FINE SAND SEABED DEFORMATION AROUND BREAKWATERS

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1. Introduction:

The development of scour zones around coastal structures may cause toe failure and threaten the structure stability. Seabed deformations are commonly related to the wave kinematics and less interest is given to the seabed stresses. The deformations of fine sand seabed were visualised around hydraulic models of composite and submerged breakwaters. The BEM-FEM model is used to compute the wave kinematics around the breakwaters. A poro-elastic FEM model is used to evaluate the wave-induced stresses around the breakwaters as well. The wave kinematics, seabed stresses and the observed scour in the experiment are discussed and correlated.

2. Hydraulic Models:

Sand bed of 0.38 mm in diameter was used under composite and submerged breakwater models as shown in Figs.1 and 2. Coloured sand layers, each of 1.0 cm thickness, were utilised to elucidate the deformations of sand. The experiments sustained for 8 hr using an incident wave height of 5.0 cm while the wave period was 2.2 and 1.8 sec for the composite and submerged breakwaters, respectively. Digital and Movie cameras were also employed to record the seabed deformation every 1.0 hr.

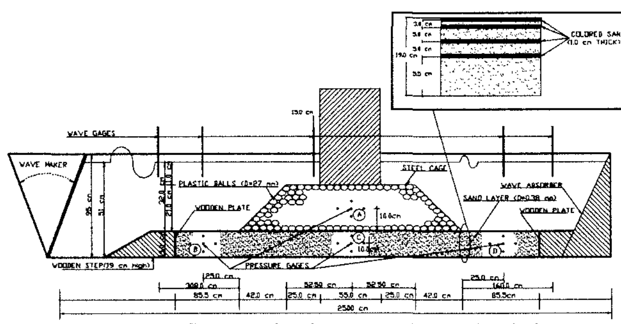

Fig.1 Composite breakwater over fine sand seabed

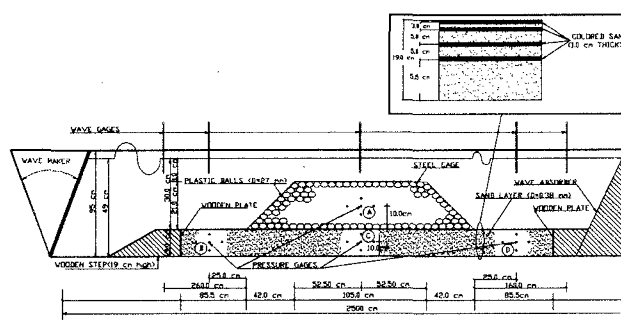

Fig.2 Submerged breakwater over fine sand seabed

3. Numerical Models:

The BEM-FEM model employs fully nonlinear potential and modified Navier-Stokes equations for the wave field and porous media, respectively. The poro-elastic FEM model is based on Biot's equations (1941) and adopts nonlinear coefficient of permeability. It also uses the surface pressure computed by the BEM-FEM model as a boundary condition.

4. Results and Discussions:

The experiment showed that the area offshore of breakwater is vulnerable to scour and formation of ripples while the onshore seabed is almost safe against scour. The seabed deformations under the breakwater are almost null because the seabed thickness is small and the seabed seems to be even stiff enough to carry the breakwater laid over it. During the experiment, the seabed ripples were almost fixed in case of the submerged breakwater but were oscillating offshore of the composite breakwater. One scour zone of nearly 2.8 cm maximum depth at X/L=1.68 was observed offshore of the submerged breakwater toe (X/L=1.75). Two scour zones were formed offshore of the composite breakwater toe (X/L=2.07) and had maximum depths of 1.4 and 1.7 cm at X/L=2.03~2.05 and X/L=1.94~1.98, respectively.

The development of negative stresses in the seabed means that the contact pressure between the sand grains is null and the grains can move easier than before. This causes the seabed material to be readily swept away even under the effect of relatively small velocities. The horizontal stresses at the seabed level offshore of the caisson, being at X/L=2.25, are demonstrated in Fig.3. It is obvious that the wave non-linearity influences the horizontal stresses at this location and maximum negative stresses take place at X/L=1.97. Negative horizontal stresses as deep as 0.108ds (≅2.0 cm) and 0.08ds (≅1.6 cm) are developed at X/L=1.97 and 2.045, respectively (Fig.4). The observed scour depth in the experiment is comparable to the depth of tensile stresses. Thus, it can be thought that the depth of tensile horizontal stresses gives an overestimation for the seabed scour offshore of the examined composite breakwater. The horizontal pore velocity, computed by the BEM-FEM model, is non-linear and reaches its maximum within the observed scoured zone by the virtue of being under the wave node (Fig.5). The horizontal velocity, dϕ/dx, is higher than the pore velocity and has a phase difference from it (Fig.6).

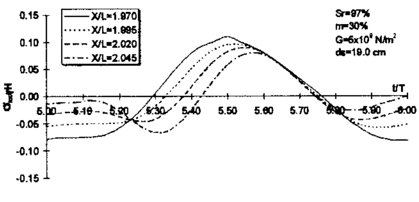

Fig.3 Seabed horizontal stresses for composite breakwater

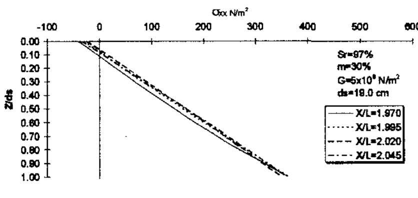

Fig.4 Maxi. seabed horizontal stresses for composite breakwater

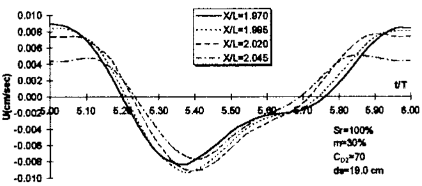

Fig.5 Seabed horizontal pore velocity for composite breakwater

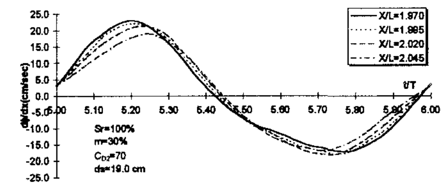

Fig.6 Seabed horizontal velocity for composite breakwater

The normalised horizontal stresses in the seabed offshore the toe of the submerged breakwater, T=1.8 sec, seem to have less higher harmonics and slightly larger magnitude than the composite breakwater case (Fig.7). The maximum depth of horizontal tensile stresses in Fig.8 is nearly 0.165 ds (3.2 cm) and 0.11 ds (2.1 cm) at X/L=1.75 and 1.70, respectively. Thus, the observed scour depth in the experiment is larger than the depth of tensile horizontal stresses at X/L=1.68 while deposition occurred at X/L=1.75 and this can be explained by analysing the bed velocity. The horizontal pore velocity is non-linear and small due to the low permeability of sand (Fig.9). The seabed horizontal velocity computed as dϕ/dx also shows large difference in phase and magnitude from that in the sand pores (Fig.10). It can be noticed that the seabed velocity at X/L=1.75 is much less than that from X/L=1.65~1.70. Thus, the water particles have higher potential to scour the bed at X/L=1.65~1.70 and the transported sand would be blocked by the breakwater toe on the onshore side being at X/L=1.75. Since the sand ripples were observed to be almost fixed in their place, the water velocity could scour the loose sand layer and go deeper at X/L=1.68. This implies that both the horizontal stresses and the water velocity distributions should be considered to predict the scour depth in terms of the tensile stresses depth.

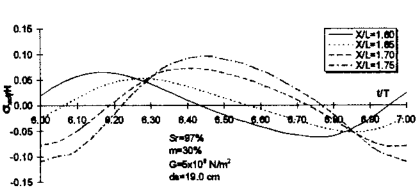

Fig.7 Seabed horizontal stresses for submerged breakwater

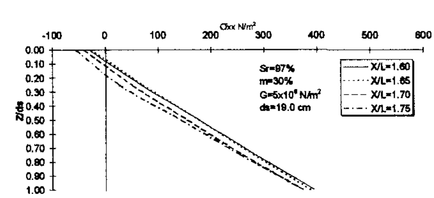

Fig.8 Maxi. seabed horizontal stresses for submerged breakwater

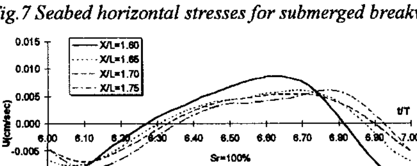

Fig.9 Seabed horizontal pore velocity for submerged breakwater

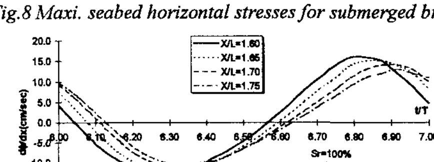

Fig.10 Seabed horizontal velocity for submerged breakwater