Calibration of a diffusion model for aggrading channel after sediment overloading experiments with near-critical flow

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This presentation participates in OSPP

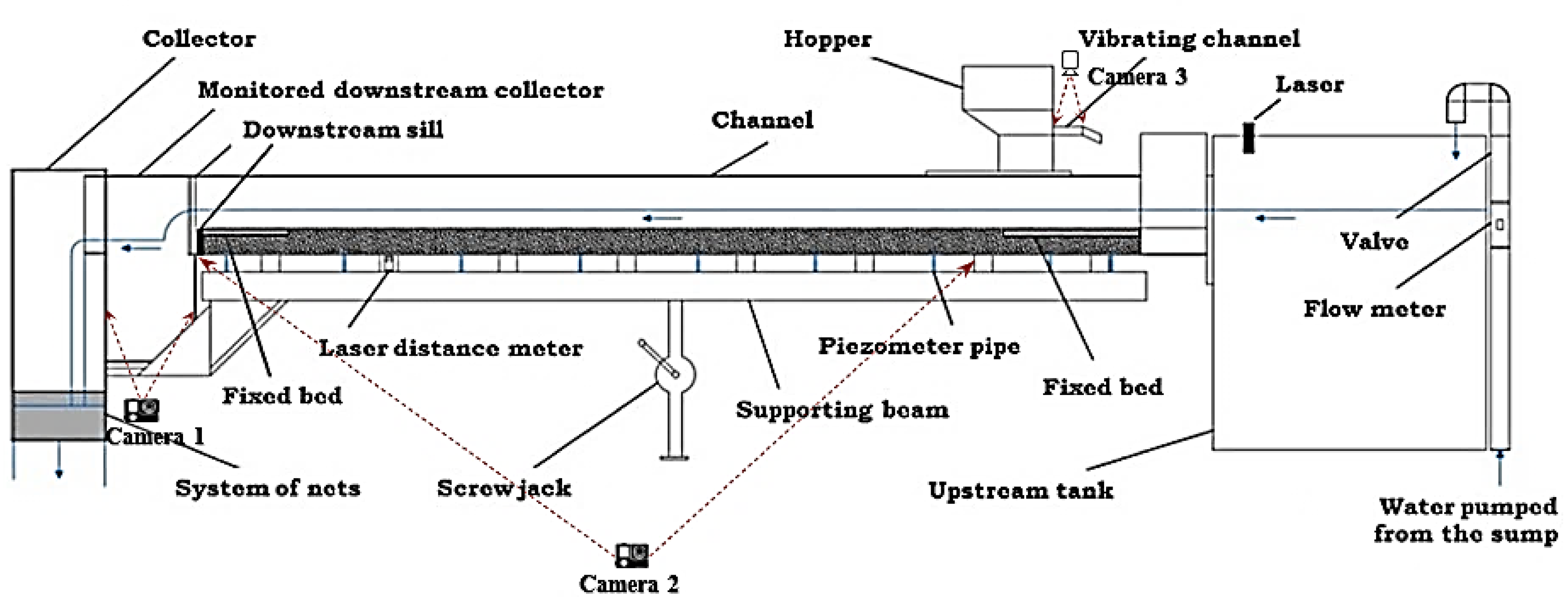
Outstanding Student & PhD candidate Presentation contest

1. Objectives

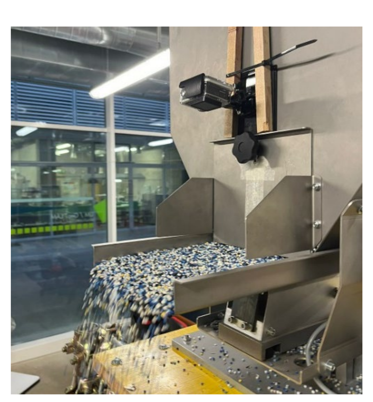
- Application of a mathematical model based on linear diffusion to eighteen aggradation experiments carried out in near-critical condition.
- Calibration of the linear diffusion model based on the experimental results.
- Investigation of the dependency of the calibrated parameter (linear diffusion coefficient, K) on the controlling parameters e.g. overloading ratio and Froude number.

2. Experimental setup and measurement methods

- Rectangular channel, width = 30 cm, height = 45 cm, length = 5.2 m, erodible bed with uniform sediment.
- Sediment: PVC grains, d = 3.8 mm, density = 1443 kg/m^3.
- During each experiment channel is fed with a sediment discharge (Q_{sin}) via a hopper installed at the upstream part.
- Six constant water discharges (Q) of 3, 4, 5, 6, 7 and 8 l/s.
- Five values of overloading ratio (Lr = sediment inflow discharge/sediment transport capacity of the channel) of 1.55, 1.85, 2.15, 2.75 and 3.25.



- Different parameters including bed and water surface elevation and sediment inflow discharge are measured during each experiment by using different cameras and applying image processing methods.



3. Conceptual framework, literature model

- The Saint-Venant-Exner system of equations describing the evolution of bed and water surface elevation can be simplified to a linear diffusion equation by applying some assumptions (Soni et al):

$$\frac{\partial z}{\partial t} = K\frac{\partial^2 z}{\partial x^2}$$

- Gill (1983) proposed an analytical solution for this equation:

$$Z(x,t) = S_\infty(L-x) + \frac{8L(S_o - S_\infty)}{\pi^2}\sum_{n=1,3,5,\ldots}^{\infty}\frac{1}{n^2}e^{-\frac{n^2\pi^2Kt}{4L^2}}\cos\frac{n\pi x}{2L}$$

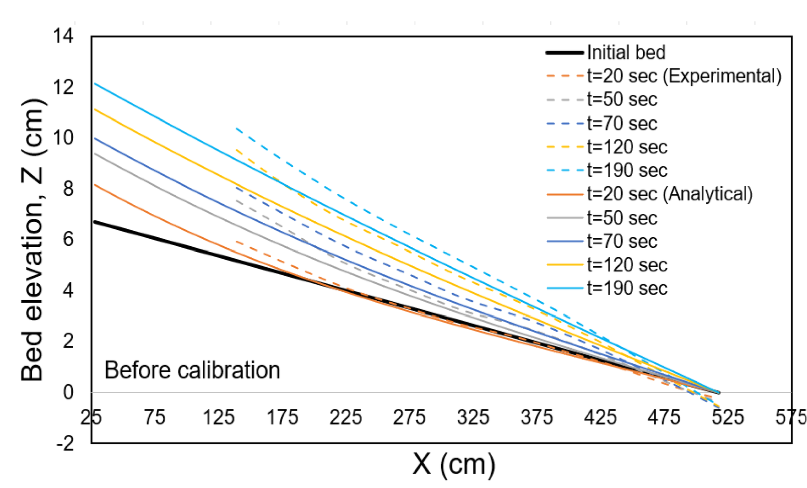
- The first-guess value for diffusion coefficient, K, is estimated by:

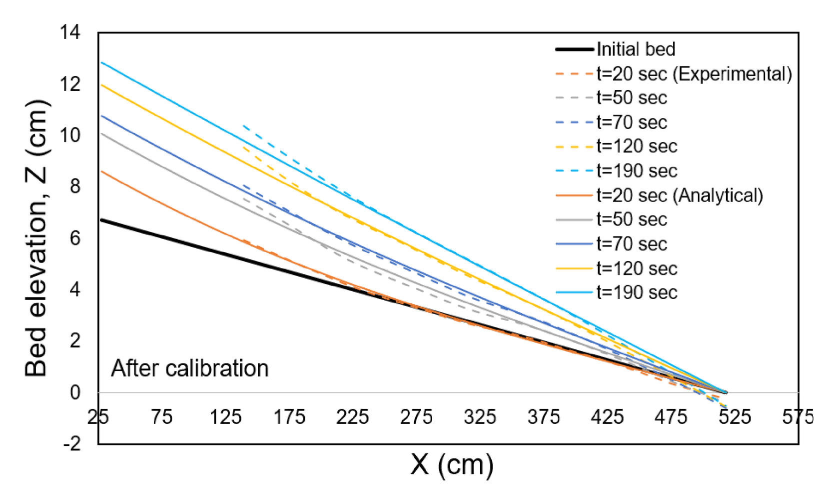
$$K_{Gill} = \frac{q_\infty - q_{s0}}{(1-P_0)(S_\infty - S_0)}$$

- Z is bed elevation, S_0 and S_∞ are bed slope at initial and equilibrium times, q_{s0} and q_∞ are sediment discharge per unit width at initial and equilibrium times, P_0 is porosity.

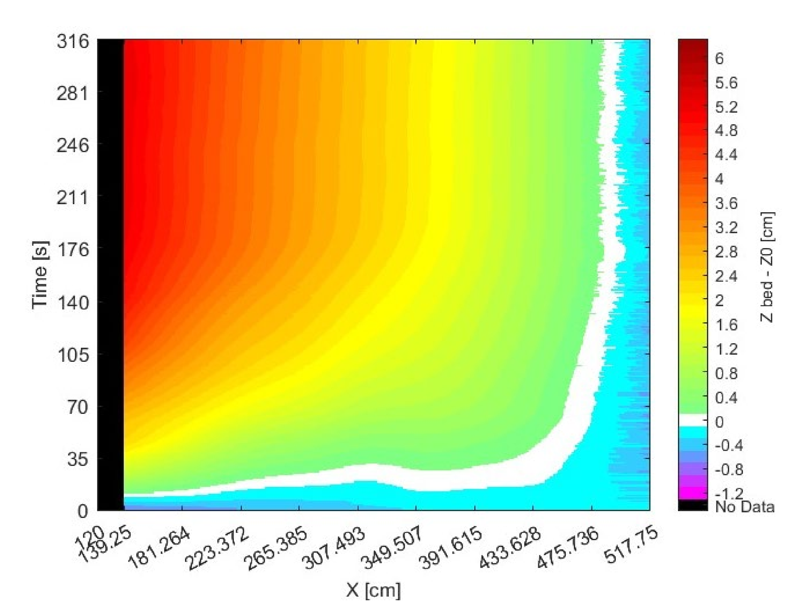
4. Results and calibration of diffusion model

- Comparison between analytical bed profiles and experimental ones before and after calibration of diffusion model (as an example for one experiment), calibrated parameter: K

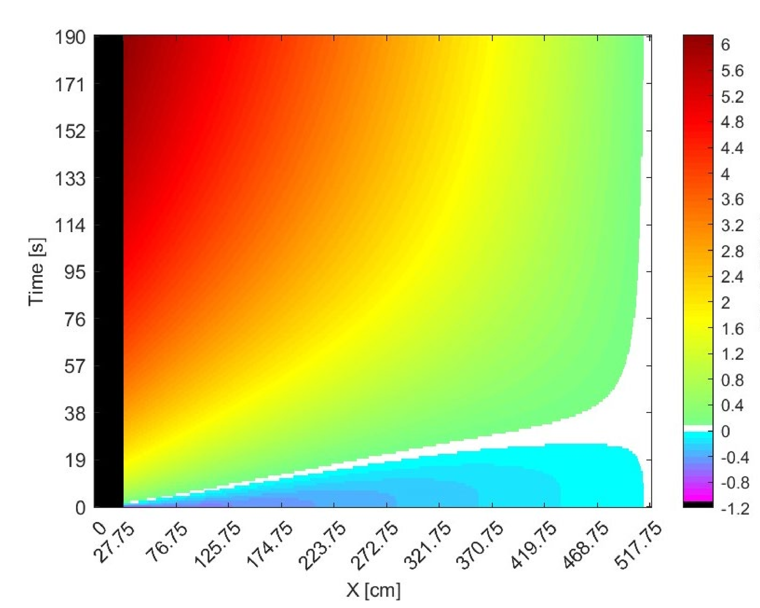




- Experimental and analytical color gradient maps of space-time evolution of bed surface after calibration:



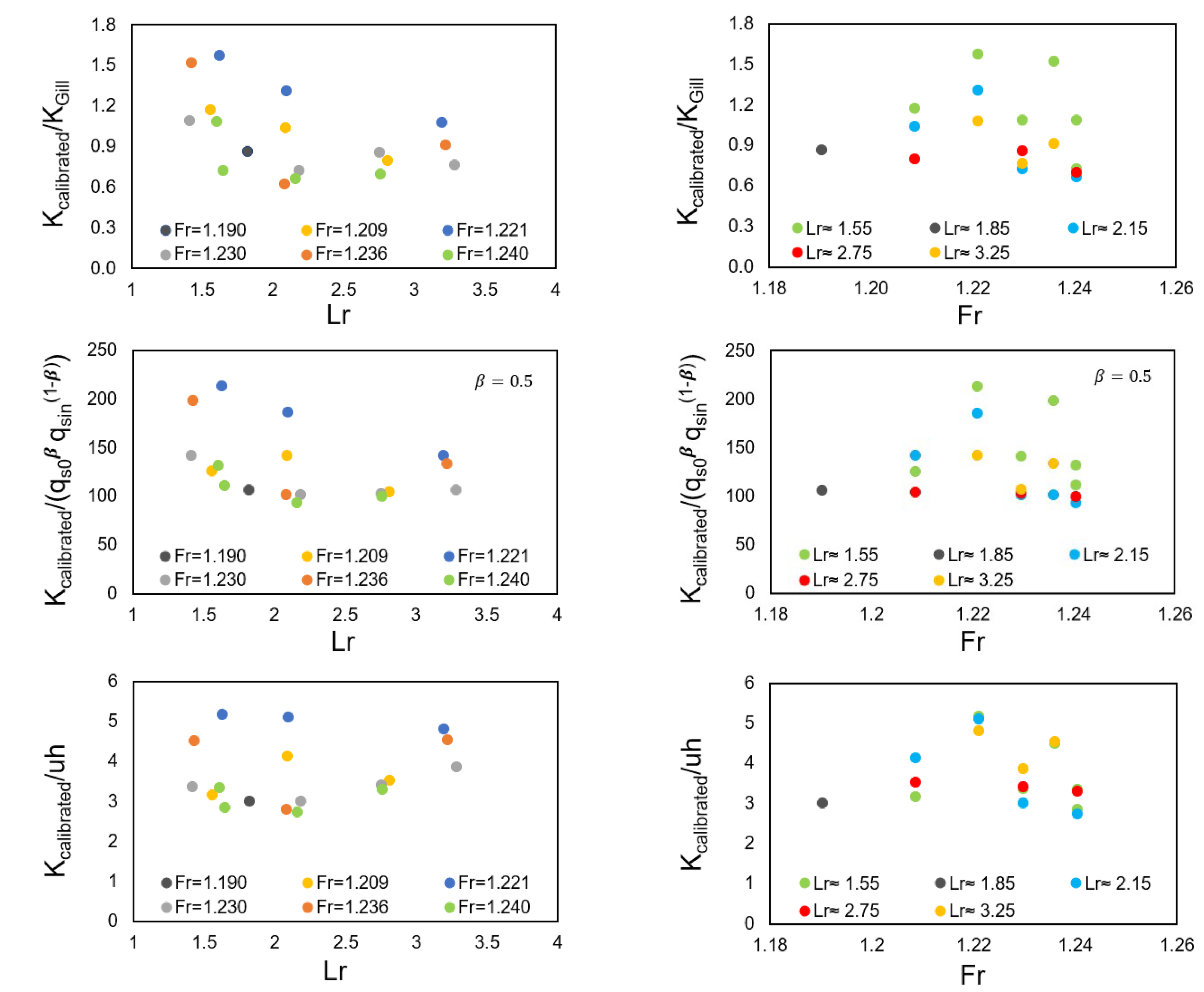
Experimental



Analytical

5. Bulk analysis of diffusion coefficient

- Calibration was performed for each of the eighteen experiments. Moreover, the dependency of dimensionless diffusion coefficient on overloading ratio and Froude number was investigated.



6. Conclusions

- A constant value of the diffusion coefficient is adequate to reproduce the space-time evolution of bed surface.
- The diffusion coefficient needs to be varied from an experiment to another.
- It seems that while for $Lr < 2$, the dimensionless diffusion coefficient decreases with increasing overloading ratio, it remains constant for $Lr > 2$.
- $K_{Calibrated}/K_{Gill}$ is largely different from 1 for low Lr, while it is more similar to 1 for larger Lr.
- The dimensionless diffusion coefficient appears unaffected by the Froude number, but the range of Froude number in the conducted experiments may be too small to demonstrate a clear impact.

7. Acknowledgements

- The present study has been financially supported by the Italian Ministry of University and Research through the Ph.D. scholarship of H.E. and by the European Union – Next Generation EU through the PRIN project "Sediment Transport REsearch for cAtchments Management" (STREAM), project no. 2022SAFKS4.