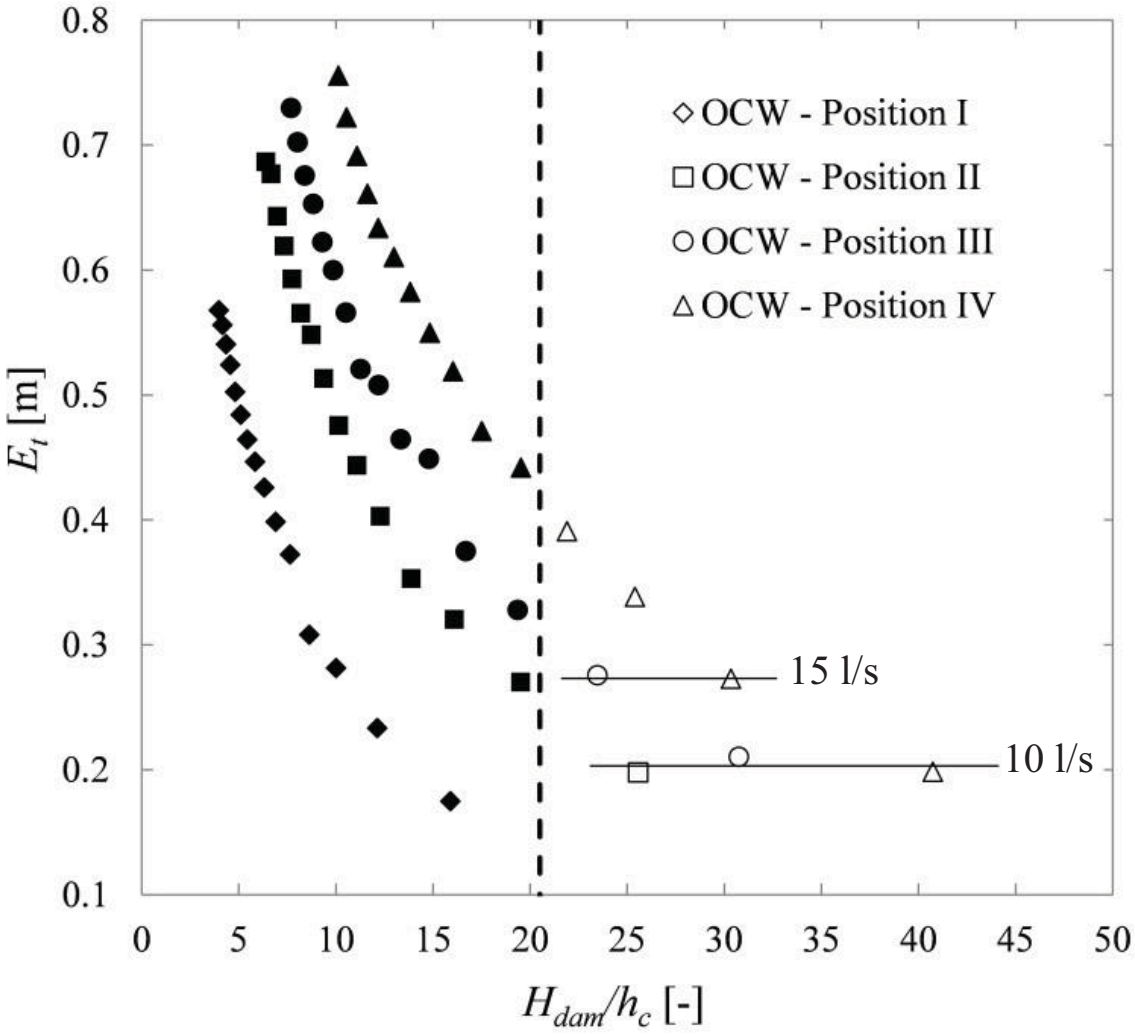








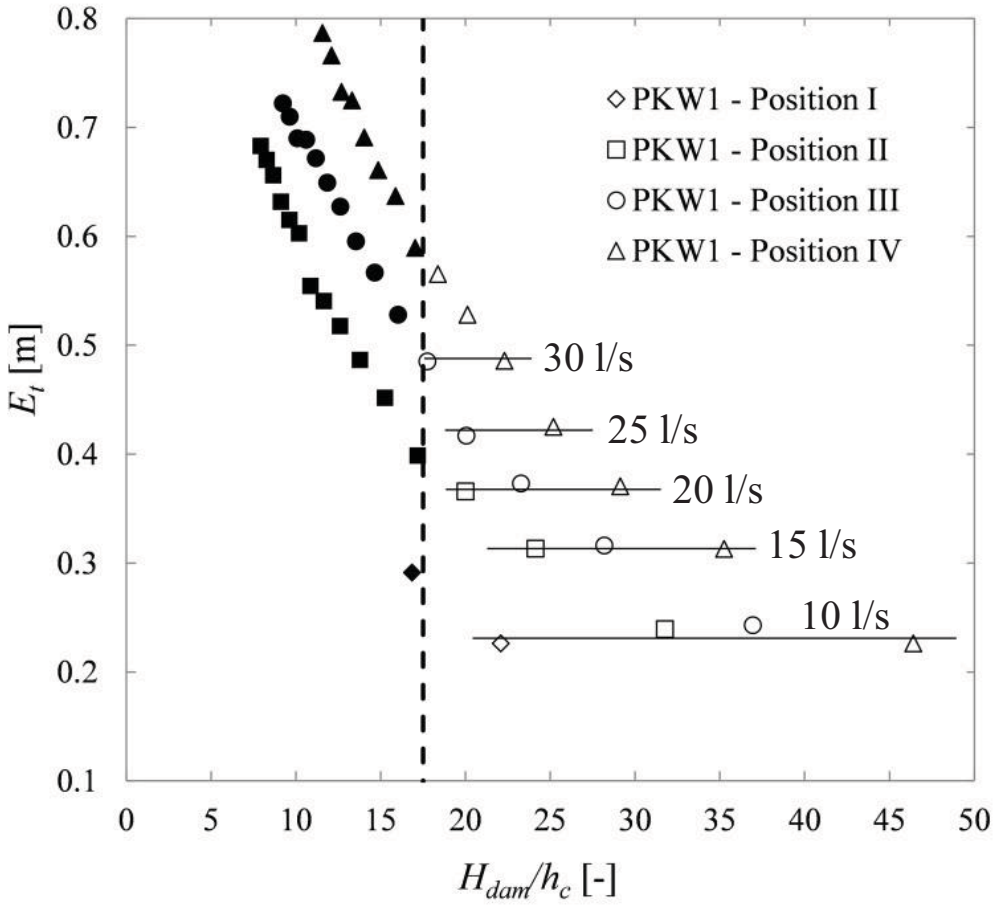
Uniform flow conditions → criterion on dam height

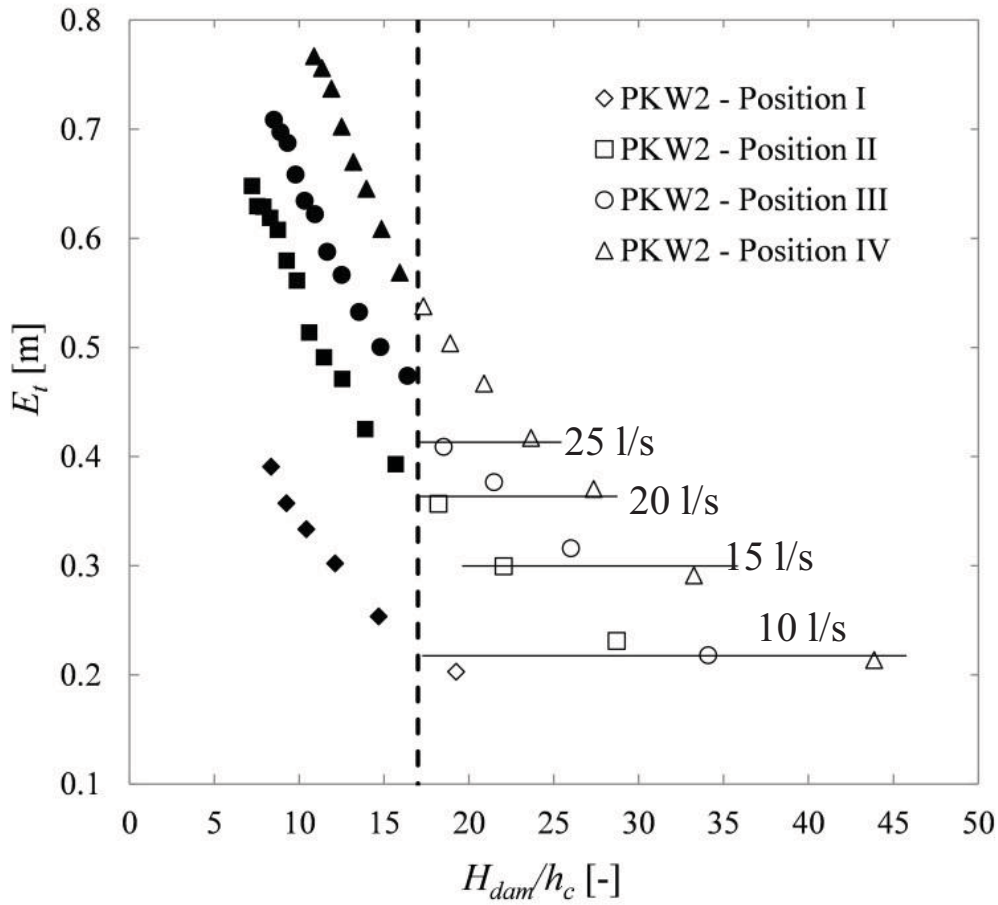


OCW → good comparison with Boes & Hager 2003 criteria

$$\frac{H_{dam,u}}{h_c} = 24\left(\sin\phi\right)^{2/3} = 20.5$$

Uniform flow conditions → criterion on dam height





→ shorter length required to reach uniform flow conditions

$$\frac{H_{dam,u}}{h_c} \cong 17.5$$

OCW with uniform flow conditions

and

Theoretical uniform flow energy $E_{f,u}$ (Boes & Hager 2003)

$$\frac{E_{f,u}}{E_{\max}} = \frac{F}{\frac{H_{dam}}{h_c} + \frac{3}{2}}$$

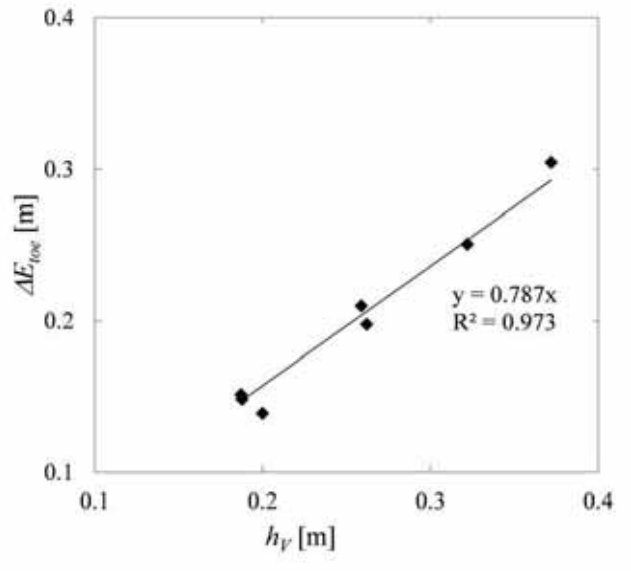
E_{max} = maximum reservoir energy head

F = parameter related to the bottom roughness

→ Evaluation of the local head loss ΔE_{toe} due to slope transition between the spillway to the downstream channel

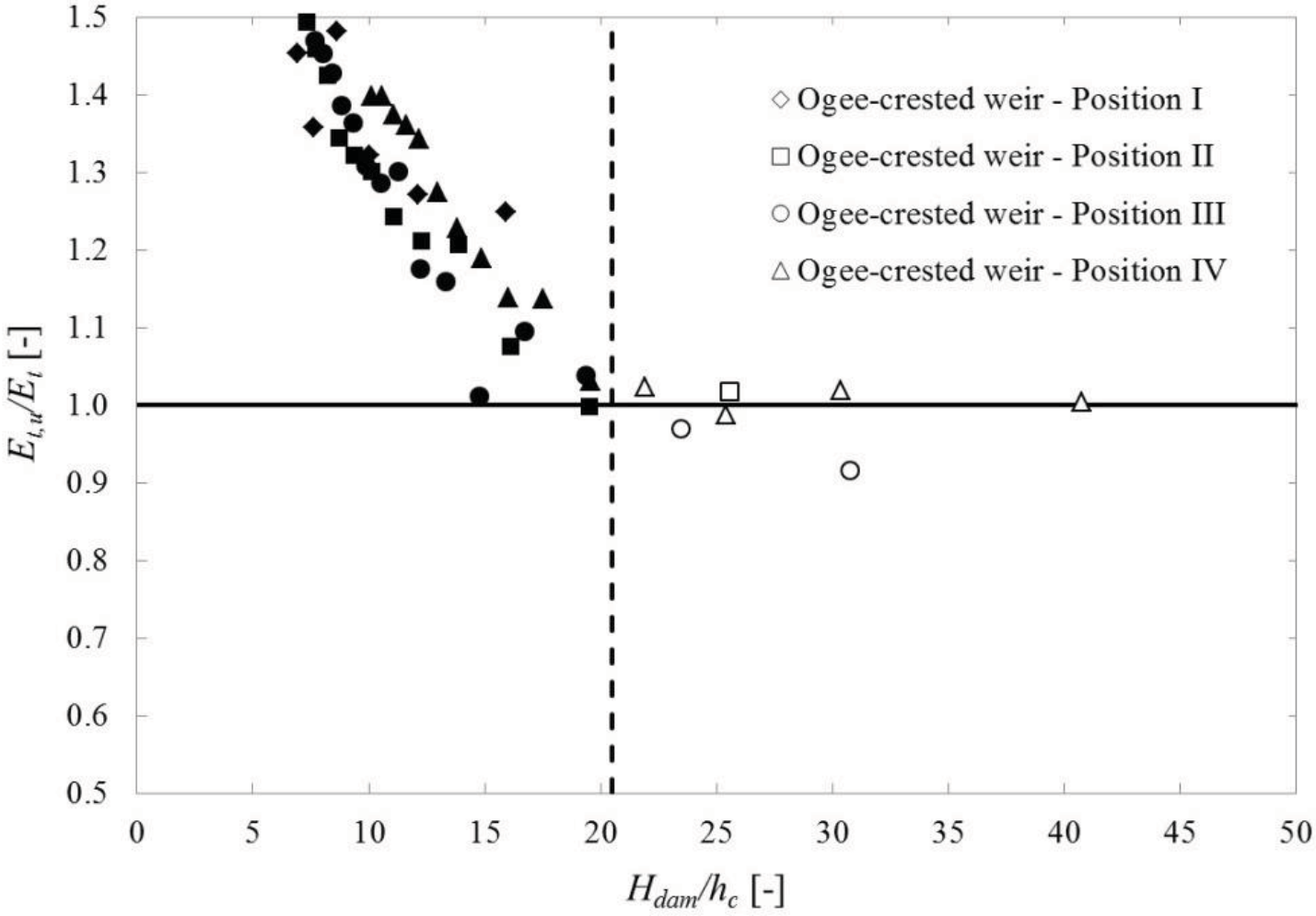
$$\Delta E_{toe} = k \frac{\left(q/h_t\right)^2}{2g} = k\, h_V$$

h_V = kinetic term of the downstream flow



Results and discussion

Using the same local head loss equation and coefficient whatever the flow conditions on the spillway,
Computation of a theoretical uniform flow energy at the spillway toe from Boes & Hager 2003 relation



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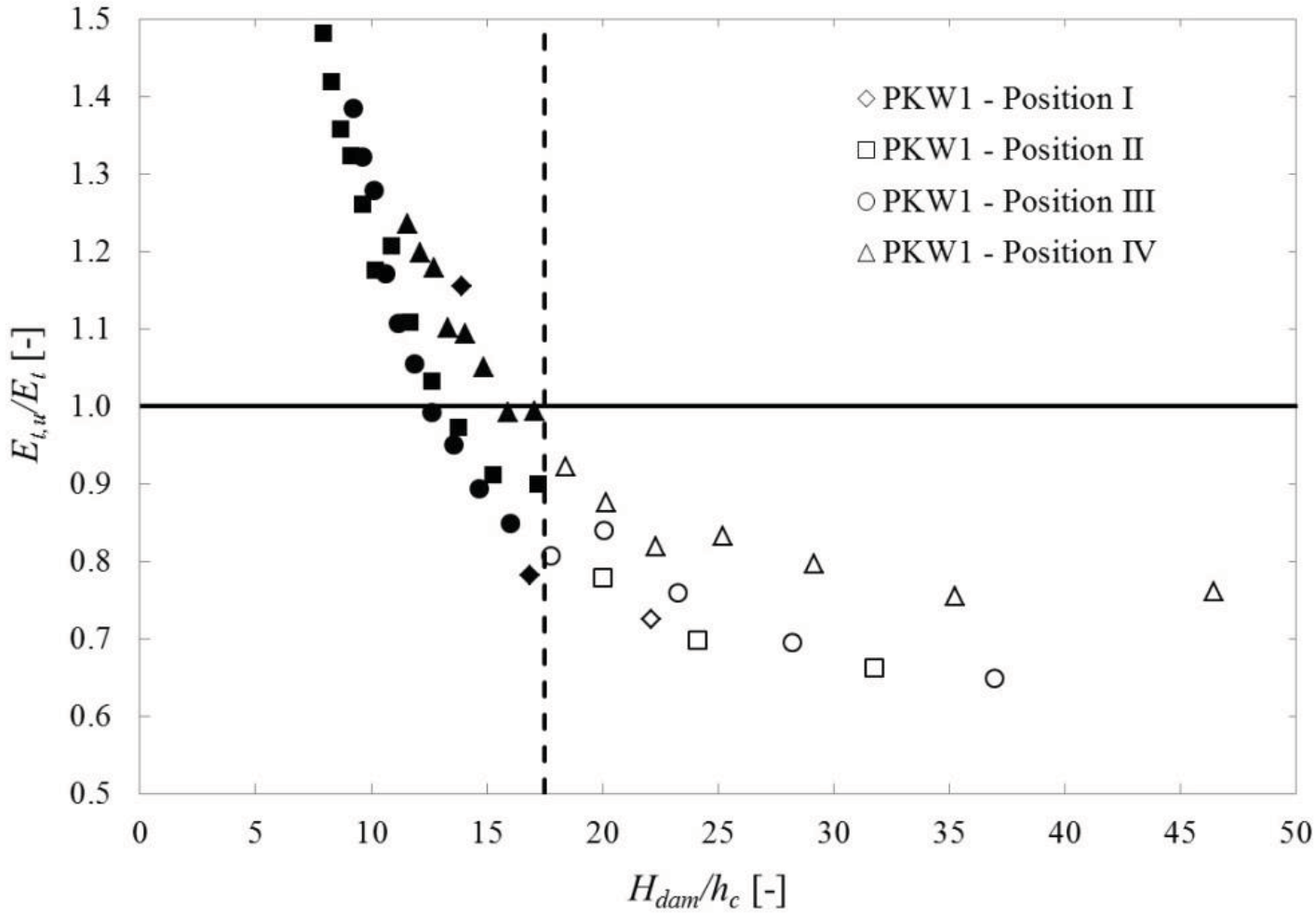

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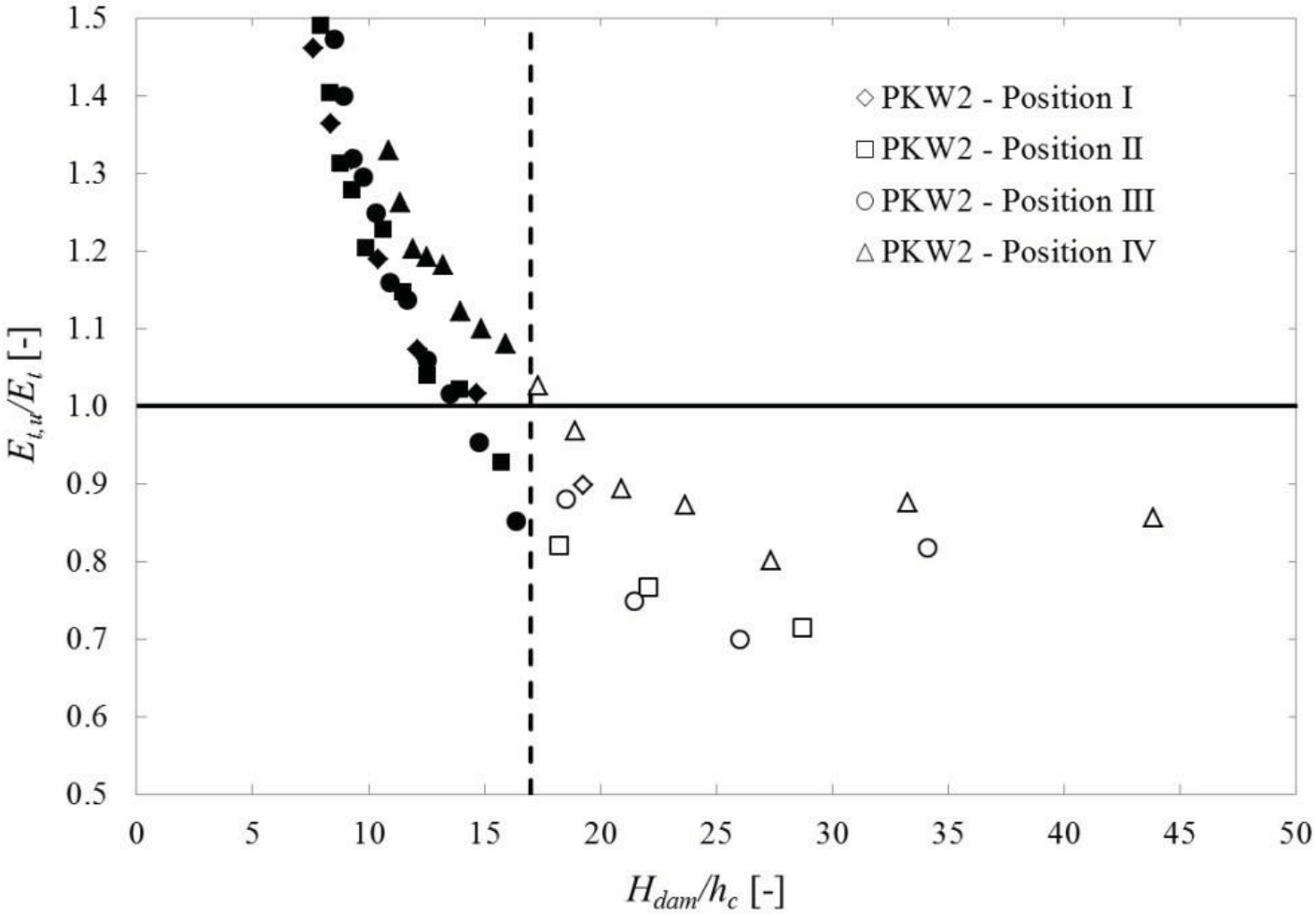

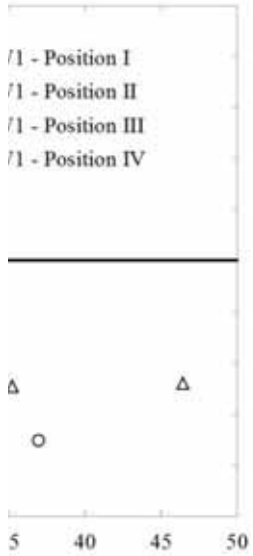

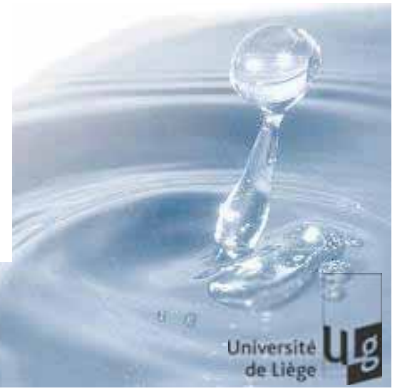

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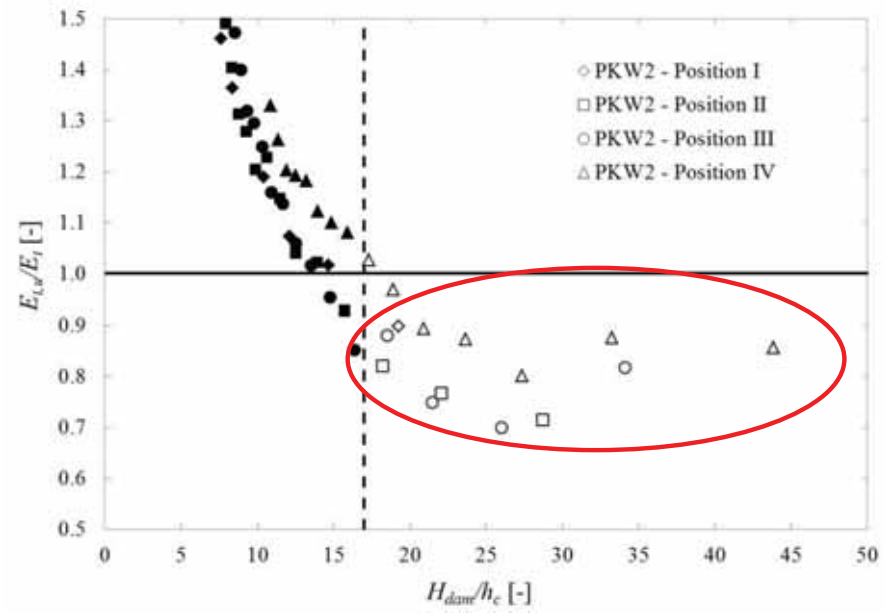

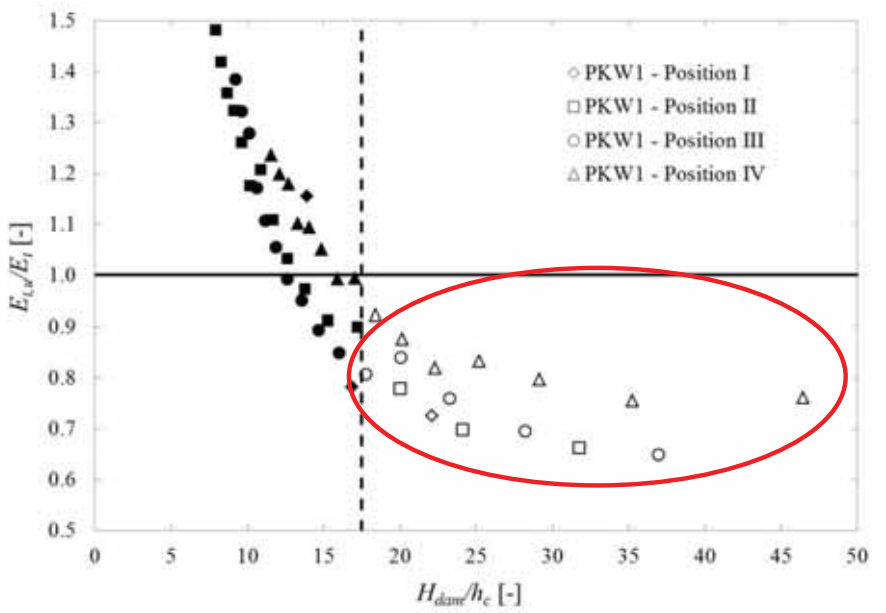

→ Higher uniform flow energy downstream of a PKW than the OCW

→ Uniform flow energy depends on the PKW geometry

Conclusions

Systematic experimental study to compare the residual energy at the toe of a 52° stepped spillway of varied length considering an ogee crested weir or a PKW at the top of the structure

→ Uniform flow conditions are reached on shorter spillway downstream of a PKW than an ogee crested weir

→ Uniform flow energy depends on the type of weir

→ Uniform flow energy is higher downstream of PKW than ogee crested weir

Further analysis is needed to highlight the reasons of this energy difference

I thank you for your attention!