

Numerical study of turbulent open-channel flow in the presence of emergent vegetation located at the lee side of a single groyne

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INTRODUCTION AND AIM

Groynes are widely recognized for their role in protecting river and coastal banks from erosion. Due to a reduction in velocity magnitude, the area downstream of the groynes becomes susceptible to sediment deposition, creating a favorable habitat for aquatic organisms and vegetation. In this study, a three-dimensional turbulent open-channel flow ($Fr = 0.19$) with a single groyne was numerically simulated using the ANSYS FLUENT solver. Additionally, the case of a vegetated patch located at the lee side of the single groyne was also examined. The scope of this work is to study the flow structure, i.e. the velocity field as well as the reattachment lengths, downstream of the single groyne, both with and without the presence of vegetation.

METHOD

- The simulated channel had a rectangular cross-section with a width of $B = 0.9144\text{m}$ and a bottom slope of $S_0 = 10^{-4}$, while the length of the channel was 36.576m . The groyne structure, located at the middle of the channel, ($x/b = 120$) was a parallelepiped with a length of $b = B/6 = 0.1524\text{m}$ and thickness of 3mm . The flow upstream of the groyne was subcritical, with a Froude number $Fr = 0.19$ and normal flow depth $d = 0.189\text{m}$, while the bulk mean velocity was set to $U_0 = 0.262\text{m/s}$.
- Vegetation was modeled using vertical, rigid cylinders located near the downstream face of the emerged, impermeable groyne, within its recirculation zone. The emergent vegetated stems were arranged in a uniform, parallel array of eighteen (3×6). Each stem had a diameter of 5mm , and the distance between stems was set to 25mm .
- The numerical solution of the governing equations was based on a finite-volume discretization, utilizing the CFD code ANSYS FLUENT (FLUENT, 2022). The standard $k-\epsilon$ turbulence model was employed for turbulence closure, while the VOF method was used for free surface treatment.

RESULTS AND DISCUSSION

The computed velocities were found to be in good agreement with the experimental data of Rajaratnam and Nwachukwu (1983) and the numerical results of Koutrouveli et al. (2019).

Due to the presence of the groyne, the streamwise velocity increases in the deflected region (the area between the tip of the groyne and the opposite wall) up to 50% relative to the bulk mean velocity, while it decreases upstream as the flow approaches the groyne and within its recirculation zone (Figs. 1,3a). Comparison with the vegetated case shows that the presence of emergent stems decreases the velocity magnitude within the vegetated area, with the largest decrease observed at the end of the vegetated patch ($x/b = 121.06$) (Fig. 1).

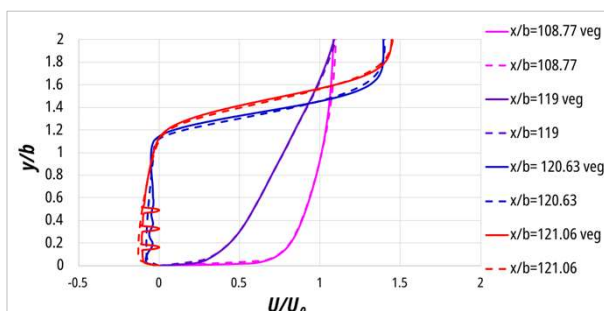


Figure 1. Spanwise profile of the streamwise velocity at $z/d = 0.5$ at different x/b positions. Continuous lines correspond to the vegetated case and dashed lines to the non-vegetated one.

The presence of the vegetated stems also affects the turbulence structure, leading to a decrease in turbulent viscosity within the vegetated region (Fig. 2). At the end of the vegetated patch ($x/b = 121.06$), turbulent viscosity drops by approximately 70% compared to the non-vegetated case, but it eventually returns in its original state downstream.

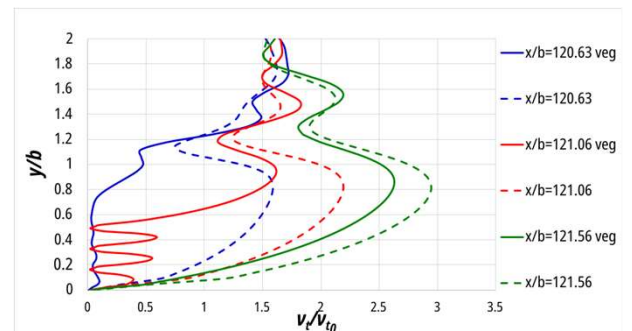


Figure 2. Spanwise profile of the turbulent viscosity at $z/d = 0.5$ at different x/b positions. Continuous lines correspond to the vegetated case and dashed lines to the non-vegetated one.

In the case of a single groyne without vegetation, the numerical results show that a recirculation zone is created with a reattachment length varying between $15b$ and $12b$ from the bed to the free surface, where b corresponds to the groyne length. The same reattachment length is calculated for the vegetated case (Fig. 3b).

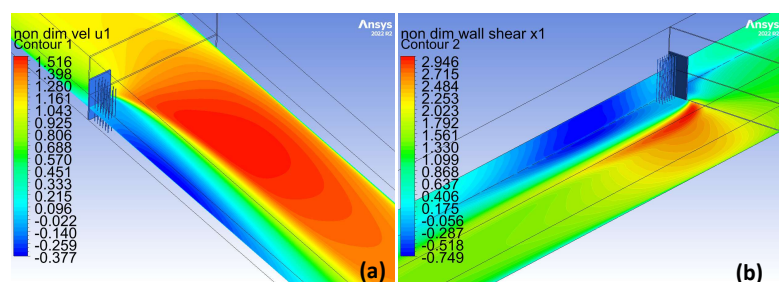


Figure 3. Contours of non dimensional (a) streamwise velocity (U/U_0) at $z/d = 0.5$ and (b) streamwise wall shear stress (τ/τ_0) at $z/d = 0$, for the vegetated case.

CONCLUSION

The comparison between the two cases shows that the presence of the vegetated patch does not affect the reattachment length of the recirculation zone. On the other hand, turbulent viscosity and flow velocity are decreased in the vegetated area.

FUTURE WORK / REFERENCES

- ANSYS. *ANSYS FLUENT 2022 R2*, User's Guide, ANSYS Inc.: Canonsburg, PA, USA, 2022.
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