Bed instability generated by turbidity currents

*Norihiro Izumi[1], Sakura Hagisawa[1]

1. Faculty of Engineering, Hokkaido University

Once relatively fine sediment is entrained into water on the ocean floor of the continental shelf or the continental slope, water near the ocean floor increases its density due to the entrained sediment, and starts to flow in the downslope direction. This density flow is called a turbidity current in particular. A turbidity current has unimaginably high capabilities for erosion of the bed and sediment transport, and therefore, it is one of the major agents for the formation of submarine morphology such as submarine canyons and bedforms. As turbidity currents transport not only sediment also a large amount of organic matters originated in the continental areas to the deep ocean floor, they are one of the most essential processes for the generation of petroleum and methane hydrate. In addition, turbidity currents cause destructive damages on submarine infrastructure such as submarine cables. Therefore, study on turbidity currents is important from view points of the maintenance of submarine infrastructure.

A totally 3000 km long submarine delta thought to be formed by turbidity currents is confirmed to lie on the vast ocean floor from the Bay of Bengal to the Indian Ocean. It had not been known for long how turbidity currents can travel this long distance. In the case of saline or thermal density flow, it increases the thickness due to the entrainment of surrounding water as it flows down the slope, decreases the concentration of suspended sediment, and ends up with extinction. On the other hand in the case of turbidity currents, Luchi (2015) has shown that the layer of high-concentrated suspended sediment (referred to as a high-concentrated layer, hereafter) is not diffused out because of the balance between the settling of sediment and the diffusion of sediment; a normal flow condition can be achieved in the high-concentrated layer. This finding can explain that turbidity currents can travel as far as the ocean floor is inclined. In addition, the existence of normal flow conditions facilitates theoretical analyses on the formation of a variety of submarine morphologies.

In this study, we propose a linear stability analysis of bed waves formed due to instability between the ocean floor and turbidity currents with the use of the assumption of normal flow conditions and a simple turbulent model of the mixing length hypothesis. In the analysis, we employ the flow equations including the concentration of suspended sediment as the driving force, the dispersion/diffusion equation of suspended sediment, and the continuity equation describing the time variation of the bed elevation. Normalizing those governing equations, we obtain two important non-dimensional parameters: the densimetric Froude number and the settling velocity normalized by the shear velocity. If the normalized settling velocity is larger than 0.08, we obtain an unrealistic result that the concentration of suspended sediment vanishes at the top of the high-concentrated layer. This might mean that the high-concentrated layer in the normal flow condition cannot be achieved when sediment is too coarse.

We introduce perturbation on the velocity, the suspended sediment concentration, and the elevations of the bed and water surfaces, and perform a linear stability analysis. It is found that the flat ocean floor becomes unstable in the range of the densimetric Froude number larger than 0.5 to 0.8, and that the dominant wavenumber ranges from 0.3 to 0.5. In addition, bed waves with large wavenumbers migrate downstream while those with small wavenumbers migrate upstream. This result is consistent with experimental results.

Keywords: turbidity currents, bed instability, linear stability analysis

