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EFFECTS OF COMPUTATIONAL MESHES ON HYDRODYNAMICS OF AN OPEN CHANNEL JUNCTIONS FLOW USING CFD TECHNIQUE

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SUMMARY

- Background
- Objectives
- Methodology
- Results
- Conclusions
- Perspectives

BACKGROUND

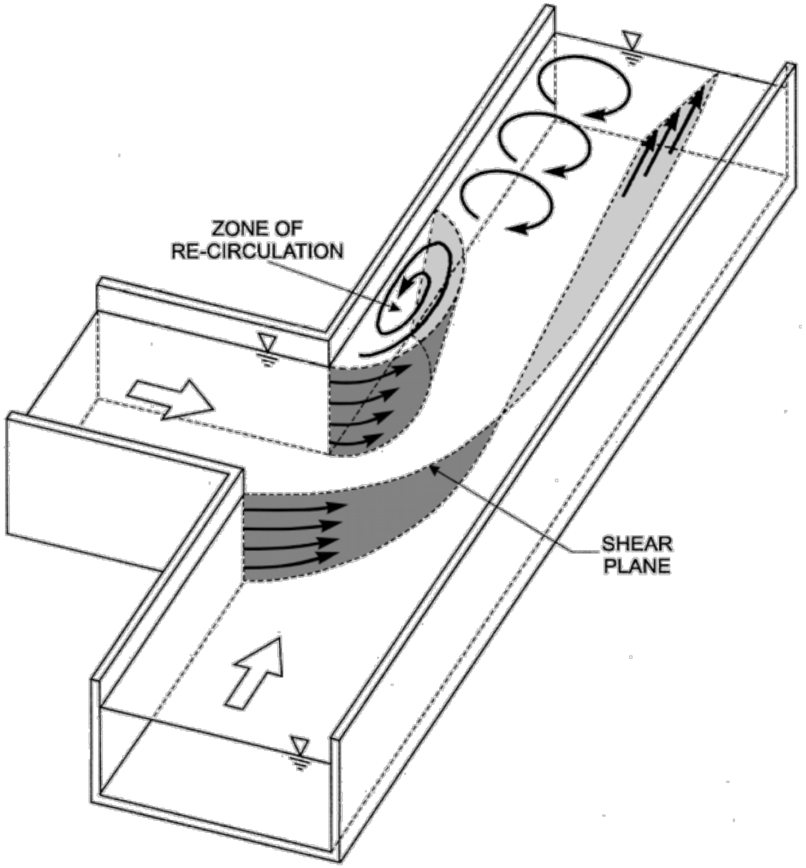
- Junctions: complex structures often encountered in sewers

- Exhibit a complex flow pattern that leads to complex: hydrodynamics/pollutants transport/flow measurement, etc.

BACKGROUND

- Some key flow patterns - Weber et al. (2001):

- a re-circulation zone
- a shear plane
- a particular velocity profile downstream the junction



BACKGROUND

- Using **CFD modelling**/lab experiments/field data may help to understand junction hydrodynamics

- Regarding CFD modeling (RANS-based approach):
  - Depends on multiple parameters
  - Mesh is one of the most important

- Effects of CFD strategy (**mesh**, turbulence models, discretization schemes, etc.) on simulations results ?

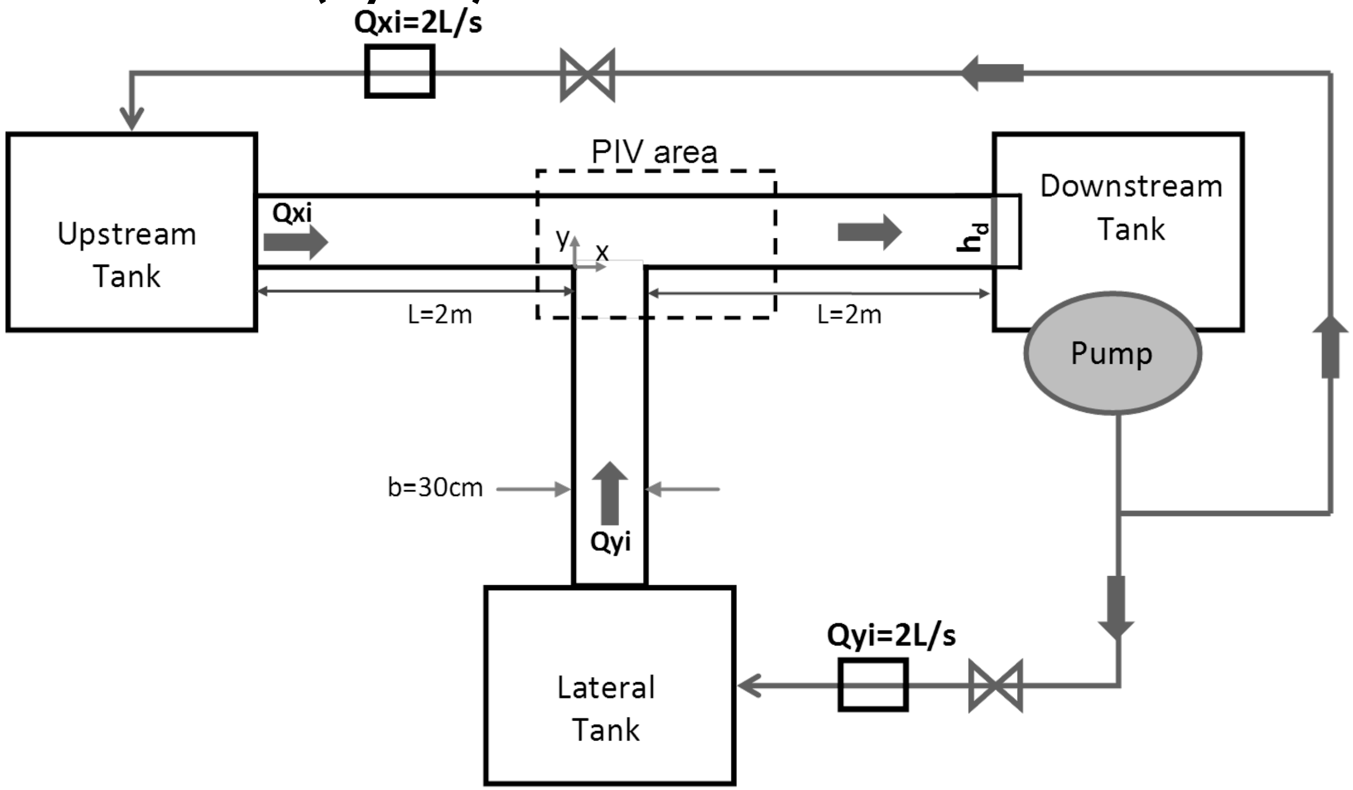
OBJECTIVES

- Mesh sensitivity study: influence of mesh density and shape on CFD solutions (hydrodynamics representation)

- Define an appropriate CFD strategy related to the simulation of junction steady flows:
  - Computational Mesh: density ? shape ?
  - Turbulence model?
  - Discretization schemes?
  - Pressure-velocity coupling approach?

METHODOLOGY

- Velocity field measurement using PIV technic at LMFA-INSA (Lyon):

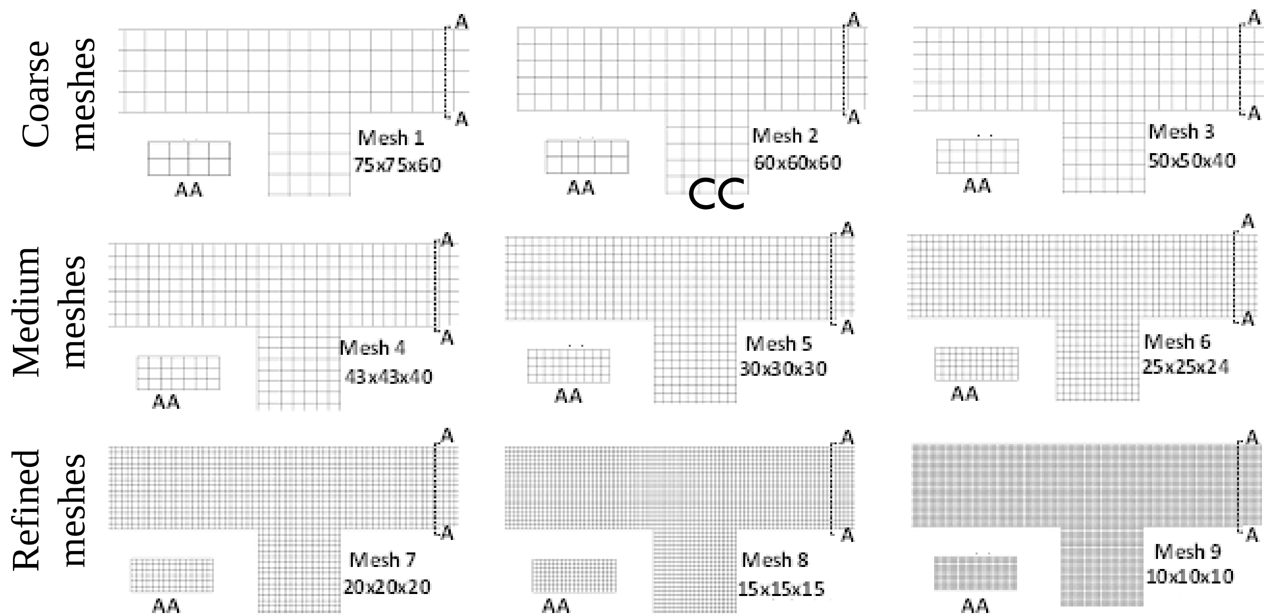


METHODOLOGY

- Global CFD strategy:
  - **Computational meshes**: hexa and tetra cells
  - Boundary conditions : Velocity inlet/pressure outlet/ fixed lid/roughness
  - Turbulence model: RNG-k-epsilon
  - Second-order spatial discretization schemes
  - Pressure-velocity coupling strategy: SIMPLE

METHODOLOGY

- CFD modelling of lab facility flows according to different cells arrangement, gathered in 3 groups:



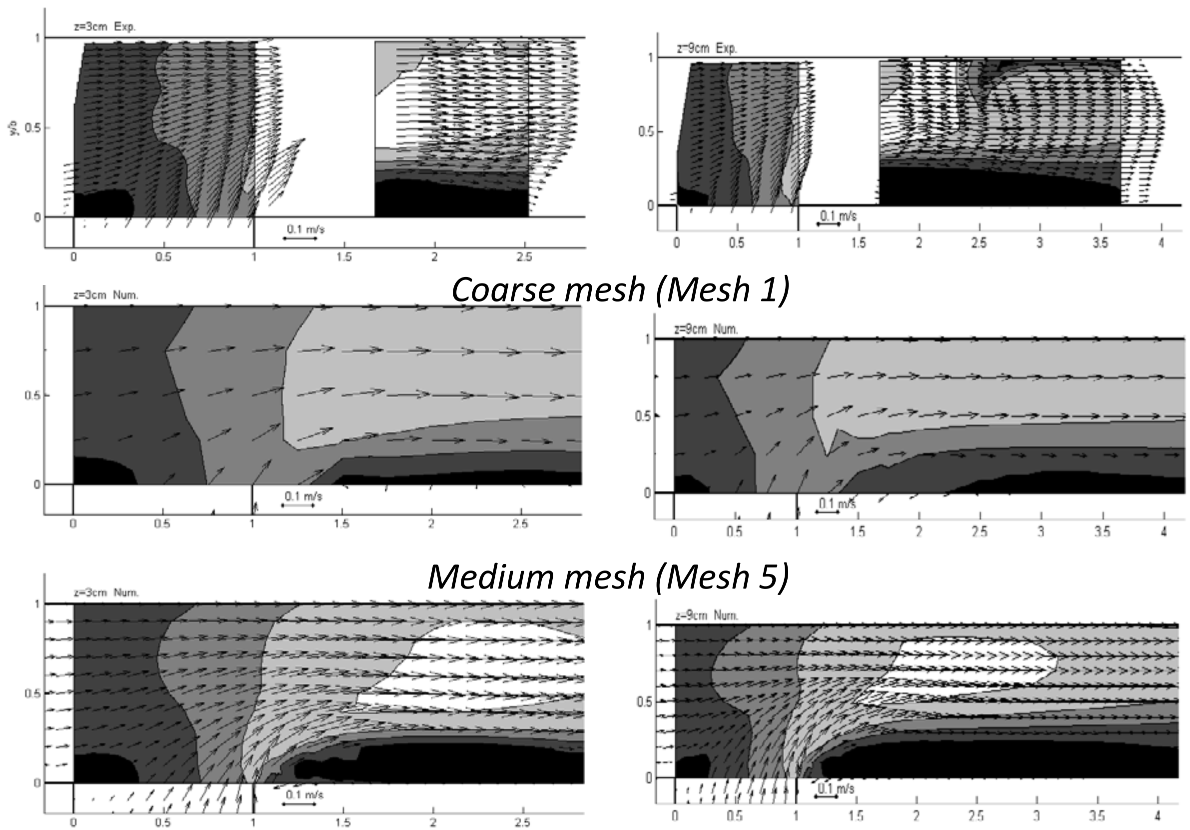
- An additional mesh with the same density as mesh 9 and tetrahedral cells (labeled Mesh 10)

METHODOLOGY

- Mesh sensitivity study: ability to represent 4 key flow characteristics regarding PIV data:
  - Re-circulation zone after the junction:
    - max width of the recirculation
    - Length of the recirculation
  - A disturbed downstream velocity profile
  - The shear plane position in the junction

RESULTS

- Comparison of velocity fields:



RESULTS

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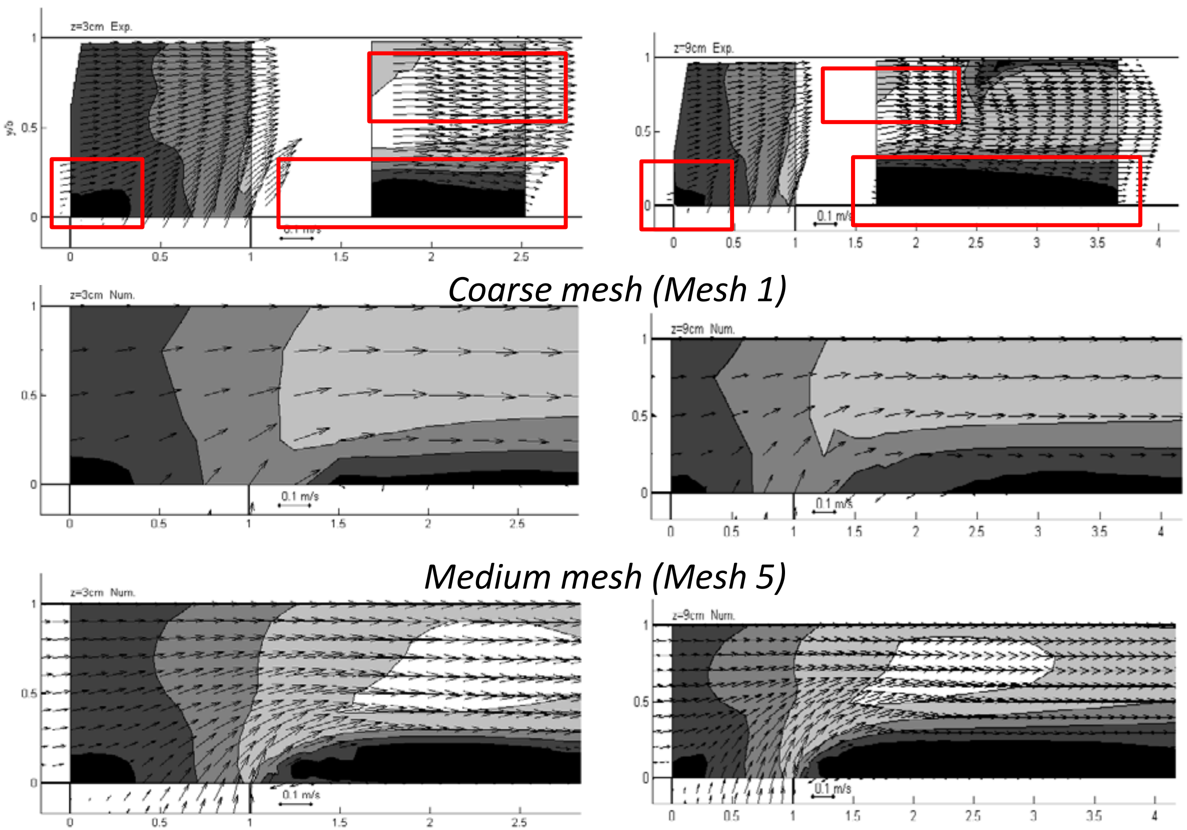
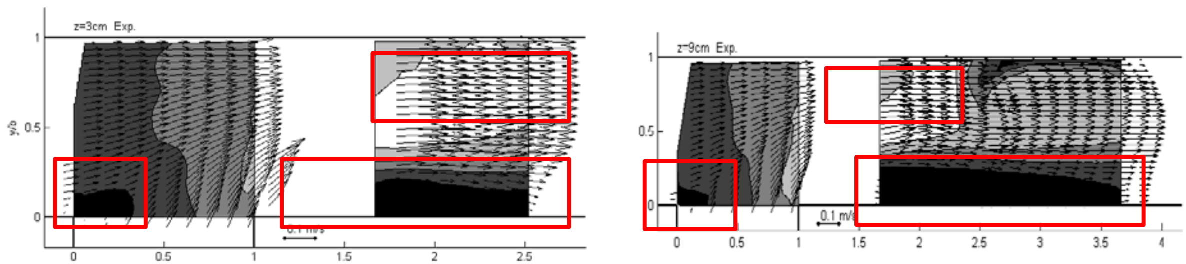


Coarse mesh (Mesh 1)

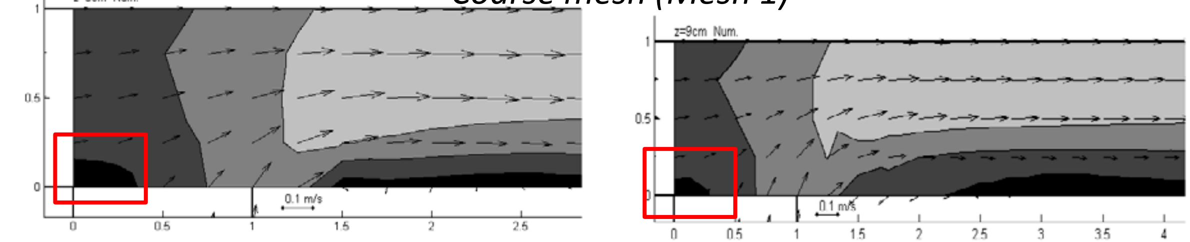
Medium mesh (Mesh 5)

RESULTS

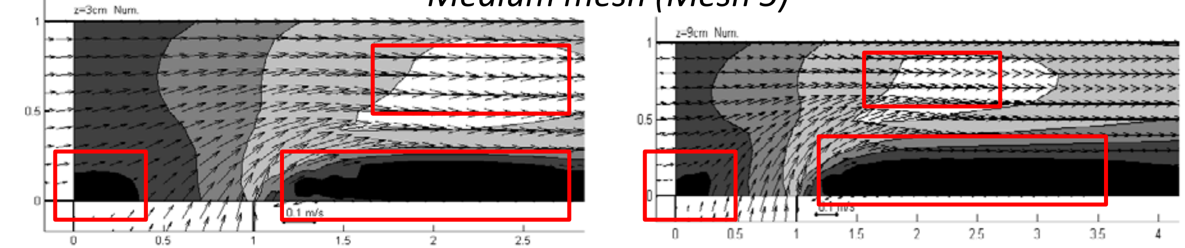
- Comparison of velocity fields:



Coarse mesh (Mesh 1)



Medium mesh (Mesh 5)



RESULTS

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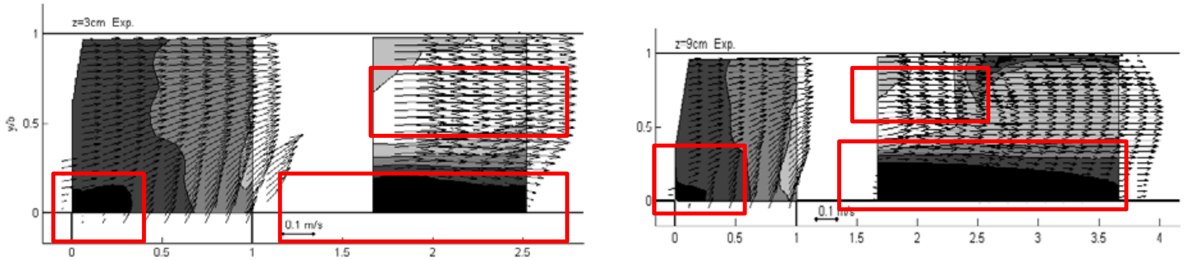
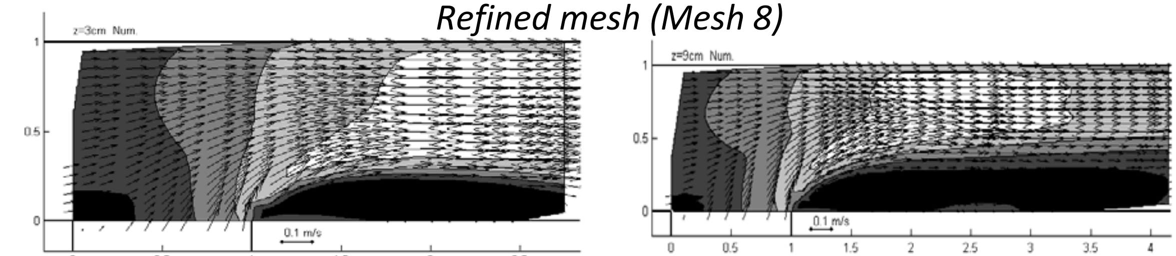
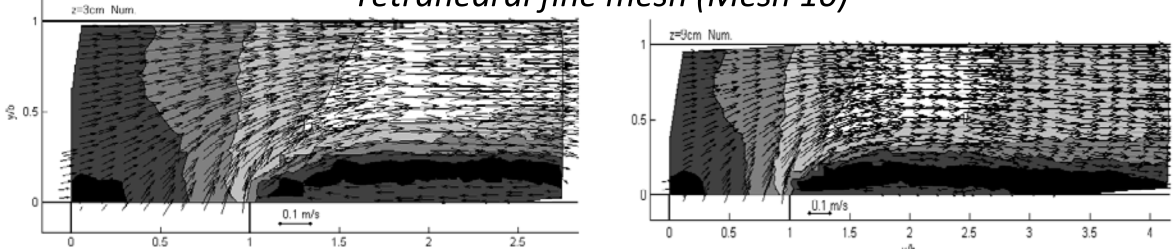


Refined mesh (Mesh 8)



Tetrahedral fine mesh (Mesh 10)



RESULTS

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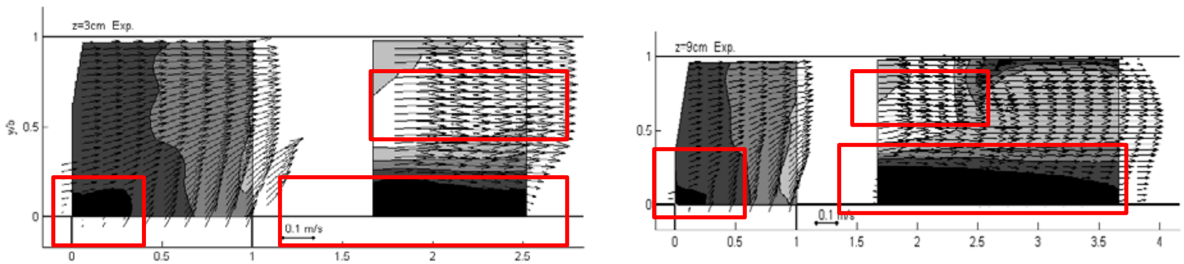

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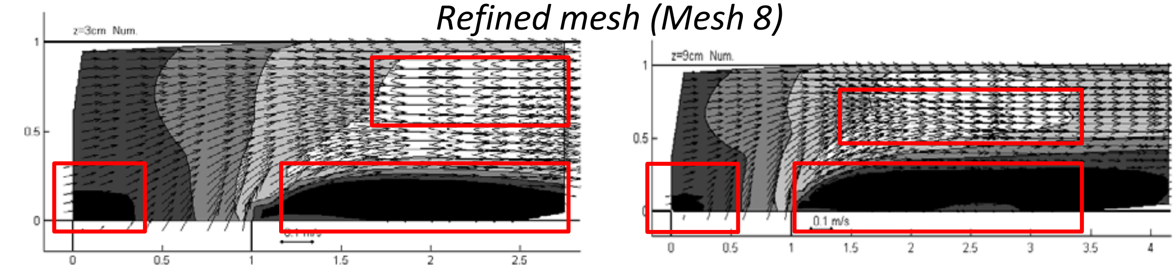

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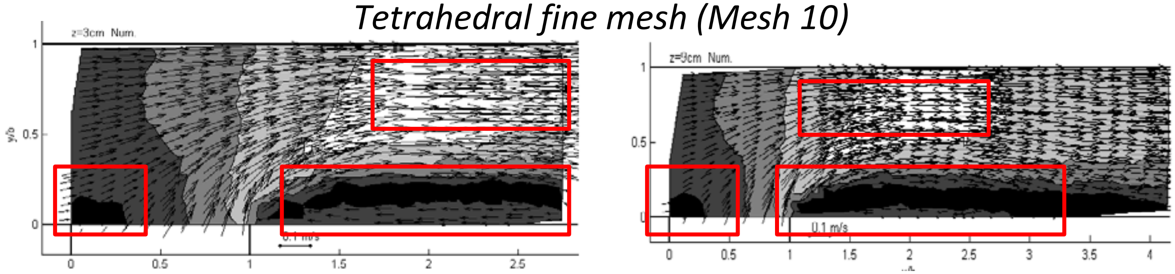
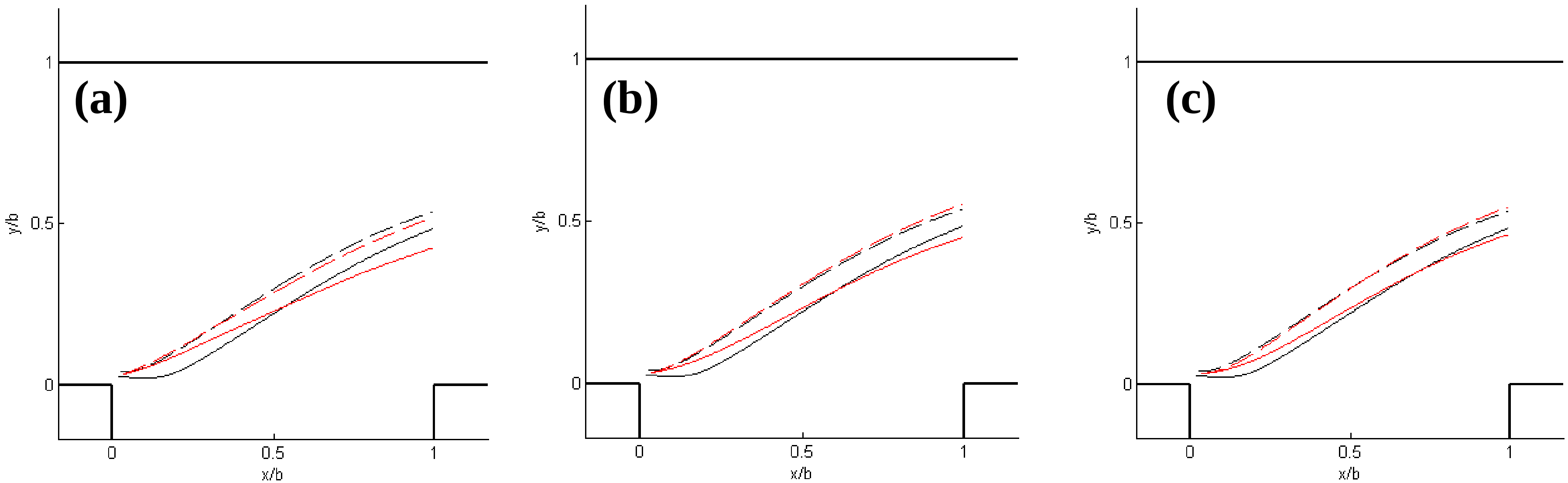


RESULTS

- Comparison of shear plane positions:

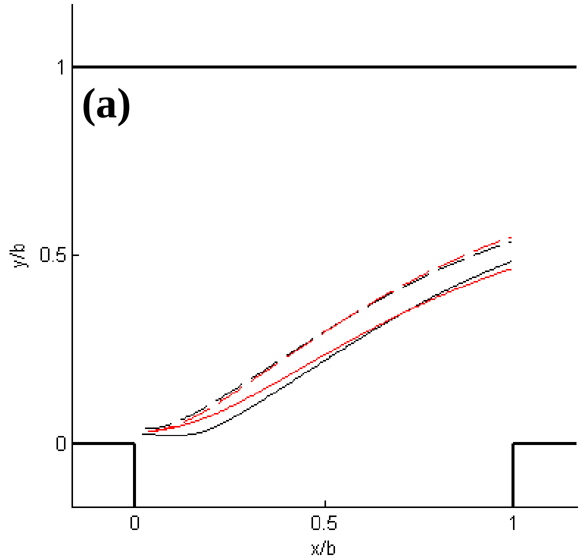


Coarse meshes (mesh 1) | Medium meshes (mesh 5) | Refined meshes (mesh 9)

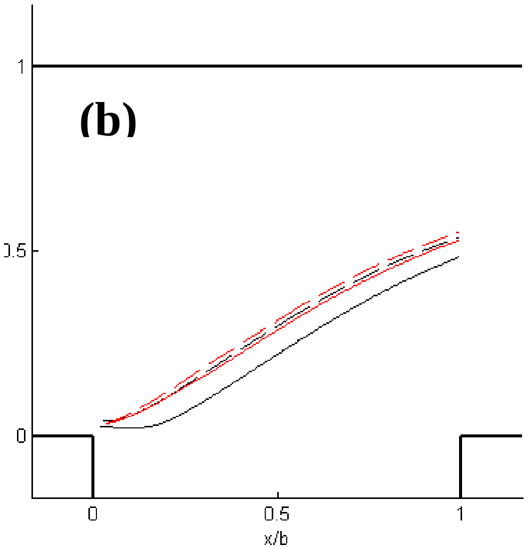
——— : Measurements at z = 3 cm
— — — : Measurements at z = 9 cm
——— : Simulated results at z = 3 cm
— — — : Simulated results at z = 9 cm

RESULTS

- Comparison of shear plane positions:



Refined meshes
(mesh 9)



Tetrahedral mesh
(mesh 10)

: Measurements at z = 3 cm

: Measurements at z = 9 cm

: Simulated results at z = 3 cm

: Simulated results at z = 9 cm

RESULTS

- Comparison of the re-circulation zone sizes:
  - Normalized length:

	Measured	Mesh 1	Mesh 6	Mesh 8	Mesh 9	Mesh 10	Gurram (1997)	Borghei (2003)	Best (1984)
z = 3 cm	1.25	1.33	2.33	2.00	2.05	2.37	-	-	-
z = 9 cm	1.97	2.13	2.67	2.77	2.37	2.50	2.53	1.70	1.87

  - Normalized maximum width:

	Measured	Mesh 1	Mesh 6	Mesh 8	Mesh 9	Mesh 10	Gurram (1997)	Borghei (2003)	Best (1984)
z = 3 cm	0.19	NaN	0.20	0.27	0.28	0.38	-	-	-
z = 9 cm	0.33	NaN	0.20	0.33	0.35	0.30	0.37	0.47	0.37

CONCLUSIONS

- Proposed CFD strategy seems relevant in this case
- A minimum mesh density is required (30x30x30 mm) to represent satisfactorily the downstream velocity field
- Shear plane position near the free surface is easily reproduced (even with coarsened meshes!)
- Shear plane near the bottom of the channel is not well reproduced

CONCLUSIONS

- Tetrahedral cells seem less regarding the representation of the max width of the recirculation close to the bottom, although it's pretty good for the velocity fields representation

- Length of re-circulation zone is systematically overestimated

- Max width of re-circulation zone near the bottom of the channel is overestimated

- Max width of re-circulation zone near the free surface is well reproduced

PERSPECTIVES

- Improve the model: wall function, pressure-velocity coupling (PISO?), etc.
- Run a non-uniform mesh, with a higher density in high gradient zone and lower density elsewhere
- Effect of a free surface capturing model?

PERSPECTIVES

- Study other cases of junction: different angles (30, 45 and 60°), different shape (circular, trapezoidal, egg-shaped)

- Development of an optimal location tool for discharge sensors placement downstream to junctions in sewers (WP 3.5 - European Project FP 7 PREPARED)