SOLITARY-WAVE-INDUCED BOUNDARY LAYER FLOWS OVER PERMEABLE BEDS

Nimish Pujara, University of Wisconsin-Madison, npujara@wisc.edu
Claudio Meza-Valle, University of Wisconsin-Madison, meza4@wisc.edu
Philip L.-F. Liu, National University of Singapore, ceellfp@nus.edu.sg

In the nearshore environment, viscous effects of wave-induced boundary layer flows above sea beds are important in evaluating sediment fluxes and wave damping. These effects need to be included in phase-resolved nearshore models for accurate determination of quantities such as the bed shear stress and the decrease in wave height due to frictional dissipation. Figure 1 shows an idealized setup of such a problem: a solitary wave travels over a permeable sea bed.

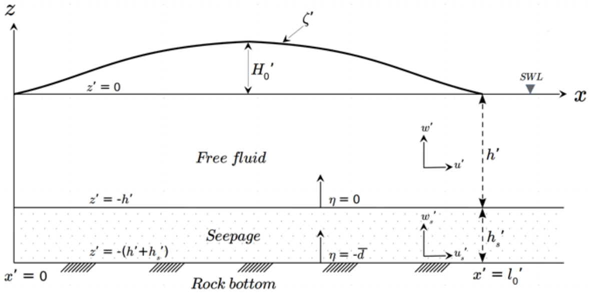

Figure 1 - Definition sketch.

Liu and Orfila (2004) provided a general framework for including viscous effects in the bottom boundary layer over an impermeable bed for the propagation of transient long waves using a perturbation approach and a Boussinesq approximation. Using this approach, Liu et al. (2007a) computed the boundary layer velocity profile for a solitary wave travelling in a channel of constant cross-section and compared the experimental measurements with theoretical predictions. Both theory and experiments showed that while the irrotational velocity in the bulk of the water column only experiences a forward velocity, the flow in the boundary layer is initially in the forward direction before reversing direction when faced with the adverse pressure gradient in the deceleration phase of the wave.

Flow in permeable sea beds induced by long waves have previously been examined by Liu et al. (2007b) using Darcy's law. For the case of a solitary wave travelling over a permeable bed, they found that there is potential for the wave-induced flow to momentarily and locally fluidize the bed and that the seepage flow in the bed can induce significant wave damping. However, both of these effects are very sensitive to the degree of saturation in the bed. Unsaturated beds are more likely to become fluidized and generate higher wave damping.

In the present work, we extend these solutions to investigate the boundary layer flow over a permeable bed. Waves travelling over a permeable bed can induce flow through the porous medium of the bed via transmission of pressure gradients and this flow can couple to the flow above the interface between the fluid and permeable bed. This results in boundary layers developing on both sides of this interface. We examine this situation both from the fluid side and the permeable bed side.

The boundary layer in the fluid domain is calculated using perturbation approach as before (separation of fluid velocities into an irrotational and rotational component). The effects of the permeable bed are taken into account via altering the bottom boundary condition using two different methods: (1) assuming that Darcy's law applies right up to the upper edge of the permeable bed; (2) using a slip velocity at the permeable wall based on the Beavers and Joseph (1967) boundary condition. Figure 2 shows results of using the first approach, where the effects of increasing the hydraulic conductivity of the permeable bed on the boundary layer velocity profiles can be seen. As the hydraulic conductivity increases, the boundary layer dynamics change qualitatively because the pressure-gradient-induced flow in the seabed becomes significant. We plan to extend these calculations to also use the second approach and compare the results of both approaches to laboratory investigations.

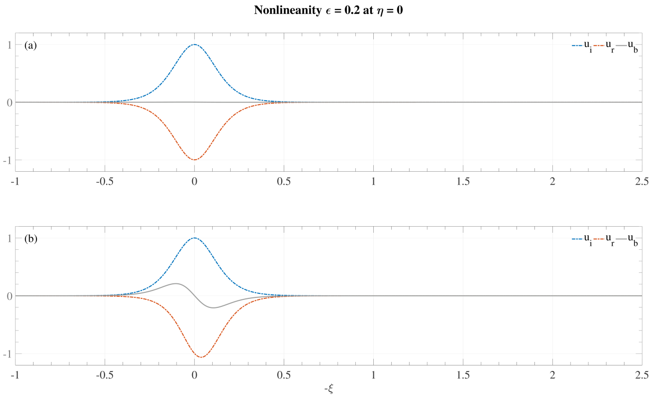

Figure 2 - Velocity at the fluid-bed for a solitary wave traveling in a channel of constant cross section over (a) an impermeable bed, and (b) over a permeable bed. Here, u_i is the irrotational velocity, u_r is the rotational velocity, and $u_b = u_i + u_r$ is the full solution.

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