Numerical and Experimental Study on Wave-Current Interactions over a Submerged Bar

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INTRODUCTION

Submerged structure is the most common construction in costal engineering. As the incident waves propagating over it, a combination of shoaling, reflection, and diffraction effects modify the wave profile. Many scholars applied the standard or extend Boussinesq equations to simulate wave transformation problems.

But waves in the coastal environment usually co-exist with currents. The coexistence of current can significantly alter the wave characteristics. And the relating studies on a wave–current field over submerged obstacles are still limited. In this study, the wave-current interactions over a submerged bar is investigated numerically and experimentally.

EXPERIMENTAL SETUP

The experiments were conducted in a flume with scale 69m×3m× 1.8m. Five wave gauges were installed to record the wave transformation and propagation. The flume is equipped with a hydraulically driven, irregular wave generator at one end, and a wave absorber at the other.

The still-water depth is h=0.6m. A vertical submerged bar was installed along the bottom of flume, whose scale is 0.4m height and 0.5m width. The incident wave amplitude A varies from 0.025m to 0.054m, and incident wave periods (T) are 1s and 2s, respectively. An acoustic Doppler velocimeter (ADV) was used to measure the current velocity and the mean velocity U_0=0.2m/s was chosen.

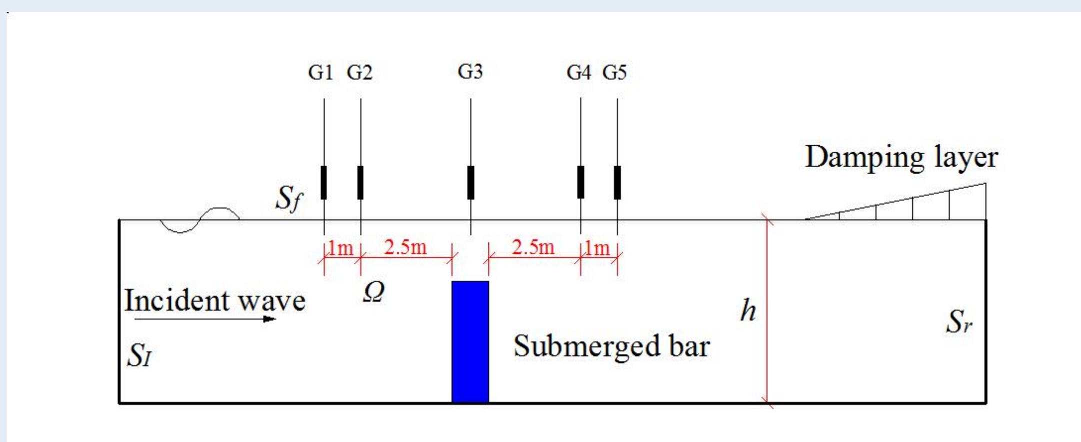


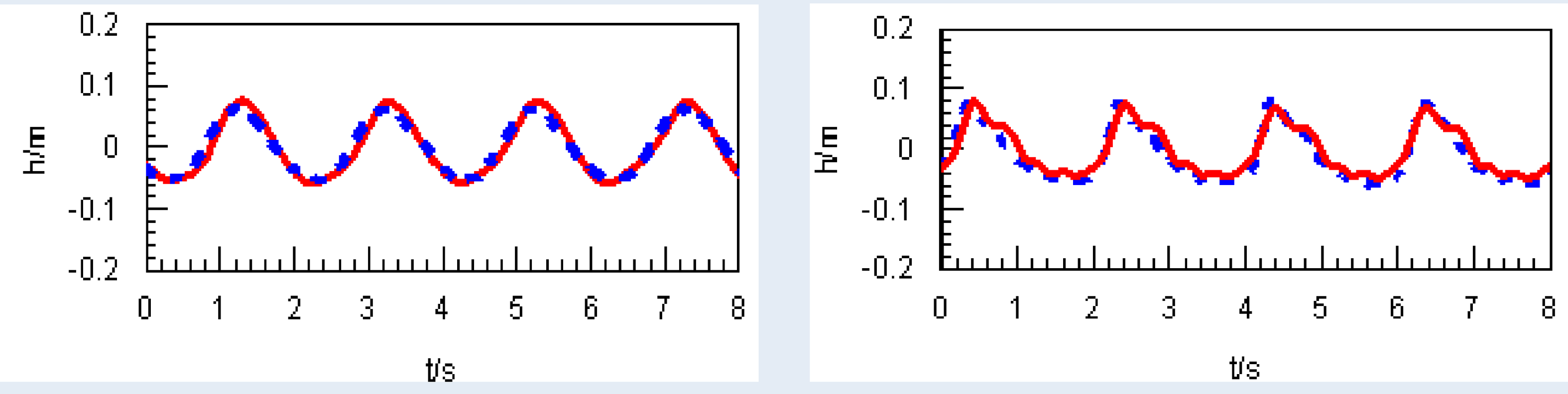
Fig.1 Sketch of the experimental setup

NUMERICAL MODEL AND VALIDATION

Boundary integral equation model based on potential theory and the Second Green Identity was developed (Ligget & Liu, 1983). Laplace equation and the following boundary conditions are satisfied:

$$\left.\begin{aligned} \frac{D\vec{X}_F(t)}{Dt} &= U(x)\mathrm{i}+\nabla\phi-\mu(x)(X-X_0) \\ \frac{D\phi}{Dt} &= \frac{1}{2}\nabla\phi\cdot\nabla\phi-g\eta-\mu(x)\phi \end{aligned}\right\} \quad \text{on } S_f$$

$$\frac{\partial\phi}{\partial n}=\frac{\partial\phi_I}{\partial n}=-\frac{\partial\phi_I}{\partial x} \quad \text{on } S_I \text{ and } \quad \frac{\partial\phi}{\partial n}=0 \quad \text{on } S_b \text{ and } S_r$$

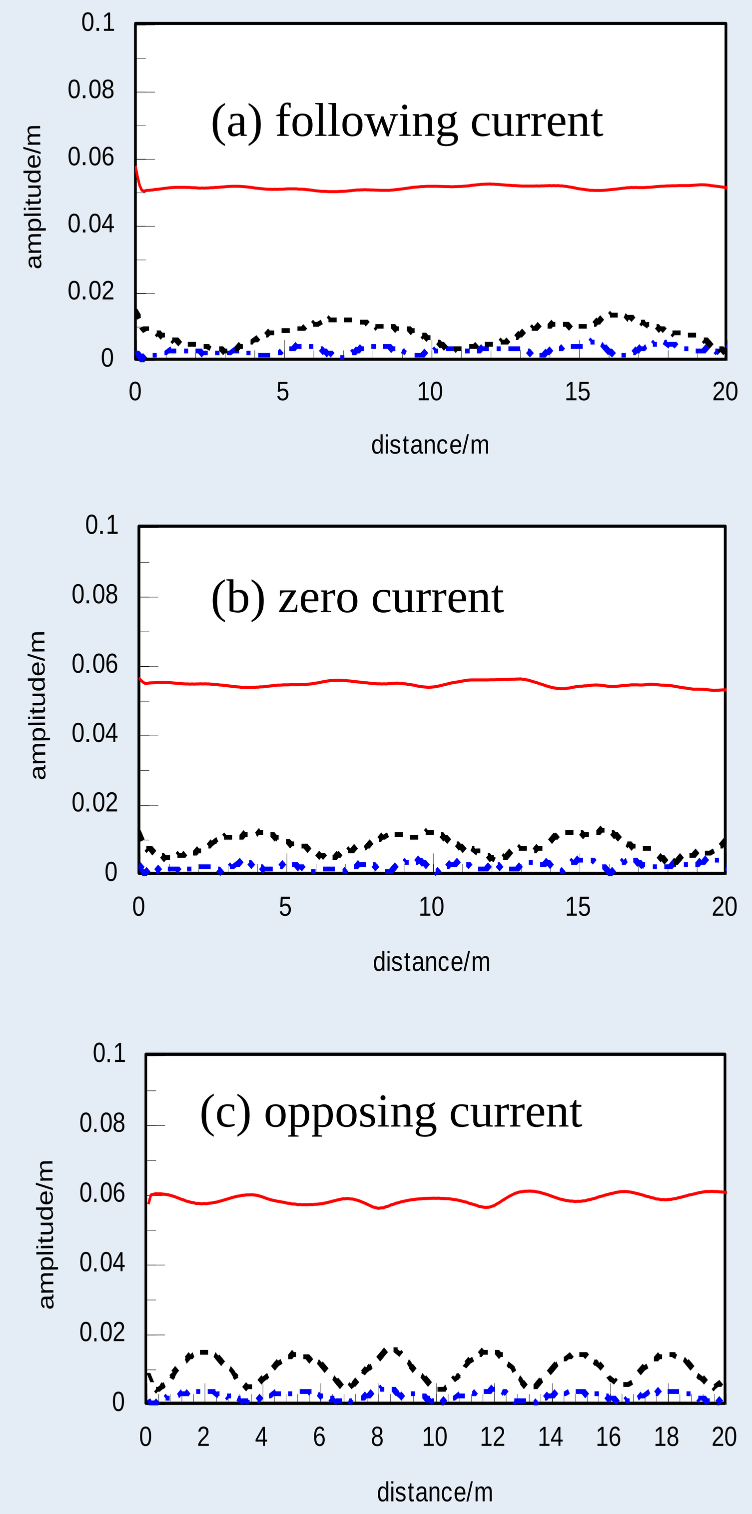


(a) following current (b) opposing current

Fig.2 Time series of surface elevation at G3 for (a) U_0=0.2m/s and (b) U_0=-0.2 m/s with T=2s and A=0.054m (Real line: Numerical; Dash line: Experimental.)

The dispersion relation considering current effect is adopted. The MEL scheme is adopted to track the transient free surface with the fourth-order Runga-Kutta method for refreshing wave profile and velocity potential at the next time step. The whole boundary is discretised and solved by a higher-order boundary element method (See Lin et al. (2014) for detail) . The Fig.2 shows the comparisons of surface variation at G3 over the submerged bar from experimental data and numerical result.

RESULTS AND DISCUSSION



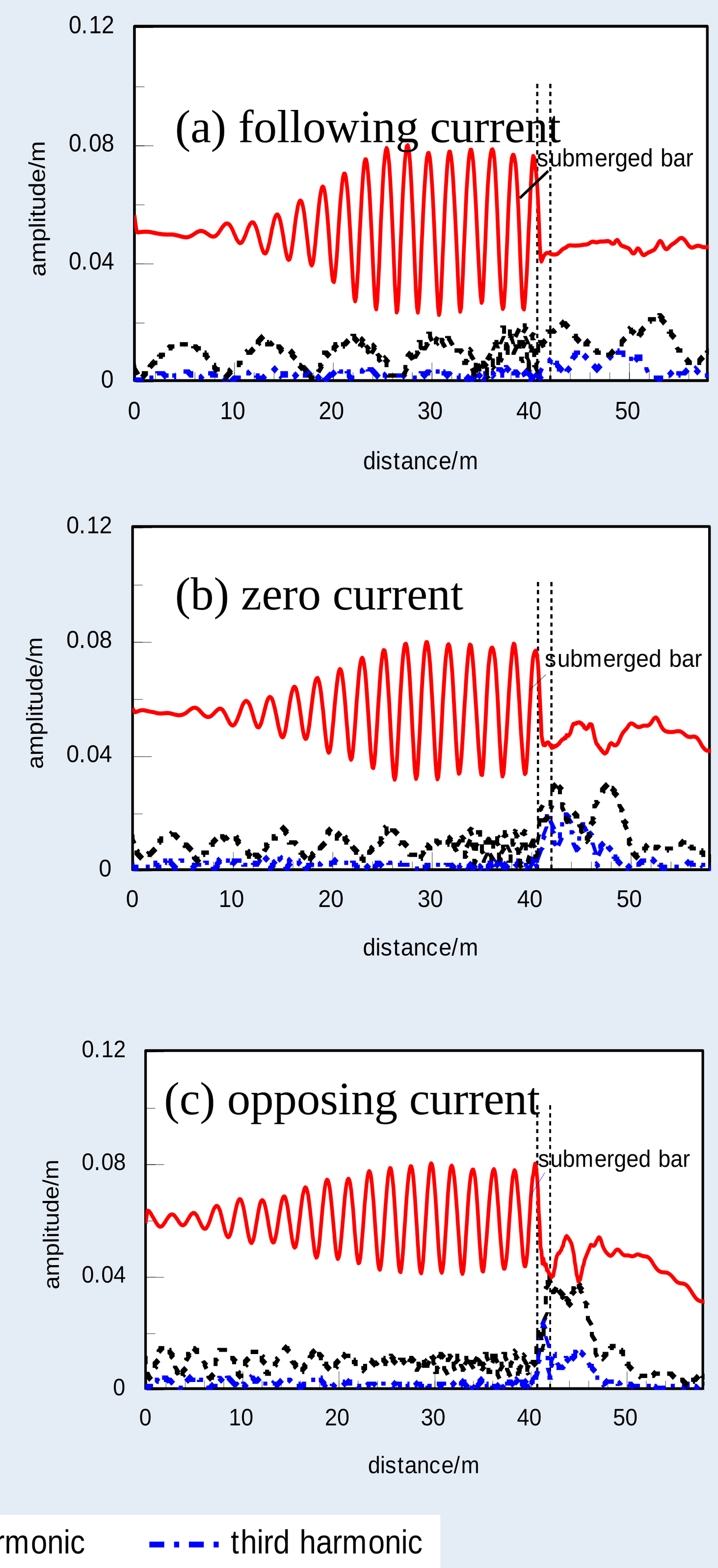


Fig.3 Spatial variations of the first three harmonic amplitudes without structure (T=2s, A=0.054m and U_0=0.2m/s)

Fig.4 Spatial variations of the first three harmonic amplitudes with a structure (T=2s, A=0.054m and U_0=0.2m/s)

Fig.3 shows that the following current decreases the first harmonic amplitude and enlarges the second harmonic wave length, vice verse for the opposing current, in a flat-bottom flume.

Fig.4 shows that the reflected wave from the submerged bar results in the first harmonic amplitude fluctuating along the value in the flat-bottom flume, increased in the following current and decreased in the opposing current.

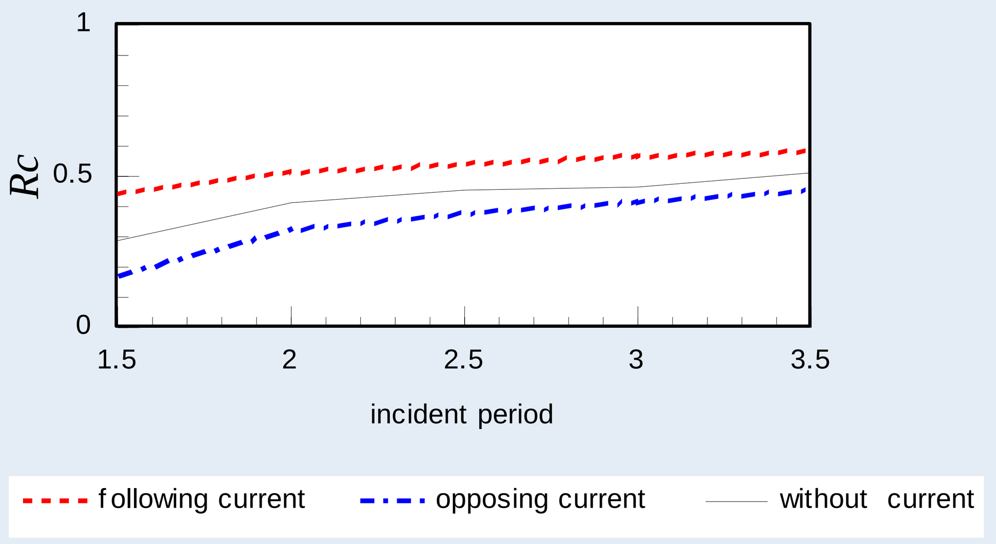


Fig.5 Variation of reflection coefficient against incident wave period

Fig.5 shows that the reflected coefficients increase with the increase of wave period and then converge to a constant value. The following case has larger reflection coefficient than the opposing case and the zero-current case is placed between them.

CONCLUSIONS

The phenomenon of wave propagation over a submerged bar in a uniform current is simulated by a powerful numerical model. And the model is examined by the experiments conducted by authors. Numerical examples show that the wave profile and higher harmonics are greatly influenced due to the existence of current and submerged structure.

REFERENCES

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2. Lin, Ning, Zou, Teng and Chen (2014): Current effects on nonlinear wave scattering by a submerged plate, J. Waterway, Port, Coastal, Ocean Eng., http://dx.doi.org/10.1061 /(ASCE)WW.1943-5460.0000256.

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