

Abstract

An exhaustive analysis of the formation of scour around bridge piers due to the action of flow current and/or waves is presented in this study. Initially, analytical modelling has been employed to frame equations for calculating the scour hydrodynamics parameters. A comprehensive review on the mechanism of formation of local scour due to the evolution of vortices has been presented. The role of the size, velocity, and strength of the horseshoe vortices (HSV) in influencing the scour hydrodynamics has been investigated. The formation of HSV as a result of the separation of laminar and turbulent boundary layer has been explained in detail. Later, a general scour depth equation under steady current has been developed considering an arbitrary shaped scour hole at the upstream and the downstream sections, by applying energy balance theory. The current status of research on the scour around piers under the action of the waves is presented. This includes a summary of different bridge failure events due to the scour, the mechanism of scour formation, the scour depth predictors under waves, influence of pier shape on the scour depth formation, and the shape of the scour hole around piers. Further, a mathematical equation based on Airy's wave theory is developed for calculating the equilibrium scour depth around a pier under the action of collinear waves and current assuming a power-law current velocity profile. Subsequently, this mathematical model has been extended by incorporating the combined effects of the waves and the current on the scour formation around a pile considering that the direction of advancement of the waves is making an arbitrary angle with the current velocity. Further, with the aid of Computational Fluid Dynamics (CFD), the three-dimensional non-linear Navier-Stokes equation has been solved to study the hydrodynamics around piers. Both laminar and turbulent flow regimes have been considered to elucidate the origin of forces in the wake region of a pier.

A detailed study of flow past an elliptical cylinder with an emphasis on the variation of domain size on flow dynamics has been performed, which encompasses a wide range of aspect ratios. A completely new outlook on the origin of the forces in the wake of the elliptical cylinder has been presented. Further, comprehensive use of a circular outer flow domain has been made to perform the numerical analysis contrary to the conventional rectangular domain. Flow hydrodynamics around tandem cylinders for turbulent flow has been simulated using Reynolds Averaged Navier Stokes (RANS) and Large Eddy Simulation (LES), for three gap ratios ($s/d = 2, 3$ and 4). It has been observed that the LES model exhibited better accuracy compared to the RANS model.

Keywords: Mathematical modelling, scour, hydrodynamics, energy balance approach, wave current interaction, CFD, LES, RANS.