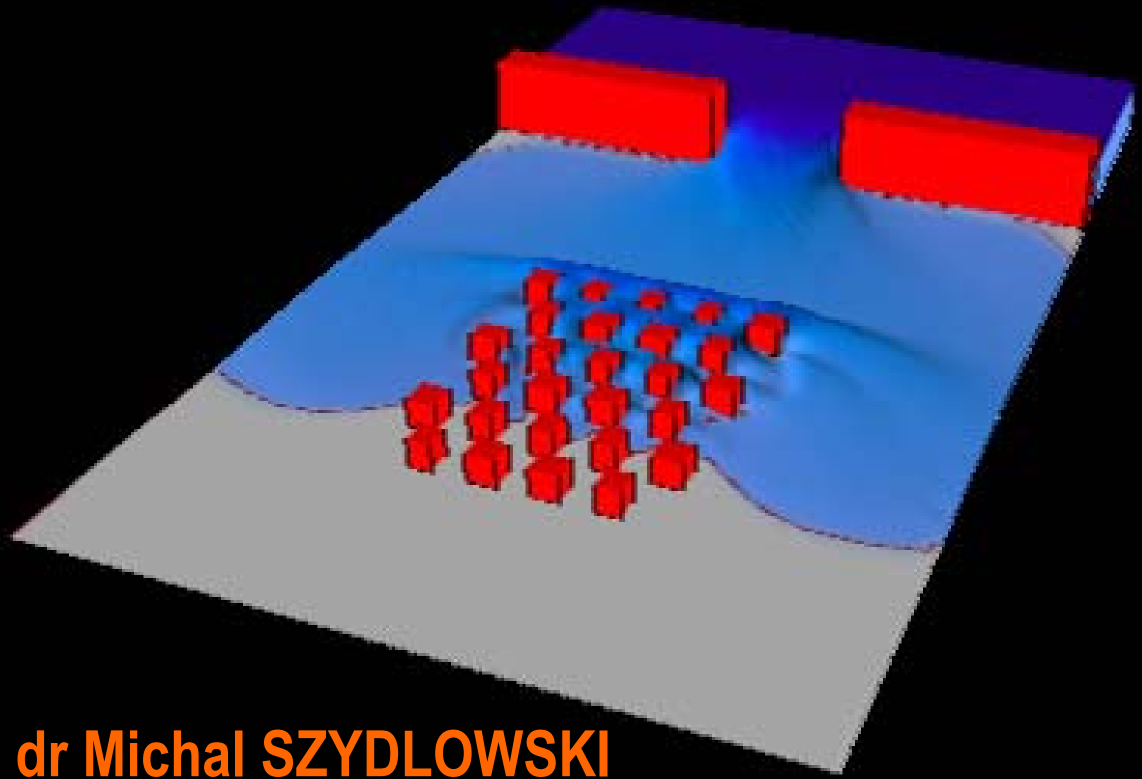
Building Wall Boundary Condition in Mathematical Modelling of Built-up Area Rapid Inundation



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Urban Flood Modelling

- DTM (digital terrain model)

  - elevation model
  - land use model

  built-up area representation

- Flood routing model

  model of unsteady free surface water flow

Mathematical model of water flow

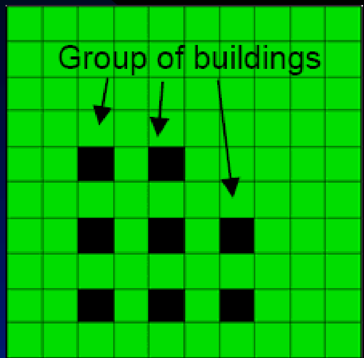
2D Shallow Water Equations

$$\frac{\partial \mathbf{U}}{\partial t}+\frac{\partial \mathbf{E}}{\partial x}+\frac{\partial \mathbf{G}}{\partial y}+\mathbf{S}=0$$

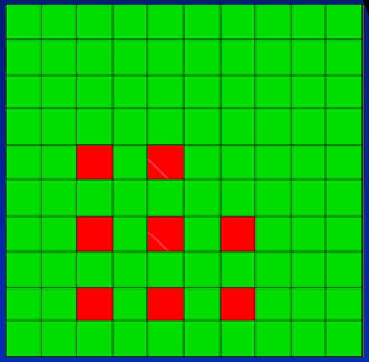
$$\mathbf{U}=\begin{pmatrix} h \\ uh \\ vh \end{pmatrix}, \quad \mathbf{E}=\begin{pmatrix} uh \\ u^2h+0.5gh^2 \\ uvh \end{pmatrix}, \quad \mathbf{G}=\begin{pmatrix} vh \\ uvh \\ v^2h+0.5gh^2 \end{pmatrix}, \quad \mathbf{S}=\begin{pmatrix} 0 \\ -gh\left(S_{ox}-S_{fx}\right) \\ -gh\left(S_{oy}-S_{fy}\right) \end{pmatrix}$$

- FVM, Roe scheme
- initial condition, boundary conditions

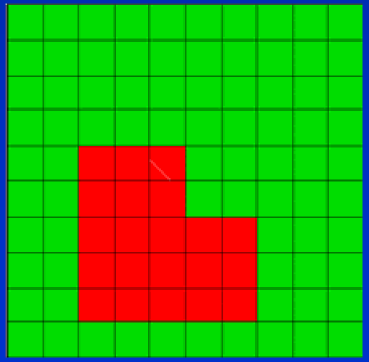
Built-up area representation



- the buildings in flow area



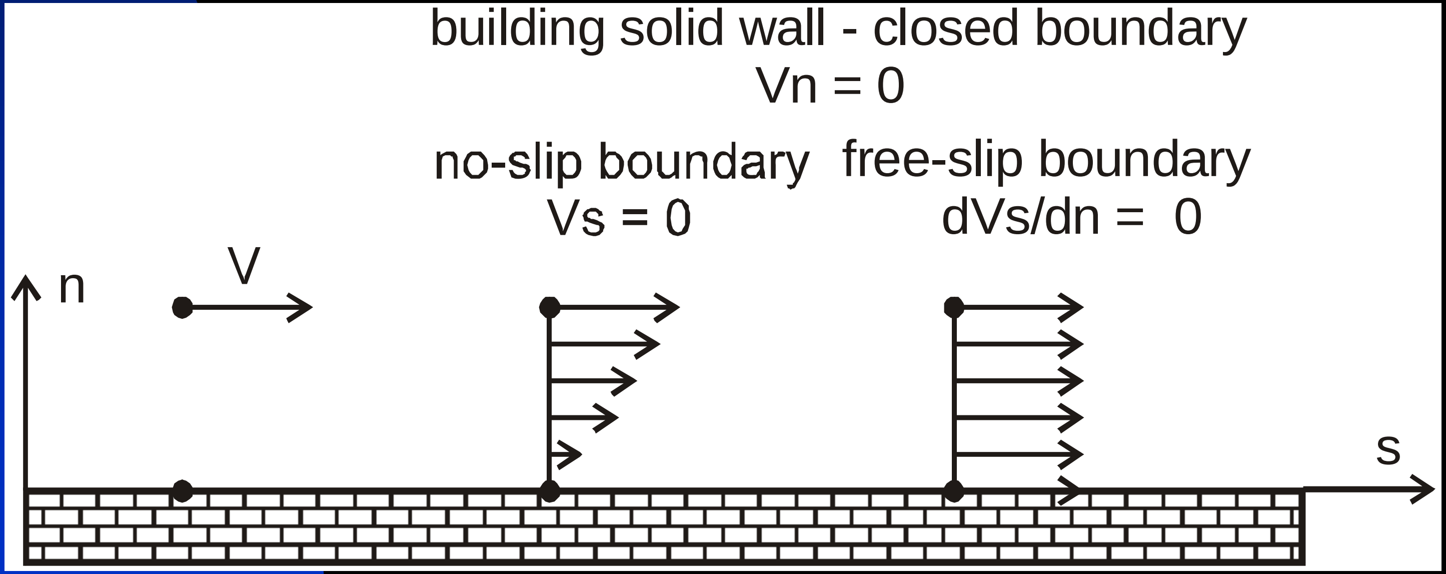
- explicit exclusion of the buildings from the numerical mesh (flow area)



- the buildings can be embedded into simulation as the sub-grid effect
  - high friction method
  - urban porosity technique

Boundary conditions on the buildings walls

- **no-slip boundary condition**
- **free-slip boundary condition**



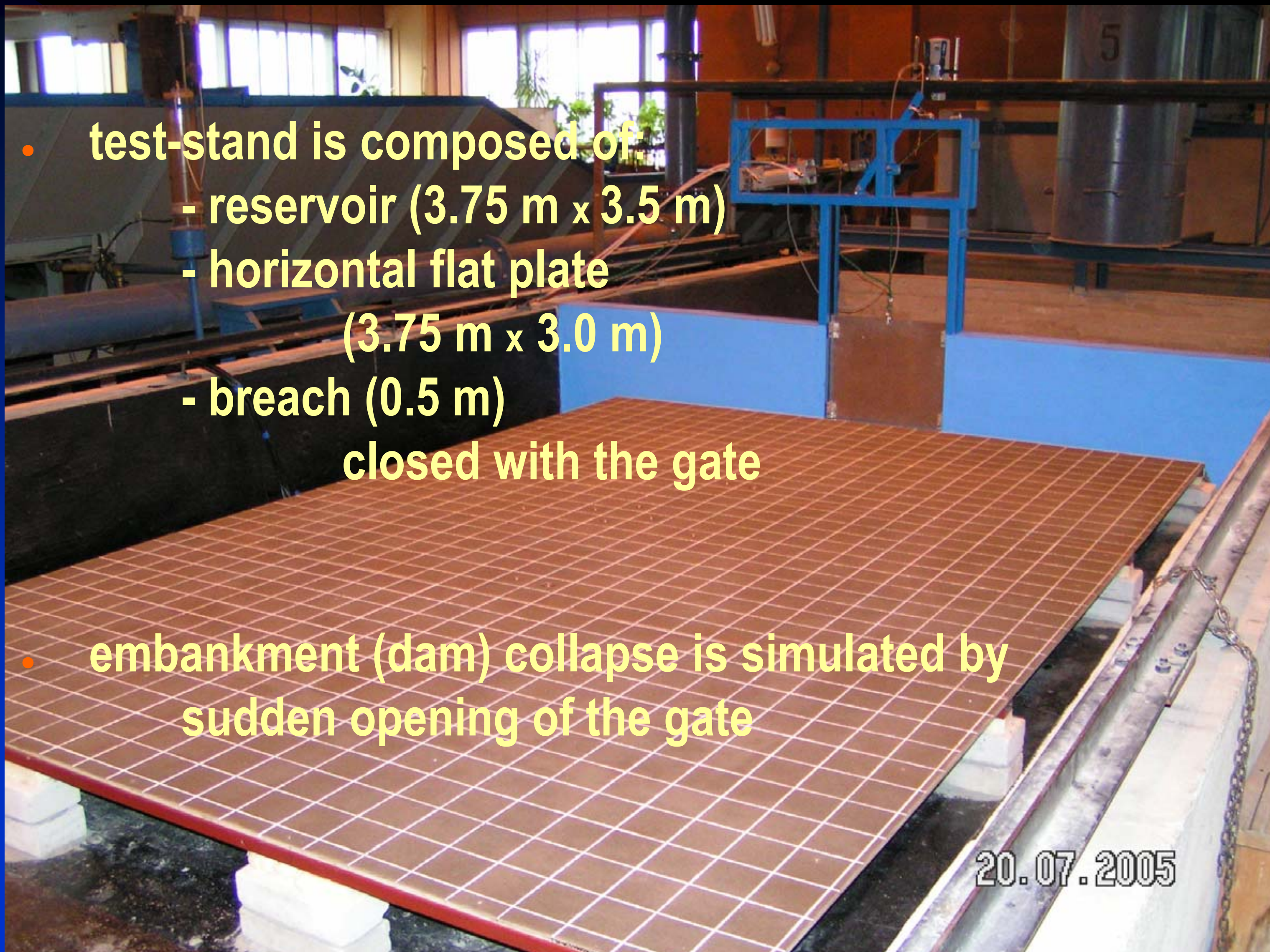
Model verification

How to verify computations ?

- the flood events have catastrophic nature
- computed results are difficult to verify
- laboratory modelling

- 2D dam-break problem was investigated in hydraulic laboratory of Technical University of Gdańsk

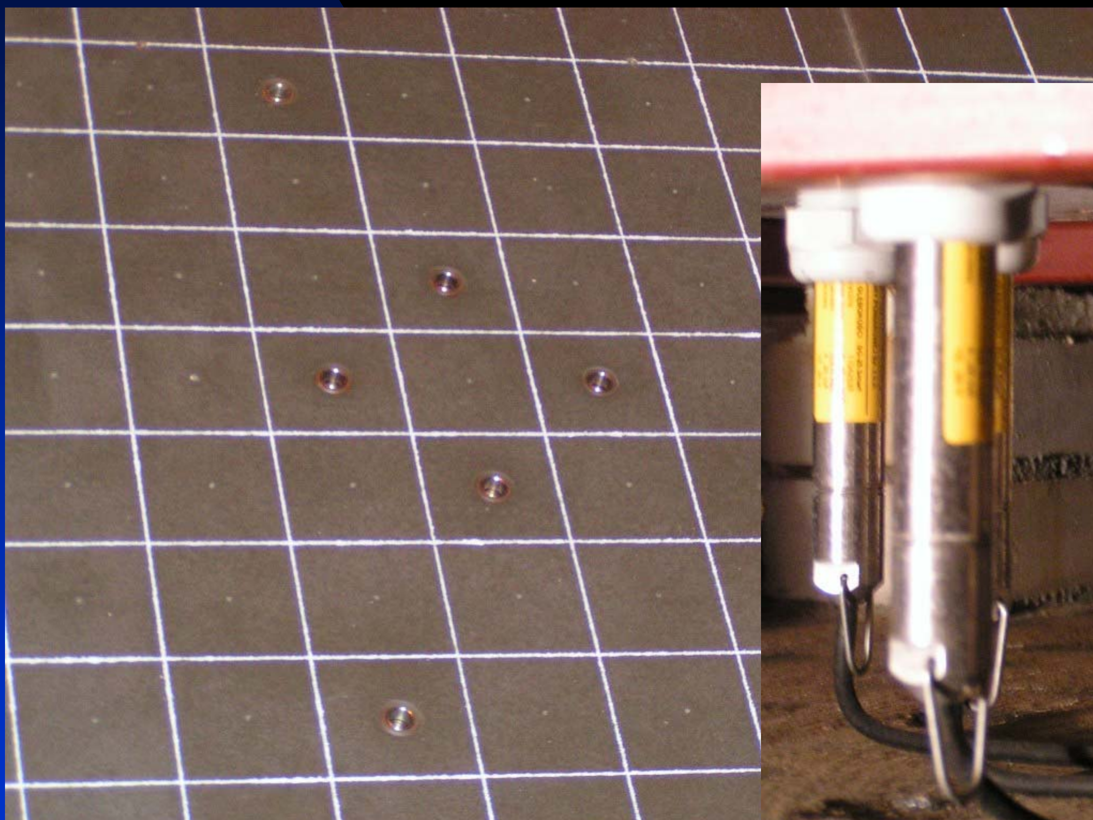
Urban Flow Modelling in TUG Hydraulic Laboratory



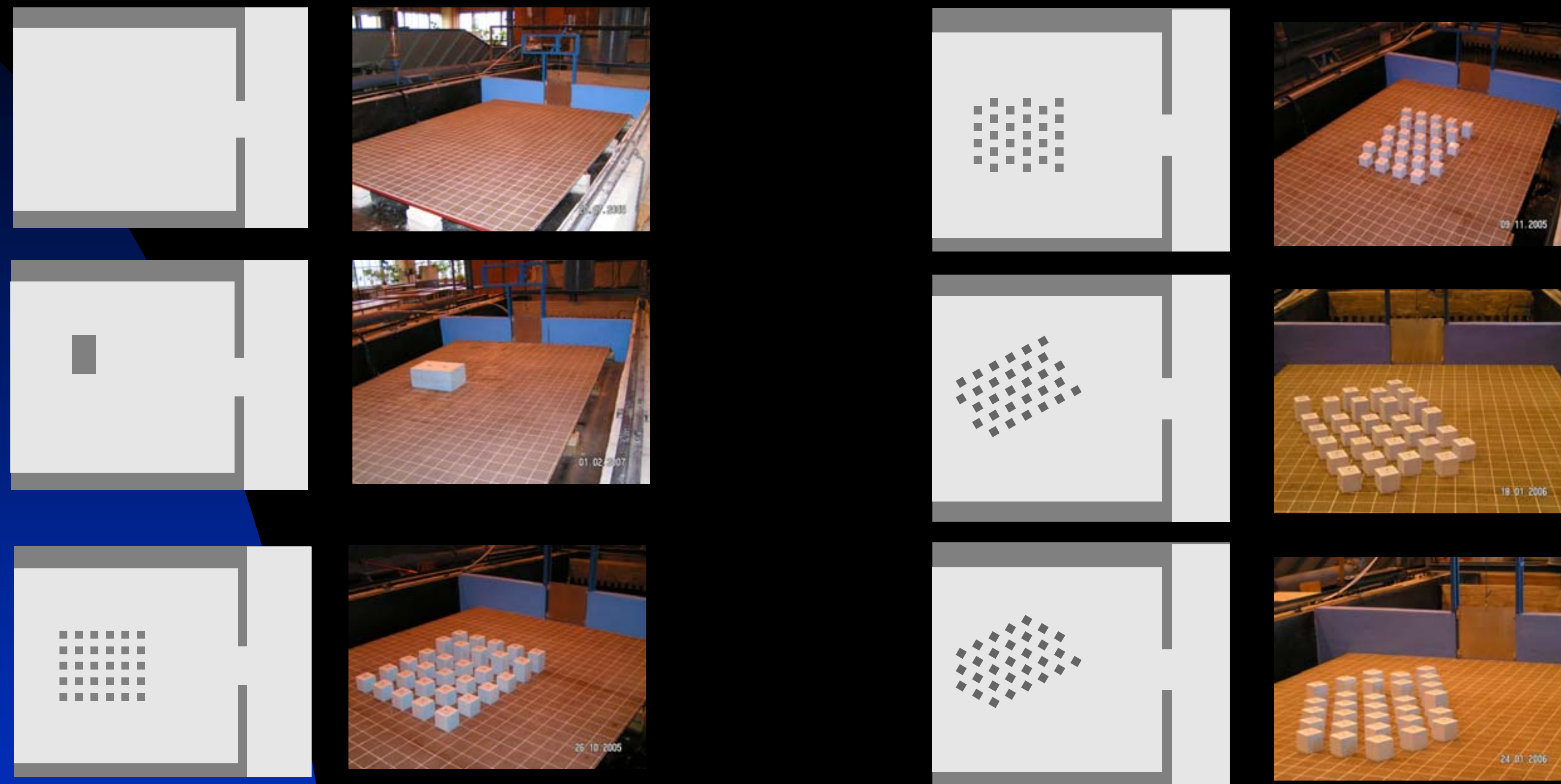
- test-stand is composed of:
  - reservoir (3.75 m x 3.5 m)
  - horizontal flat plate (3.75 m x 3.0 m)
  - breach (0.5 m) closed with the gate
- embankment (dam) collapse is simulated by sudden opening of the gate

Urban Flow Modelling in TUG Hydraulic Laboratory

- **pressure sensors**

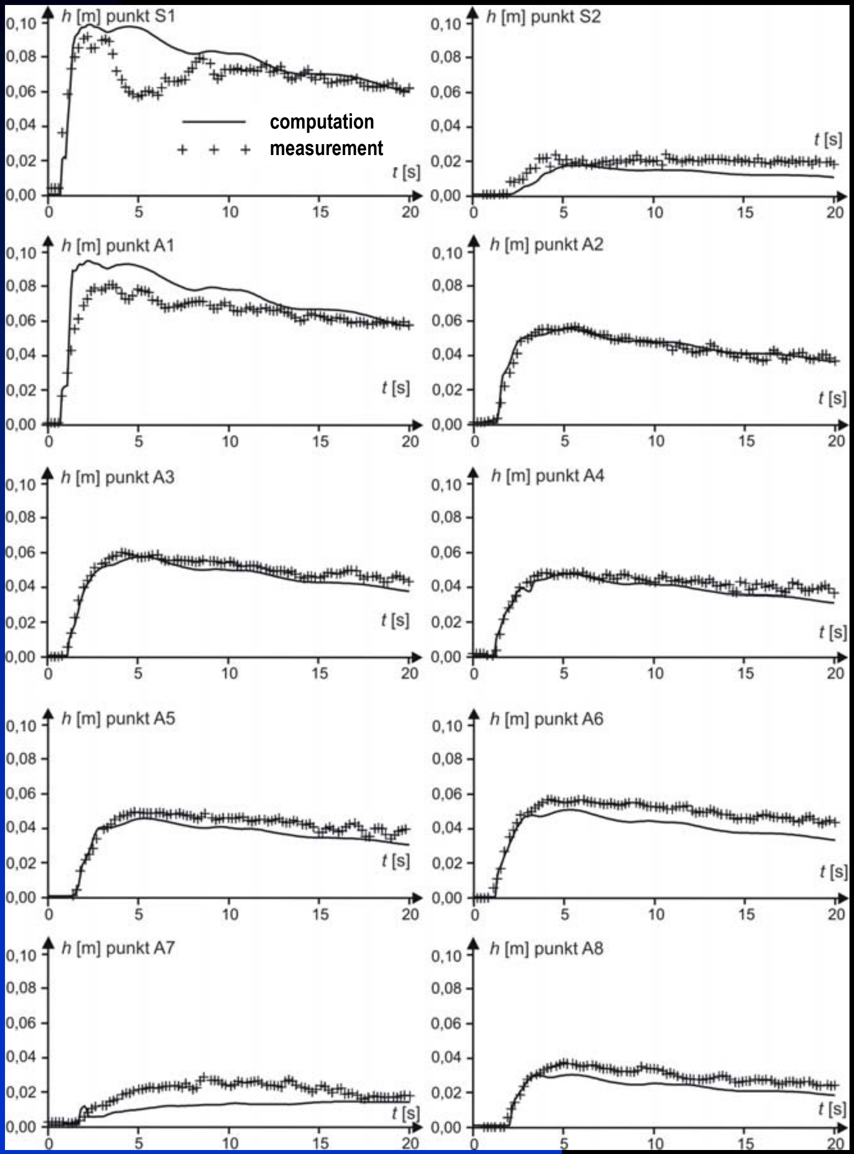


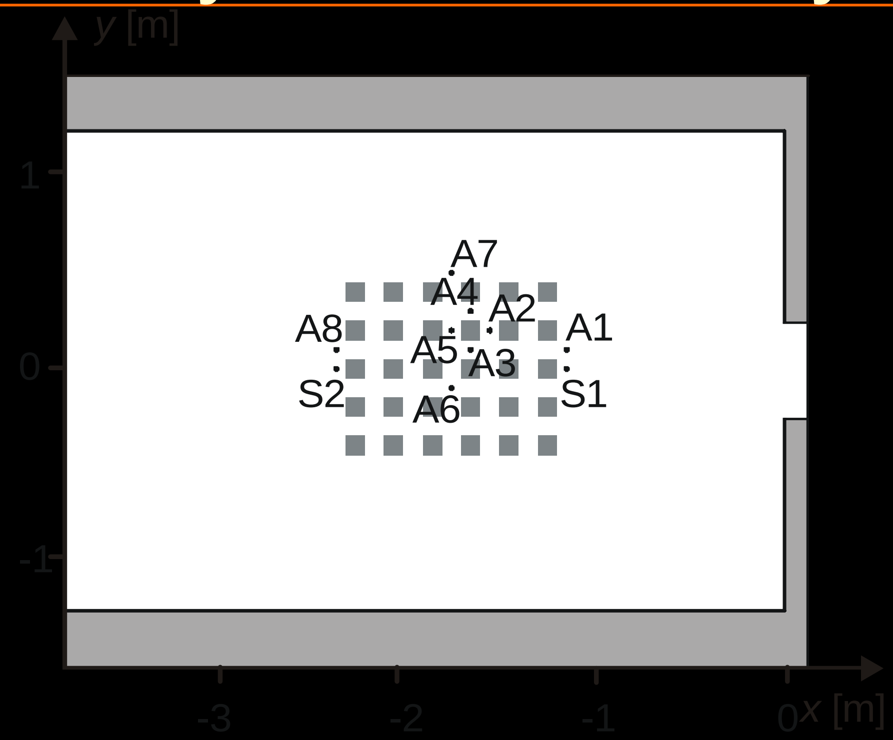
Urban Flow Modelling in TUG Hydraulic Laboratory



- **models of buildings** could be installed on the plate
- several configurations were investigated

Urban Flow Modelling in TUG Hydraulic Laboratory

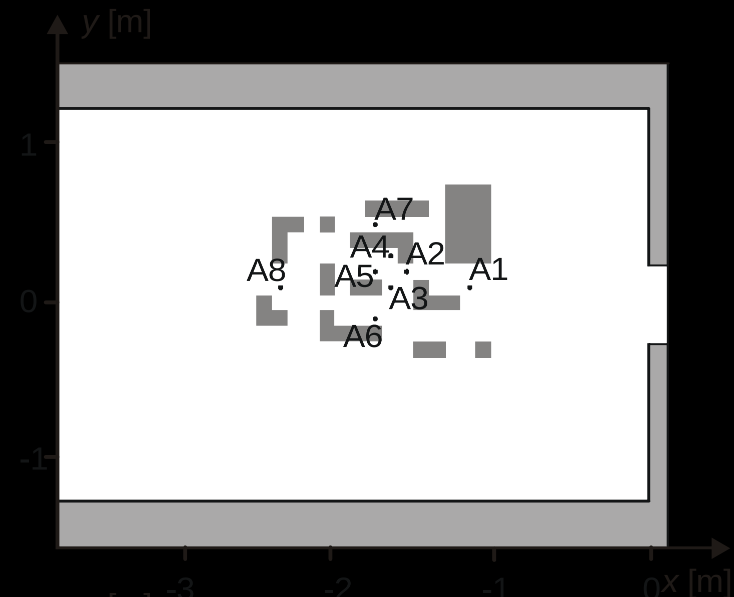


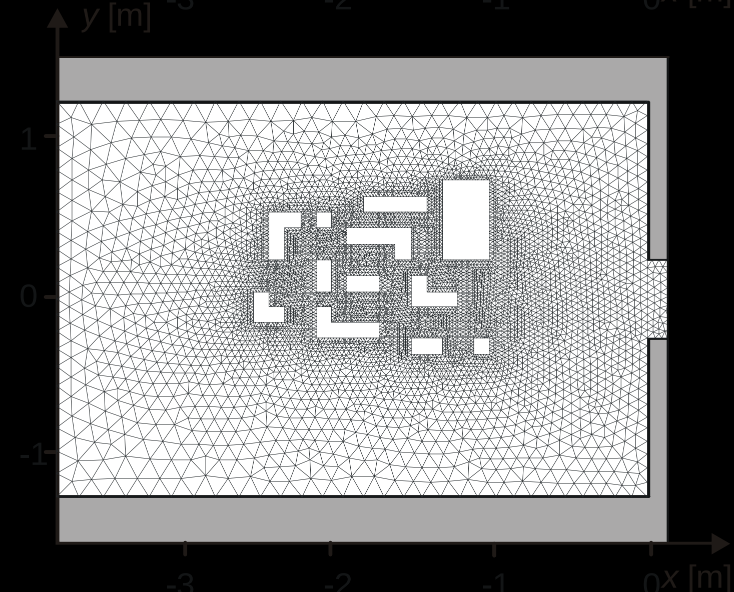


- numerical simulations of the laboratory experiment were carried out
- computed results inside built-up area were underestimated

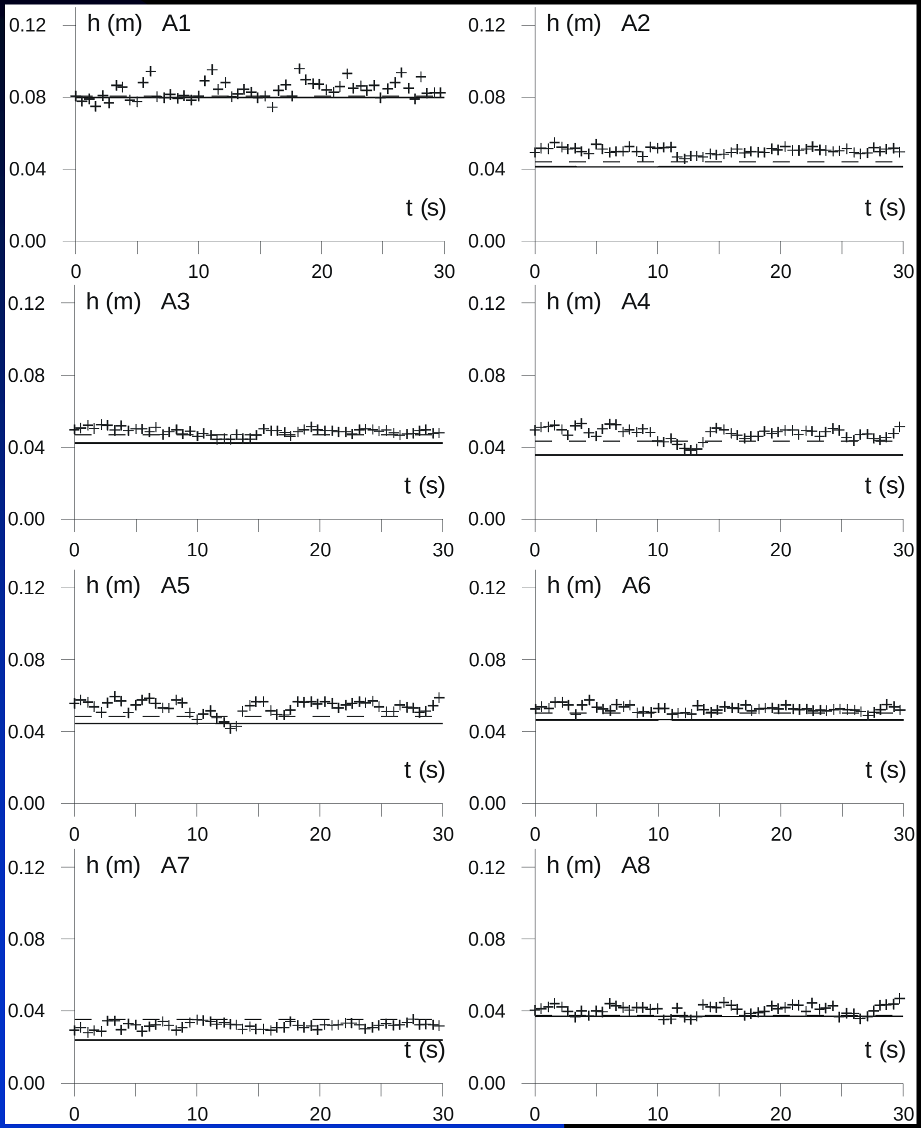
Influence of type of boundary condition

- steady flow experiment was carried out
- unstructured buildings configuration is considered
- unstructured mesh composed of 13787 computational cells
- two numerical simulations were carried out
  - free-slip condition
  - no-slip condition





Influence of type of boundary condition



depth calculated using the **no-slip boundary condition better fits** the measurements

than depth simulated imposing free-slip boundary condition

Conclusion

- It seems that the no-slip boundary condition can substitute (imitate) the wall friction, improving the quality of numerical simulations of rapid floods in urban areas using the shallow water equations