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A comparative study on the rheology and wave dissipation of kaolinite and natural Hendijan Coast mud, the Persian Gulf

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Abstract The objective of this paper is to investigate the rheological behavior of kaolinite and Hendijan mud, located at the northwest part of the Persian Gulf, and the dissipative role of this muddy bed on surface water waves. A series of laboratory rheological tests was conducted to investigate the rheological response of mud to rotary and cyclic shear rates. While a viscoplastic Bingham model can successfully be applied for continuous controlled shear-stress tests, the rheology of fluid mud displays complex viscoelastic behavior in time-periodic motion. The comparisons of the behavior of natural Hendijan mud with commercial kaolinite show rheological similarities. A large number of laboratory wave-flume experiments were carried out with a focus on the dissipative role of the fluid mud. Assuming four rheological models of viscous, Kelvin-Voigt viscoelastic, Bingham viscoplastic, and viscoelastic-plastic for fluid mud layer, a numerical multi-layered model was applied to analyze the effects of different parameters of surface wave and muddy bed on wave attenuation. The predicted results based on different rheological models generally agree with the obtained wave-flume data implying that the adopted rheological model does not play an important role in the accuracy of prediction.

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1 Introduction

Typical muddy coasts can be found in many coastal areas of the world when there is usually a source of fine particulate matter and both currents and waves exert only weak forces on the bed. Although a sieve study resulting to D_{50} is usually enough to predict sand behavior, the number of parameters which need to be determined to completely describe a cohesive sediment is quite considerable. Hayter and Mehta (1982) have mentioned 18 parameters to characterize cohesive sediments. These include type of material, nature of clay structure, chemical composition, grain properties, texture, aging, biological matter, etc. On the other hand, it is the bulk properties of cohesive sediment that determines its behavior, and the particle size does not control the mobility of sediment. That is why the study of muddy coasts is complex and highly site-specific.

A simple description of the mud-wave system, which shows an idealized vertical profile of (bulk) density and instantaneous velocity, is given in Fig. 1 (Mehta 1989). As observed, the profile is divided into three layers by the two sharp gradients. The first one, or lutocline (Parker and Kirby 1982), separates the upper column suspension from movable, compliant mud below. Fluid mud is considered to occur at the bottom of the suspension. The upper part of the stationary cohesive bed can undergo deformation, which may finally break the inter-particle or inter-aggregate bonds, and thus change the bed, possessing a structured matrix, to fluid mud. Thus, the depth of fluid mud depends on both the wave characteristics and bed properties. The