NONLINEAR INTERACTION OF FLUID MUD IN A TRENCH WITH WATER SURFACE WAVES

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1. INTRODUCTION The application of classical water wave theories in offshore designs assuming the sea bed as inert, rigid and nonporous boundary where the beds are composed with soft mud may lead to the significant theoretical drawback. The recent studies on the sea floor dynamics has proved that the sea bed is no longer a rigid boundary and it can interact with the waves bearing significant effects on wave attenuation, bed fluidization, sediment transports, erosions, depositions, water-sediments mixing and water quality in the coastal and eatuarial areas. Many scientists and engineers studied the interaction of seabed and sea waves from different points of view. Dalrymple and Liu(1978) investigated interaction problems for linear water waves assuming that the mud layer can behave like a viscous fluid. Foda et al.(1993) reported the fluidization of the soft marine mud and solved for the fluidization depths as a function of the imposed wave height assuming that the fluidized mud can behave visco-elastically. The present study assumes that the seabed mud can behave like a viscous fluid as assumed by Dalrymple and Liu(1978) and the model developed here envisages the interaction of seabed mud with the nonlinear surface waves. Laboratory experiments are also conducted to compare with the numerical results.

2. THEORITICAL FORMULATIONS **Fig.1** shows the definition sketch for the two-layers flow system under consideration. The governing equations for the system are the continuity and Navier-Stokes equations while the boundary conditions are the followings:

Kinematic condition: $w=\frac{\partial\zeta}{\partial t}+u\frac{\partial\zeta}{\partial x}$ at $z=\zeta$ and $\{u-(U+\hat{U})\}\frac{\partial\xi}{\partial x}-(w-W)=0$ at $z=-h+\xi$

Dynamic condition: $p=0$ at $z=\zeta$ and $p_1-2\rho_1\nu_1\frac{\partial w}{\partial z}=p_2-2\rho_2\nu_2\frac{\partial W}{\partial z}$ at $z=-h+\xi$

Continuity of shear stress: $\frac{\partial(U+\hat{U})}{\partial z}+\frac{\partial W}{\partial x}=0$ at $z=-h+\xi$

Continuity of horizontal and vertical velocities: $u=U+\hat{U}$ at $z=-h+\xi$ and $w=W$ at $z=-h+\xi$

Rigid bottom condition: $W=o$ at $z=-(h+d)$

where ***u*** and *U* are the horizontal velocities, ***w*** and ***W*** are the vertical velocities, ρ_1 and ρ_2 are the densities, ν_1 and ν_2 are the kinematic viscosities respectively for upper and lower layers, ζ and ξ are respectively the free surface and interfacial displacements, p_1 and p_2 are the pressures at the interface for upper and lower layers respectively, and $\hat{U}$ is the horizontal rotational velocity at the interface. The vertical rotational velocity for both layers at the interface is neglected for its smallness. Using the governing equations and incorporating the above boundary conditions, the perturbation analysis leads to a set of Boussinesq type equations in the following forms:

$$\zeta_t+\nabla(\zeta+h-\xi)\overline{u}+\nabla(d+\xi)\overline{U}=0 \quad (1); \qquad \xi_t+\nabla(d+\xi)\overline{U}=0 \quad (2)$$

$$\overline{u}_t+\overline{u}\nabla\overline{u}+g\nabla\zeta-\frac{h^2}{3}\nabla^2\overline{u}_t-\frac{hd}{2}\nabla^2\overline{U}_t=0 \quad (3)$$

$$\overline{U}_t+\overline{U}\nabla\overline{U}+g(1-\gamma)\nabla\xi+g\gamma\nabla\zeta-\frac{d^2}{3}\nabla^2\overline{U}_t-\frac{\gamma h^2}{2}\nabla^2\overline{u}_t-\gamma hd\nabla^2\overline{U}_t-2(\nu_2-\gamma\nu_1)\nabla^2\overline{U}=0 \quad (4)$$

where γ is the density ratio defined as ρ_1/ρ_2. The terms related to the viscosity have been retained up to the order of nonlinearity parameter $O(\varepsilon)$.

3. RESULTS AND DISCUSSION The surface waves of 1.0 to 1.6 s and the mud of fine silt having density and viscosity of 1.3 g/cm^3 and 0.015 m^2/s (as see bed material) respectively are used both in the laboratory experiments and

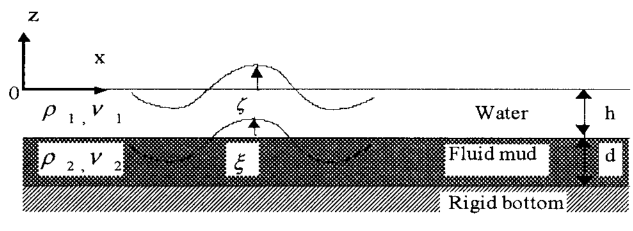

Fig.1 Definition sketch

numerical computations. A rectangular trench of 5 cm deep and 50 cm wide is excavated in the laboratory flume. Fluid mud of the above density has been prepared adding water to the commercially available mud and mixing thoroughly.The trench is filled up with the fluid mud and the flume is filled with water carefully so that the fluid mud in the trench remains intact and kept for 24 hours. Water depth of 12 cm over the mud bed is used in the experiments. During experiments, the video records are taken to catch the interfacial oscillations and the waves at some particular locations at the upstream and downstream of the trench are taken with two wave gauges.

Both the numerical and experimental results demonstrate that a clear interfacial wave is developed in response to the surface waves. Fig.2 shows the computed surface and interfacial waves and the corresponding surface and interfacial waves extracted from the experiments. The interfacial waves presented here correspond to the surface wave of period T=1.0 s. It is seen that due to the thrust from the imposed waves, the mud bed gets fluidized and the interfacial waves are

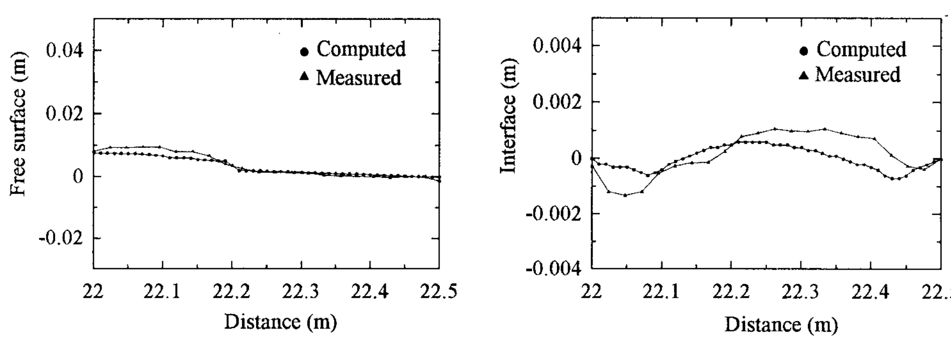

Fig.2 Spatial profiles of the free surface and interface (corresponding to the surface wave of T=1.0 s)

developed. It is found that the behavior of mud depends on the imposed wave height, water depth over the mud bed, and also on the density and viscosity of the mud.

4. CONCLUSION The information provided by the classical water wave theories assuming the seabed as rigid boundary where the seabed is composed with the soft mud or the seabed gets fluidized due to wave actions may lead to the erroneous design to some extent. The outcomes of the present models may provide important information to the designer to avoid uncertainty in design as well as to avoid misunderstanding about the concerned seabed under waves action.

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