Ocean Engineering 164 (2018) 377–387

Contents lists available at ScienceDirect

Ocean Engineering

journal homepage: www.elsevier.com/locate/oceaneng

Investigation on the effects of versatile deformating bed on a water wave diffraction problem

Manas Ranjan Sarangi, Smrutiranjan Mohapatra*

Department of Mathematics, Veer Surendra Sai University of Technology, Burla, 768 018, Odisha, India

ARTICLE INFO

Keywords:
Versatile base surface
Bottom distortion
Green's function
Sinusoidal bed
Reflection coefficient
Transmission coefficient

ABSTRACT

A hydroelastic model is considered to examine the proliferation of water waves over little deformation on a versatile seabed. The versatile base surface is modelled as a thin large plate and depends upon Euler-Bernoulli beam equation. In such circumstances, two different modes of time-harmonic proliferating waves exist rather than one mode of proliferating waves for any particular frequency. The waves with smaller wavenumber proliferate along the free-surface and the other with higher wavenumber spreads along the versatile base surface. The expression for first and second-order potentials and, henceforth, the reflection and transmission coefficients upto second-order for both modes are acquired by the strategy in view of Green's function method. A fix of sinusoidal swells is considered for instance to approve the scientific outcomes. It is seen that when the train of occurrence waves engenders because of the free-surface unsettling influence or the flexural wave movement in the fluid, we generally acquire the reflected and transmitted vitality exchange from the free-surface wave mode to the flexural wave mode. Further, we understand that the practical changes in the flexural unbending nature on the versatile base surface have a remarkable effect on the issue of water wave proliferation over small bottom distortions.

1. Introduction

The issue of diffraction of waves by a floating or submerged deterrents is essential for their conceivable applications in the territory of waterfront and marine building, and thus this kind of issues have been contemplated by numerous specialists in late decades. The issue including reflection of surface waves by little base distortions has received an increasing amount of application as its mechanism is critical in the improvement of shore-parallel bars or pipes. At the point when a stream of incident dynamic water waves experiences a deterrent on the base of a sea, the wave stream is mostly reflected by it, and is incompletely transmitted over it. In any case, there exists a class for most of the part normally occurring base standing impediments, for example, sand swells, which can be thought to be little in some sense, for which some kind of perturbation strategy can be utilized for acquiring the first-order correction to the reflection and transmission coefficients.

Miles (1981) explored the issue of slant incident surface water waves spread over a little base twisting on an impermeable seabed. A simplified perturbation technique followed by the finite cosine transform strategy are utilized as a part of the scientific examination of the issue to get the reflection and transmission coefficients up to the first order. Utilizing Fourier transform strategy, Davies (1982) settled the reflection of typical incident surface waves by a fix of sinusoidal distortion on the seabed in a finite locale. Utilizing the linearized wave hypothesis, Staziker et al. (1996) considered the issue of ordinary water wave dissipating by a bed elevation of any shape on a generally even bed surface. The conduct of water waves over an impermeable occasional bed with free-surface was understood by Porter and Porter (2003) in a two-dimensional context utilizing linear water wave hypothesis. They presented an exchange matrix technique which diminished the calculation to that required for a solitary period without bargaining the whole linear wave hypothesis. Chakrabarti and Mohapatra (2013) considered the reflection and transmission of surface water waves by semi-infinite floating flexible plates on a sea by utilizing eigenfunction extension method. At the point when a seabed is made out of permeable material, hydrodynamic attributes are modified by the wave-instigated pore weight and soil relocations inside the dirt skeleton on the seabed. Utilizing Galerkin eigenfunction extension method, Zhu (2001) contemplated the issue of water waves engendering inside permeable media on an undulating bed. Silva et al. (2002) considered the issue of reflection as well as transmission of waves in an ocean, where a permeable medium was expected to lie on the bed of fluctuating calm profundity. Jeng (2001) created wave scattering connection in a permeable seabed by utilizing the complex wavenumber in the

* Corresponding author.
E-mail address: smrutiranjan.m@gmail.com (S. Mohapatra).

https://doi.org/10.1016/j.oceaneng.2018.06.039
Received 25 January 2018; Received in revised form 13 June 2018; Accepted 13 June 2018

poro-versatile model of waves with seabed communication. Tsai et al. (2006) researched the wave transmission over a submerged penetrable barrier on a permeable inclining seabed. Mohapatra (2015) explored the issue of wave diffraction by little distortion on a permeable bed in a sea by utilizing the Green's integral hypothesis with the presentation of suitable Green's function.

Every issue depicted above is centered just around the wave movement in a sea with a free-surface, though the base is thought to be either an inflexible or permeable bed with little deformation. In any case, the flexibility of the seabed of variable profundity is additionally one of the imperative parts of the examination, which has not been represented in these past examinations. Yet, a couple of quantities of scientists have contemplated the wave-structure communication issues within sight of a flexible seabed. Saha and Bora (2015) examined the trapped modes upheld by a level submerged barrel set in either of the layers of a two-layer fluid flowing over a flexible base at a finite profundity. Recently, Mohapatra (2017) considered a hydro-elastic frame to inspect the diffracted waves by a moving sphere in a solitary layer fluid flowing over an infinitely extended versatile base surface in a sea of finite profundity. There is a remarkable enthusiasm for late circumstances to research the wave engendering issues in a sea with free-surface, while the lower surface of the fluid is enveloped by a thin sheet of the flexible horizontal base surface, displayed as a versatile plate. No examination of the issue of water wave diffraction by an uneven structure for such kind of seabed has occurred till date. This has inspired us to consider the issue of proliferation of water waves over little distortion on the flexible base surface rather than an inflexible or permeable base surface of an along the side unbounded sea. Because of the appearance of the versatile base surface at the seabed, the linearized base limit condition turns into a fifth-order one, not at all like a straightforward homogenous Neumann condition satisfied on account of an unbending bed. In the present paper, the effect of the versatile plate parameter on the proliferation of water waves over base distortion is analyzed by using the Green's function technique. It may be noted that the present paper is different than the earlier works studied by Chakrabarti and Mohapatra (2013) and Mohapatra (2015). While in Chakrabarti and Mohapatra (2013), they discussed the scattering of water waves by floating ice-plates on a sea, having an impermeable bed surface by utilizing eigenfunction extension technique and in Mohapatra (2015), he studied the reflection and transmission of water waves by a small bottom distortion on a permeable seabed by applying Green's function method. However, in the present work, we consider a hydroelastic model to study the water wave diffraction problem involving small bottom distortion on a *versatile base surface* in a sea, especially when the seabed is always changing its shape such as in the earthquake regions.

2. Formulation of the problem

Let us consider an inviscid fluid which is incompressible and comparatively small amplitude under the action of gravity flowing over a versatile base surface of the seabed. The versatile base surface is assumed as a narrow plate which obeys the Euler-Bernoulli beam condition. Further, the width of the versatile base surface is small in comparison with the wavelength of the incoming waves. Here, the motion of fluid is assumed to be irrotational and time-harmonic with angular frequency ω. The sketch of the problem in Cartesian coordinates is illustrated in Fig. 1. We consider a two-dimensional Cartesian coordinate system (x, y), where the x-axis chosen horizontal and the y-axis is taken vertically downwards. The fluid is of infinite horizontal extent in x-direction while the depth is along the y-direction. Let the line $y = 0$ represents the mean position of the undisturbed free-surface of the fluid and the line $y = d$ represents the position of the versatile base surface. Assume that a train of regular incident waves proliferates along the positive x-direction of the fluid. Further, we assume that the seabed has a small bottom deformation in the form

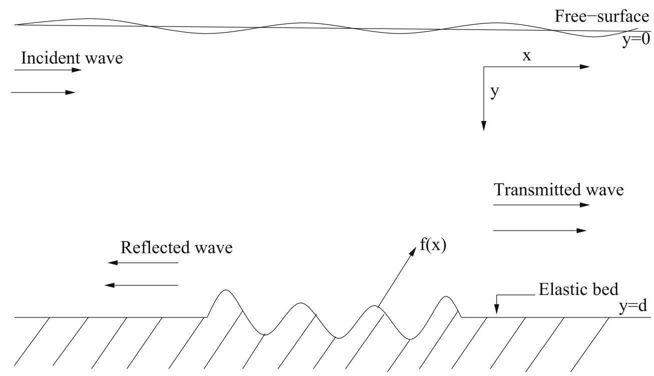

Fig. 1. Domain definition sketch.

$y = d + \xi f(x)$, where $\xi(\ll 1)$ is a non-dimensional number which represents a measure of the smallness of bottom deformation and the function $f(x)$ represents the shape of the bottom deformation, which is differentiable and converges to zero as $|x|$ tends to infinity. When a train of incident waves travelling from a large distance proliferates over a bottom deformation on the seabed, then the train of incident waves is partly reflected by the bottom deformation (say, reflected waves), and partly transmitted over it (say, transmitted waves). Here, the main concern is to evaluate the reflection and transmission coefficients associated with the reflected and transmitted wave fields, respectively.

Assuming the linearized wave theory, the motion of the fluid particle in the region, $-\infty < x < \infty,\ 0 \le y \le d + \xi f(x)$ is depicted by a potential function which is expressed as $\Re\{\varphi(x, y)e^{-i\omega t}\}$, where φ is called as the spatial potential function. In such situation, the governing equation for the physical problem involving the function φ is:

$$\frac{\partial^2\varphi}{\partial x^2} + \frac{\partial^2\varphi}{\partial y^2} = 0, \quad -\infty < x < \infty,\ 0 < y < d + \xi f(x). \tag{2.1}$$

The linearized free-surface boundary condition at $y = 0$ is

$$\frac{\partial\varphi}{\partial y} + K\varphi = 0, \qquad y = 0, \tag{2.2}$$

and the linearized versatile base surface boundary condition at $y = d$ is given by

$$\left(\mathfrak{D}\frac{\partial^4}{\partial x^4} - \varepsilon K + 1\right)\frac{\partial\varphi}{\partial n} - K\varphi = 0, \qquad y = d + \xi f(x), \tag{2.3}$$

where $K = \omega^2/g$, g is the acceleration due to gravity, $\mathfrak{D}$ represents the flexural rigidity of the versatile base surface on the seabed which is expressed as $\mathfrak{D} = Eh'^3/12\rho g(1 - P)$; E and P are the Young's modulus and the Poisson's ratio, respectively, for the versatile base surface; ρ denotes the density of the fluid; h' represents the width of the versatile base surface, $\varepsilon = (\rho'/\rho)h_e$; ρ' represents the density of the versatile base and $\partial/\partial n$ denotes the derivative in a direction normal to the bottom surface of the seabed. The time-dependence term of $e^{-i\omega t}$ has been cut off throughout the analysis.

Assuming, a non-dimensional number ξ to be small enough to neglect the third and higher-order terms, then the *linearized condition* on the versatile base surface which is given in equation (2.3) can be written in a suitable form as

$$\begin{aligned}&\left(\mathfrak{D}\frac{\partial^4}{\partial x^4} - \varepsilon K + 1\right)\left(\frac{\partial\varphi}{\partial y} - \xi\frac{\partial}{\partial x}\left[f(x)\frac{\partial\varphi}{\partial x}\right]\right.\\&\quad\left. + \frac{\xi^2}{2}\left\{[f(x)]^2\frac{\partial^3\varphi}{\partial y^3} - 2f(x)f'(x)\frac{\partial^2\varphi}{\partial x\partial y} - [f'(x)]^2\frac{\partial\varphi}{\partial y}\right\}\right)\\&\quad - K\left\{\varphi + \xi f(x)\frac{\partial\varphi}{\partial y} + \frac{\xi^2}{2}[f(x)]^2\frac{\partial^2\varphi}{\partial y^2}\right\} + \mathbf{O}(\xi^3) = 0, \qquad y = d.\end{aligned} \tag{2.4}$$