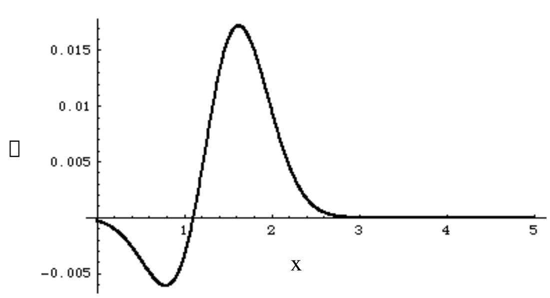
Tsunami Forces in the Runup Zone

Harry Yeh
Oregon State University

Unlike the direct seismic effects of an earthquake, there is usually a short lead-time for predicting tsunami attack after receiving a seismic signal, which makes effective warning and evacuation possible. Combined with the fact that a tsunami is a rare event, the primary mitigation measures for tsunamis have been to develop effective warning system and evacuation strategies. For this reason, research in the past has not focused on the development of methodologies for tsunami-resistant structures. While this strategy makes sense, there are emerging needs to consider tsunami-resistant designs for man-made structures, particularly those whose failures can have severe effects. Structural damage by tsunami can be caused by direct water forces, impact forces by a water-born missile, fire spread by floating materials (including burning oil), scour and slope/foundation failure, and winds induced by the wave motion -- this last effect is considered to be very local and minor. As the first step, we focus on the first and fundamental cause, direct water forces.

We first determine tsunami runup characteristics assuming the pressure field is hydrostatic as the lowest-order estimate. The simplest case to study is runup on a uniformly sloping beach in a one-dimensional configuration. The existing analytic-numeric hybrid model of the fully nonlinear non-dispersive shallow-water wave equations is used to determine the temporal and spatial variations of water depth and flow velocity in the tsunami runup region, from which the linear-momentum flux is evaluated. The momentum flux can be interpreted as the drag force for a surface-piercing stationary object being placed vertically over the flow depth, but without the constant multiplier involving the drag coefficient. The envelope of the extreme momentum-flux in the runup/rundown process is computed for an arbitrary initial tsunami condition being specified offshore. For example, a case of a typical leading depression N-wave is shown below. The result will provide the tsunami force distribution in the runup zone. The actual force acting on a specific object must be computed with its size and shape, and the drag coefficient. Our preliminary laboratory experiments indicate that the proper value of the tsunami drag coefficient is approximately 3 ~ 4, more than twice the value for a purely two-dimensional-flow; this enhanced drag coefficient is primarily caused by the free-surface effect. Some example computations will be given.

Initial Conditions



The max. fluid forces vs distance from the shoreline