An Air-Bubble Screen Used as a Countermeasure to Reduce Erosion in Open-Channel Bends

ICSE6 Paris - August 27-31, 2012

Violaine Dugué, Dr. K. Blanckaert, Prof. A. J. Schleiss

LABORATOIRE DE CONSTRUCTIONS HYDRAULIQUES

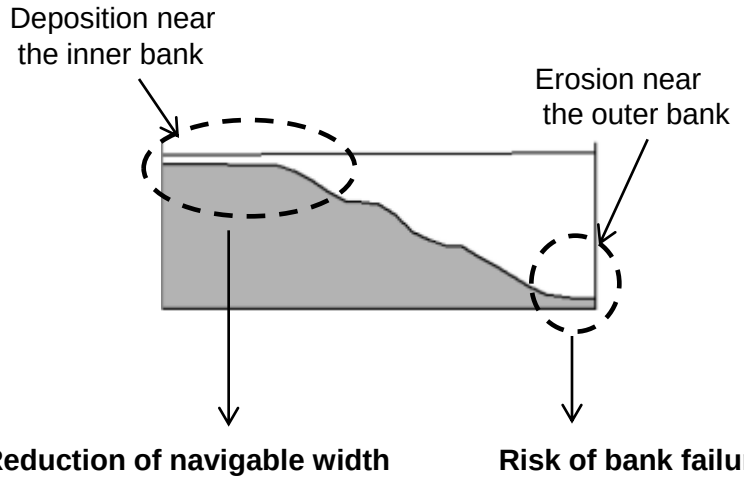
ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

Contents

- Context
- Preliminary results
- Experimental setup
- Morphological results
- Hydrodynamical results
- Conclusions and perspectives

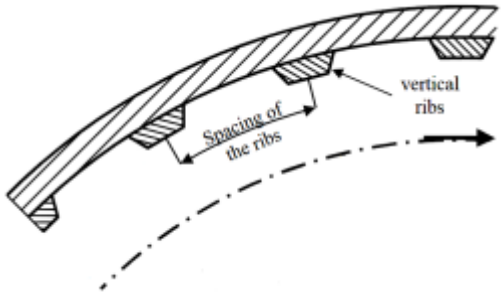
Context

Outer bend scour



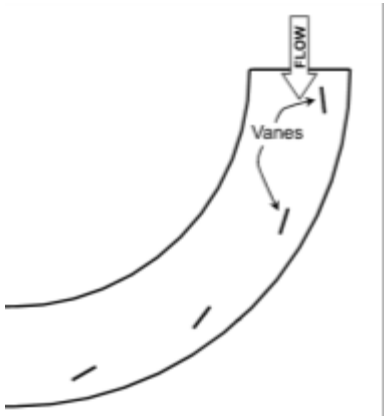
Existing controlling measures

Macro-roughness elements



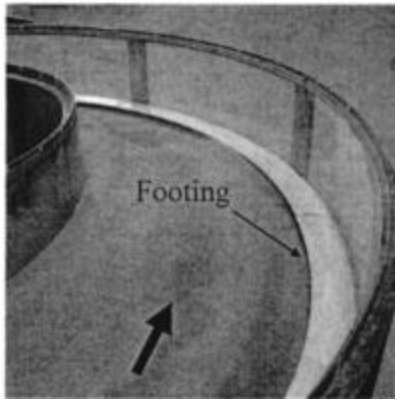
(Hersberger, 2002)

Bottom vanes



(Odgaard & Spoljaric, 1986)

Outer bank footing

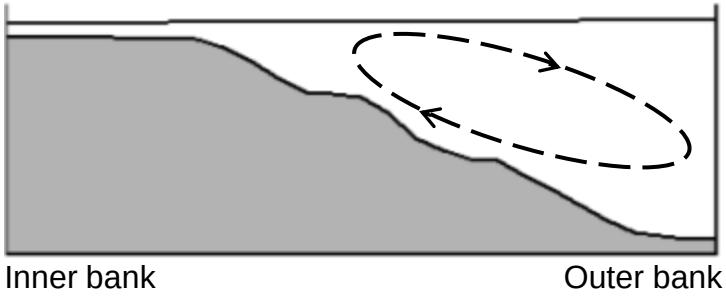


(Roca et al., 2007)

Context - Bubble screen technique

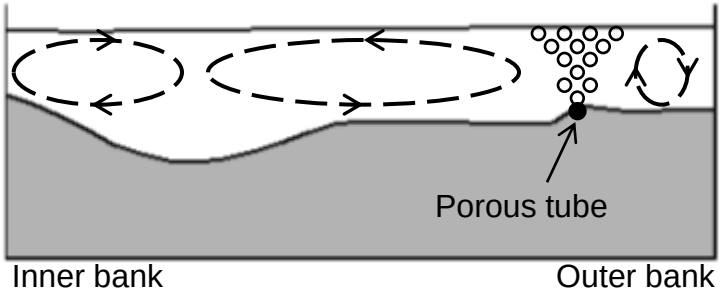
Without the bubble screen

- Curvature-induced secondary flow
- Bar-pool bed morphology



With the bubble screen

- Generation of the bubble screen by a porous tube
- Two bubble-induced secondary flows
- Redistribution of mean velocities
- Morphological impact



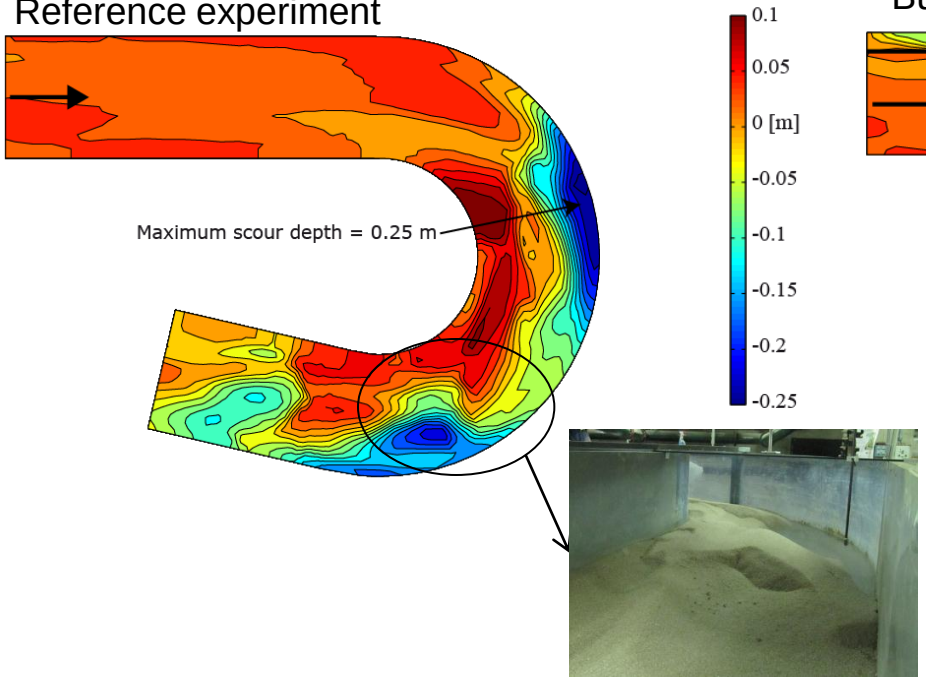
Other applications of bubble screens in hydraulic field

- Aeration and destratification of lakes and reservoirs *(Schladow 1992; Wüest et al. 1992)*
- Aeration of ice-covered rivers *(Neto et al. 2007)*
- As pneumatic barriers to reduce saltwater intrusion *(Nakai & Arita 2002)*
- As fish barriers to stop the spread of invasive species *(Welton et al. 2002)*

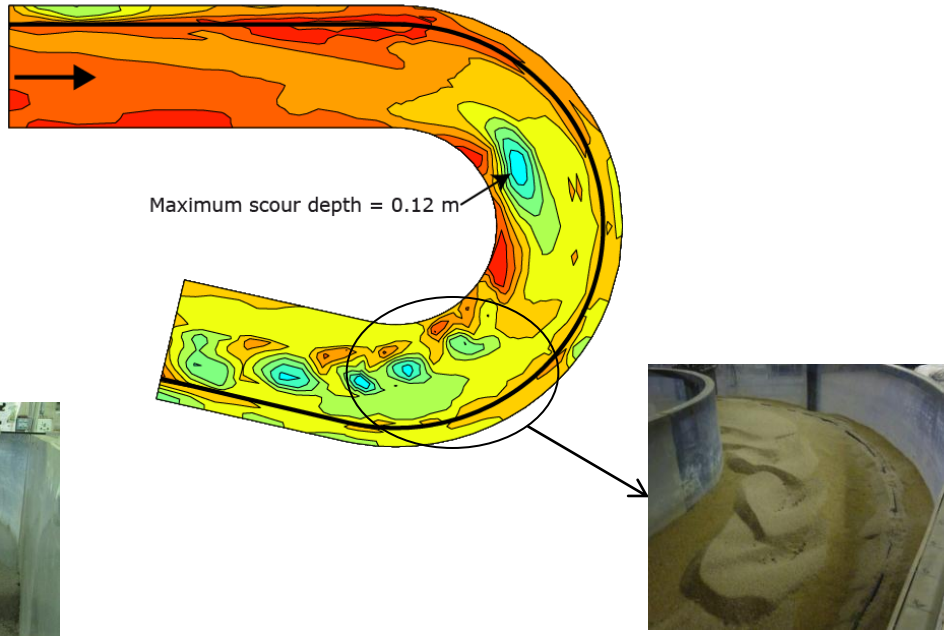
Preliminary results

Clear-water scour results *(Dugué et al. 2012)*

Reference experiment



Bubble screen experiment



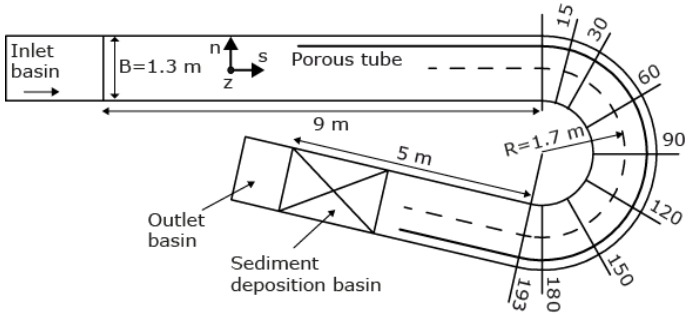
Conclusions:

- Maximum scour depth reduced by about 50%
- Scour hole shifted away from the outer banks
- Deposition bar almost vanish

Experimental setup

Open-channel bend

- Constant width B = 1.3 m
- Sharply curved 193 ° bend (R = 1.7 m)



Sediment:

- Quasi-uniform quartz sand (mean diameter d_s = 2 mm)
- Sediment feeder at the entrance of the channel (q_s = 0.025 kg/(m.s))
- Settling tank at the end of the flume

Bubble screen:

- Porous tube connected at both ends to an air-pressure device
- Ballasted with a chain and placed at 0.2 m from the outer bank
- Air pressure controlled by a manometer
- Air discharge measured with a rotameter

Experimental setup

Instrumentation

- Water surface elevation ⟶ Point gauge
- Final bed elevation ⟶ Laser distometer
- Velocity profiles ⟶ ADVP (Acoustic Doppler Velocity Profiler)

Experimental conditions:

- Live-bed conditions with constant sediment feeding (q_s = 0.025 kg/(m.s))
- Initially horizontal bed
- Two experiments performed under similar hydraulic and sediment conditions without and with the bubble screen

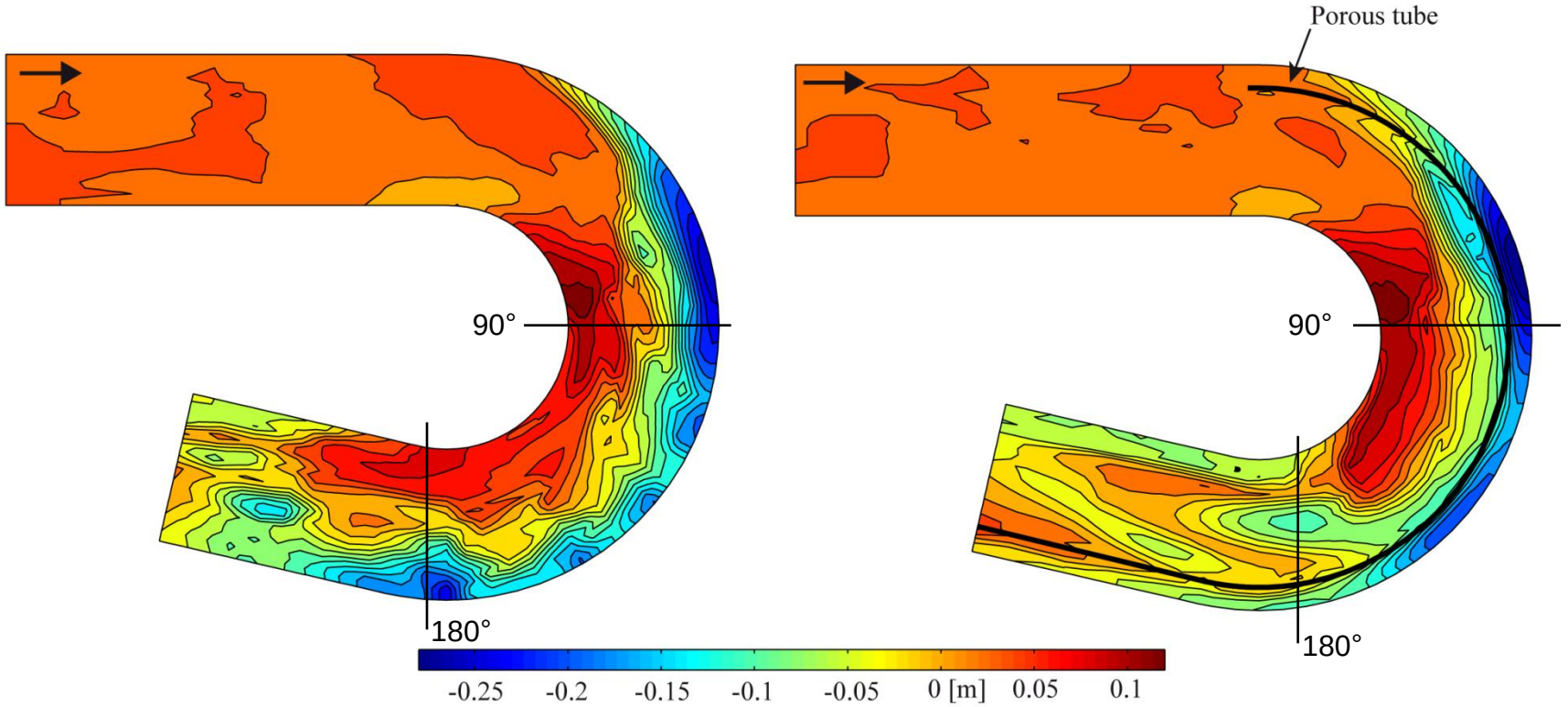
Label	*Q* *[l/s]*	*Pa* *[kPa]*	*H* *[m]*	*U* *[m/s]*	*R/B* *[-]*	*R/H* *[-]*	*B/H* *[-]*
M75_14_00	75	-	0.14	0.41	1.31	12.1	9.2
MB75_14_p6_d20	75	600	0.14	0.41	1.31	12.1	9.2

Morphology

Bottom elevation

Without bubble screen

With bubble screen

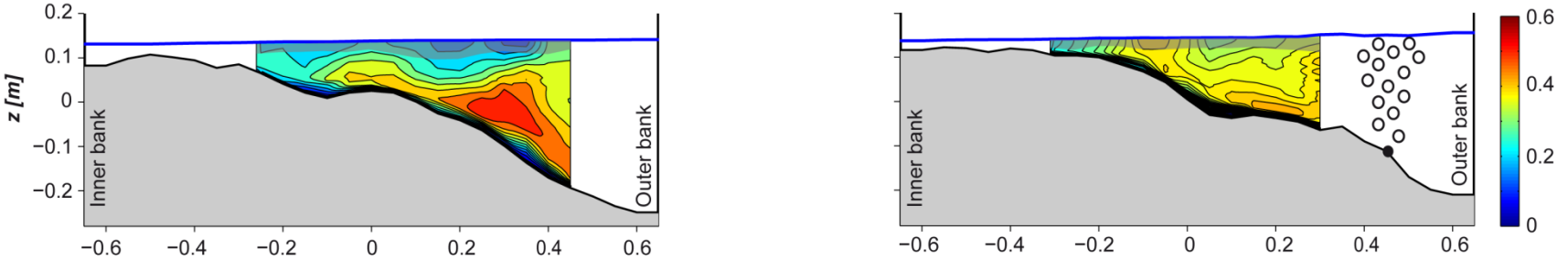


Velocity redistribution - Bend entry (90°)

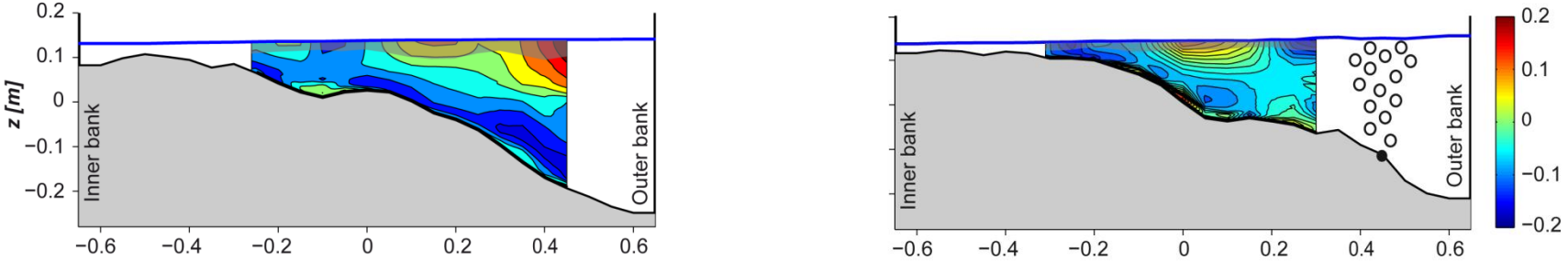
Without bubble screen

With bubble screen

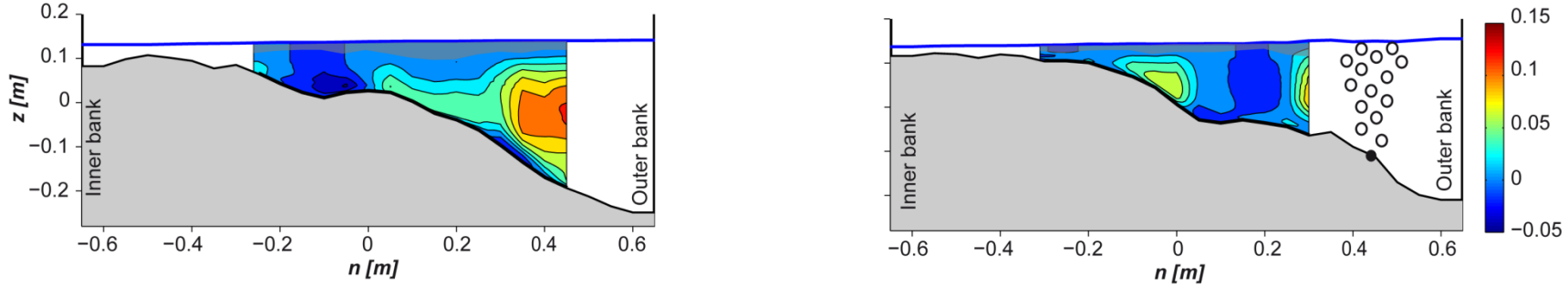
Streamwise velocity:



Transverse velocity:



Vertical velocity:

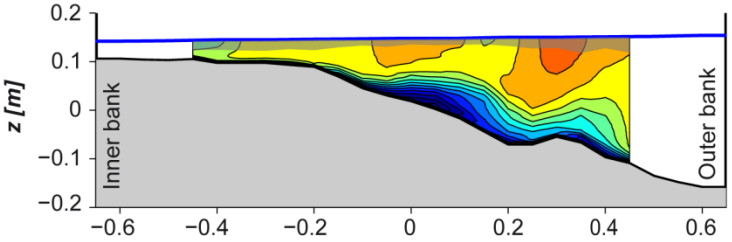


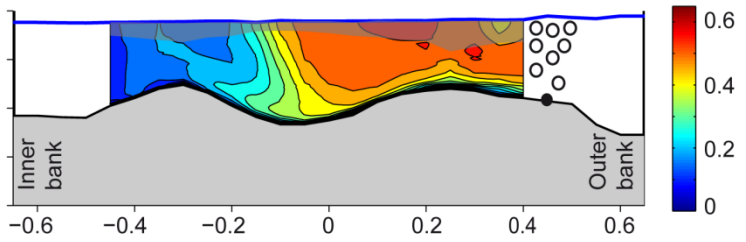
Velocity redistribution - Bend exit (180°)

Without bubble screen

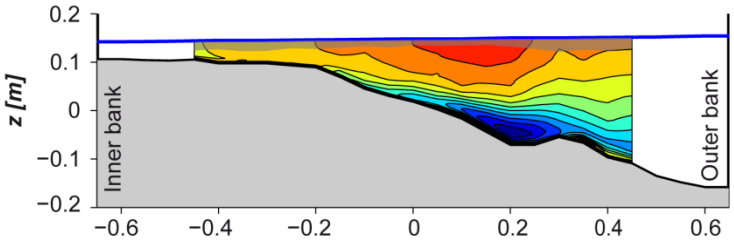
With bubble screen

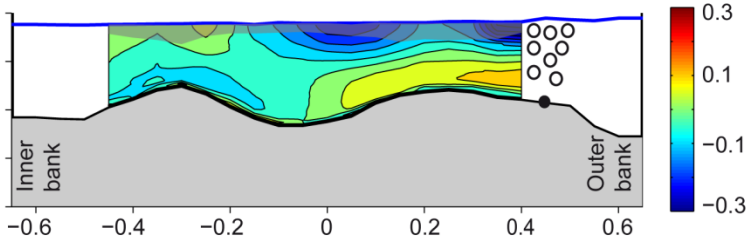
Streamwise velocity:



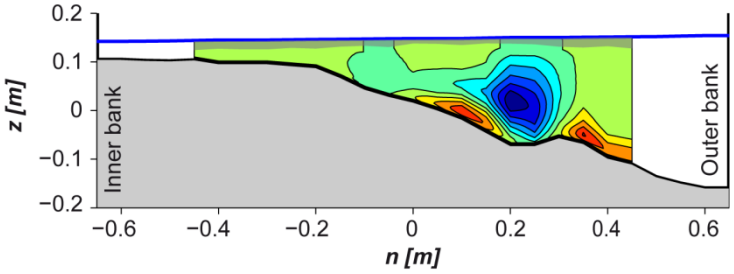


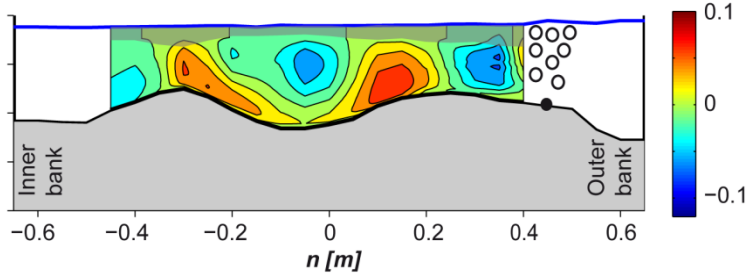
Transverse velocity:





Vertical velocity:





Conclusions and perspectives

Conclusions

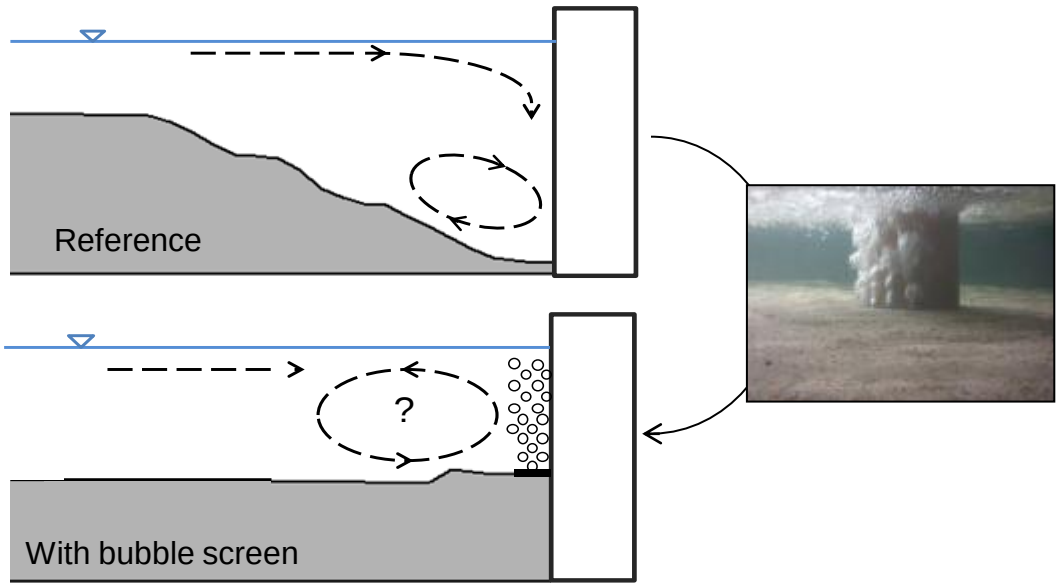
- The bubble screen can redistribute mean velocities patterns
- Higher influence on the morphology at the exit of the bend

Perspectives

- Investigation on scale effects
- Influence of sediment characteristics
- Influence of bend curvature

- Application to other scouring problems

(bridge pier or abutments..)



An Air-Bubble Screen Used as a Countermeasure to Reduce Erosion in Open-Channel Bends

ICSE6 Paris - August 27-31, 2012

Thank you for your attention

LABORATOIRE DE CONSTRUCTIONS HYDRAULIQUES

ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE