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Title:
Self-burial of Objects on Sandy Beds by Wave- and Current-Induced Scour

Abstract:
Self-burial of Objects on Sandy Beds by Wave- and Current-Induced Scour

When an object sitting on the bed extends above the surrounding bed roughness, the object will alter the local flow pattern relative to the far field boundary layer. Such perturbations increase the velocities and stresses impinging on sediment immediately adjacent to the object. Nearby grains tend to be dispersed, resulting in a scour pit that deepens until the tendency for sediment to be dispersed is balanced by a tendency for sediment to fall back into the pit. The difference in pressure at the bed upstream and downstream of the object may also drive seepage flow which can cause piping and tunnel erosion under the object. As a result of the above processes, the object may eventually become unstable and settle into the scoured depression, reducing the object's exposure height. For a given object, surrounding sediment, and far field hydrodynamics, an equilibrium value for the depth of scour-induced self-burial is anticipated to be a function of the far field waves and currents, the properties of the surrounding sediment, and the size, shape and density of the object.

This paper, which was motivated by possible threats to safety associated with the presence of abandoned, unexploded underwater ordnance (UXO), presents a compilation and analysis of existing data on equilibrium self-burial depth of objects on sandy beds as induced by local scour. More than 650 observations of equilibrium depths of self-burial (B) for objects subject to scour on sandy beds have been identified from the literature. Cylinders are the most commonly studied object type (> 500 cases), with existing data spanning diameters (D) from 1 to 50 cm, length-to-diameter ratios (L/D) of 2 to 30, and object densities relative to water (S_{object}) of 1 to 10. Median sand diameter (d) ranged from 0.1 to 0.7 mm, maximum near-bed wave plus current velocity ($U_w + U_c$) ranged from 0.1 to 1.3 m/s, and cases including waves had wave periods (T) ranging from 1 to 12 s. Other object types for which B has been documented in the literature include spheres, bullet-like shapes, and conical frustums.

The analyses presented here indicate that B/D for cylinders increases most strongly with increases in the Shields parameter ($u_*^2/[g\ d\ (S_{sand}-1)]$) describing the far-field flow and sediment size (where u_* is the far-field friction velocity) or, alternatively, with increases in the sediment mobility number (which is the Shields parameter divided by an appropriately scaled bed drag coefficient). Once variability associated with the Shields parameter (or mobility number) has been removed, the residual in observed B/D for cylinders significantly increases as the Keulegan-Carpenter number (U_wT/D) increases, as dimensionless wave period (gT/U_w) increases (where g is the acceleration of gravity), as L/D increases, as S_{object} increases, and as D/d decreases. Object shape is also found to be significant in that for a given forcing, bullet-shaped objects tend to have larger values of B/D, spheres and cylinders have intermediate B/D, and conical frustums have smaller B/D. Ongoing multivariate analysis is constraining predictive parameterizations for B/D which simultaneously include several of the above variables.