Wave decay characteristics along a long array of cylindrical legs

Hiroshi Kagemoto
University of Tokyo, Japan

1.Introduction

A very large floating structure(VLFS) of several kilometers in length and in width is now considered as a possible alternative of such land-based structures as an airport. Although there can be various types of structures that are used for such purposes, the structures proposed so far are roughly categorized into two types of structures. One is a simple thin box-shaped structure and the other one is a structure supported on a large number of cylindrical legs. For the design of a floating structure, we need to be able to estimate the hydrodynamic forces on the structure correctly. However, when the structure is so large as extends several kilometers horizontally, the computational burden for the analysis of hydrodynamic forces is so large that it is practically impossible to carry out. For a thin box-shaped structure, the author proposed an approximate but quite accurate method in exploting the fact that the structure is far larger than the ambient wavelength and thus the flow field can be assumed with good approximation to be the same as that around the structure which extends infinitely in horizontal direction[1)]. For a structure supported on a large number of legs, similar approximation can be applied in which the flow field around an array of a large number of legs is assumed to be the same as that around an array composed of an infinite number of legs (except at the vicinity of the ends of the array)[2)]. When the structure is located in head waves, however, these approximations do not work well because waves actually decay as they propagate through the structure while, if we stick to the infinite-length or the infinite-leg assumptions described above, wave amplitudes can not decay since the approximations impose that there should be no way other than the phase to distinguish the wave at one place from that at another place. For a box-shaped structure, the decay characteristics of head waves have been found to be proportional to the inverse squre-root of the distance along which the wave propagated from the up-wave end of the structure. This result coincides with that predicted by a slender-body theory. By exploiting this quantitative decay characteristics of waves, an approximate computation is still possible for the hydrodynamic analysis of a box-shaped structure in head waves[1)]. If similar quantitative decay characteristics of head waves propagating along a structure supported on a large number of legs could be found, an approximate hydrodynamic analysis of the structure may be possible in a similar way as conducted for a box-shaped structure. This is the motivation of the present work.

2.Experiment

A 3×20 array of truncated composite cylinders were fixed in regular head waves as shown in Fig.1 and the surface elevations between the cylinders were measured. Fig.2 shows the results on the amplitude of the surface elevation in waves of 4 representative wave periods. 'Cal' in the legends stands for the results obtained by the calculations based on a linear potential theory. An interesting feature is that short waves decay as they propagate from the head of the array toward the end of the array(Fig.2(a)) whereas, as the wave period becomes longer, the distribution of the wave amplitudes begins to oscillate spacewise(Fig.2(b)) and even be enhanced rather than be decayed as the wave is further elongated(Fig.2(c),(d)).

3.Parametric numerical computation

Since, as is observed in Fig.2, the linear potential theory agrees well with the experimental results, detailed computation was carried out for an array of 1×60 vertical truncated cylinders (D/d=1.0,h/d=2.0, ℓ/D=2.0 where D:diameter, d:draft,h:water depth,ℓ:distance between adjacent cylinders) while varying the wavelength systematically. Fig.3 shows some of the typical results of the computation. It should be noted that a tiny difference of the wavelength($\Delta\lambda/\ell = 0.002$) induces a big difference of the surface elevations as shown in Fig.3(b) and Fig.3(c). The large surface elevation that occurs at a certain particular wavelength($\ell/\lambda = 0.449$) may correspond to one of the resonant phenomena indicated by Maniar and Newman[3)]. Another interesting feature is that as the wavelength becomes longer, the amplitude of the surface elevation begins to oscillate spacewise (Fig.3(d)) and the wavelength of the spacewise oscillation becomes shorter as the wavelength becomes still longer(Fig.3(e)). It is also noticeable that the wave amplitude is enhanced rather than be decayed as the wave propagates along the array. This enhancement of wave amplitudes persists up to the longest wavelength($\ell/\lambda = 0.359$) conducted in the present computation, although, in principle, it should converge to the amplitude of the incident wave(ζ_a) as the wavelength becomes very long. In order to extract some of the hidden features of these wave-decay(or wave-enhancement) characteristics, Fig.3 were replotted in $\log - \log$ papers as in Fig.4. From this figure it can be known that, when waves decay, the decay rate is roughly proportional to the inverse square-root of the traveled distance of waves measured from the head of the array, which is also the case for a box-shaped very long structure. On the other hand, if we examine the relationship between the consecutive difference of ζ_i(amplitude of the surface elevation measured at i-th measured point) as shown in Fig.5, we now know that

$$\zeta_{i+1} - \zeta_i \sim \alpha(\zeta_i - \zeta_{i-1}) \quad (1)$$

in the vicinity of the head of the array, which implys that the waves decay exponentionally there.

Acknowledgement

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Reference

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(2)H.Kagemoto and D.K.P.Yue: Proc. 5th OMAE, Vol1, 206-211, 1986.
(3)H.D.Maniar and J.N.Newman: *J. Fluid Mech.*, **339**, 309-330, 1997.

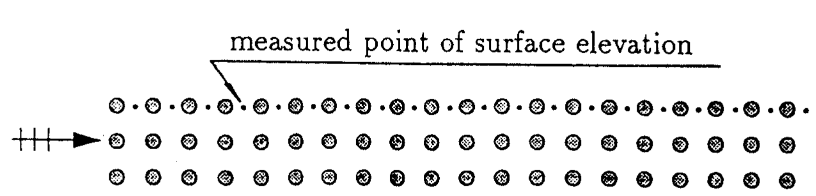
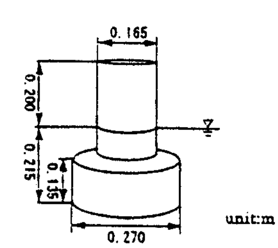


Fig.1 A 3×20 array of truncated composite cylinders (center to center distance: 0.540m)



truncated cylinder

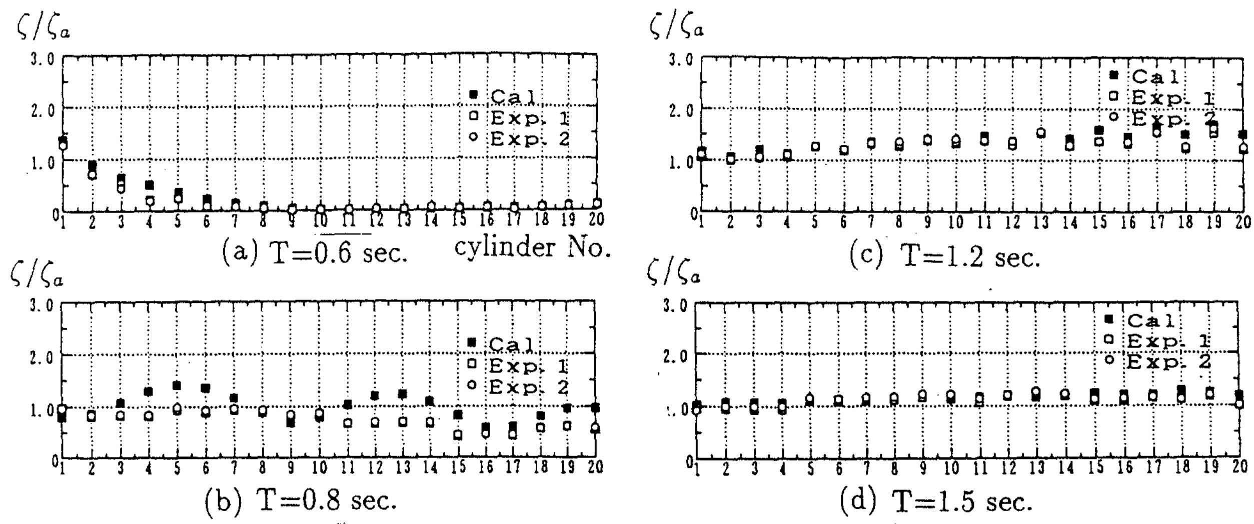


Fig.2 Comparisons of the measured amplitude of surface elevation with numerical calculations

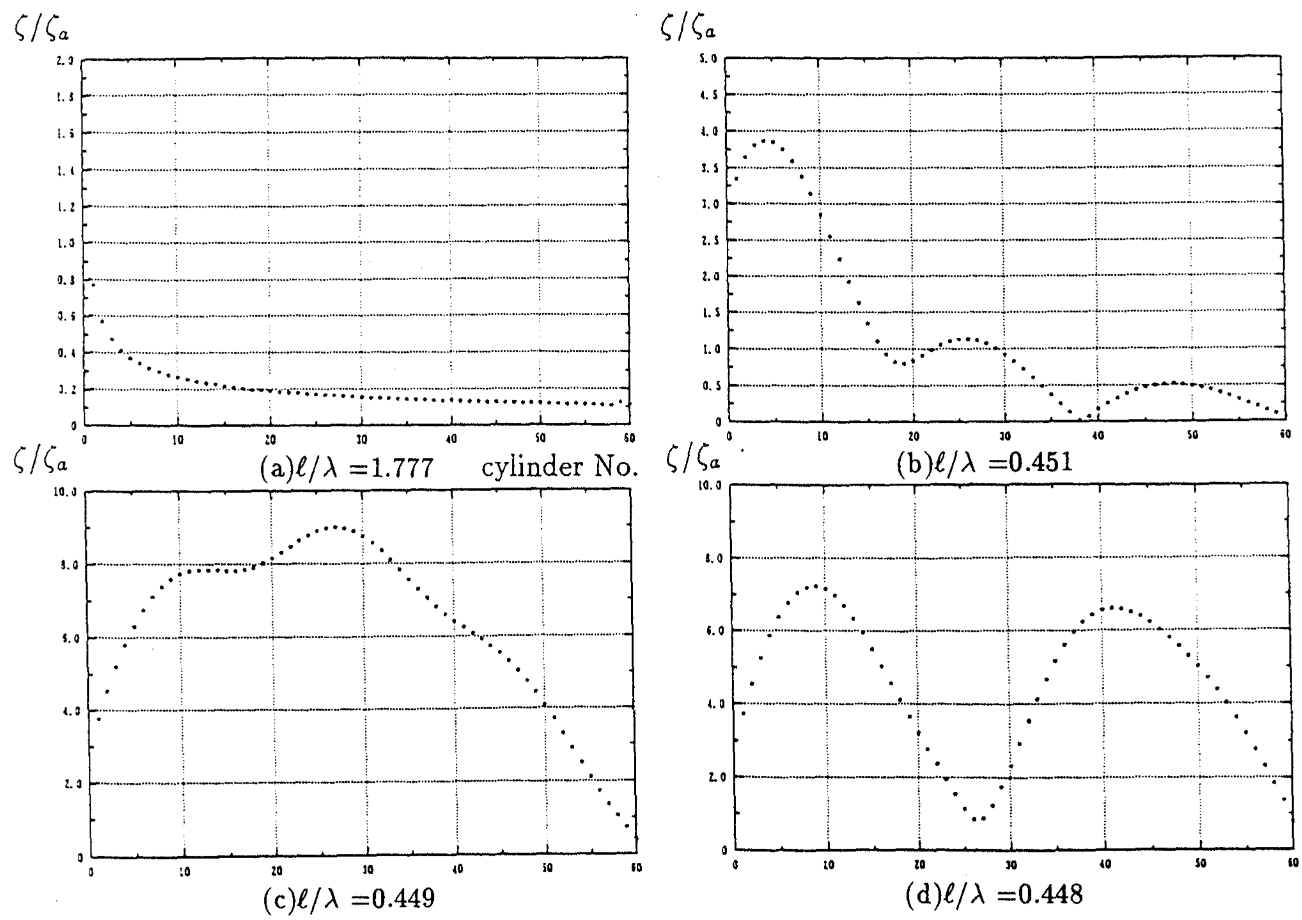
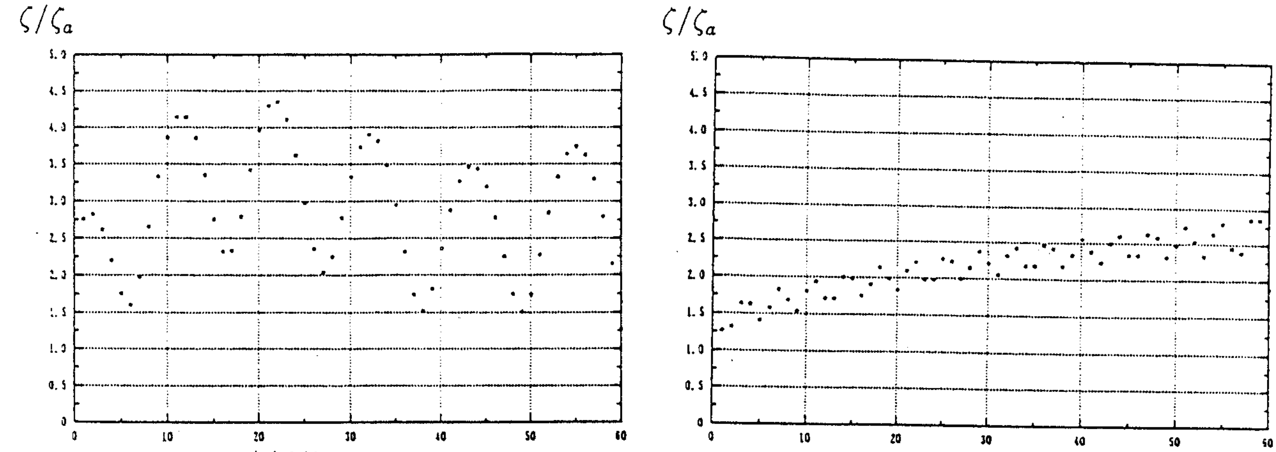


Fig.3 The variation of the amplitude of surface elevation along an array of 1×60 cylinders



(e)ℓ/λ =0.434 cylinder No. (f)ℓ/λ =0.359

Fig.3 The variation of the amplitude of surface elevation along an array of 1×60 cylinders

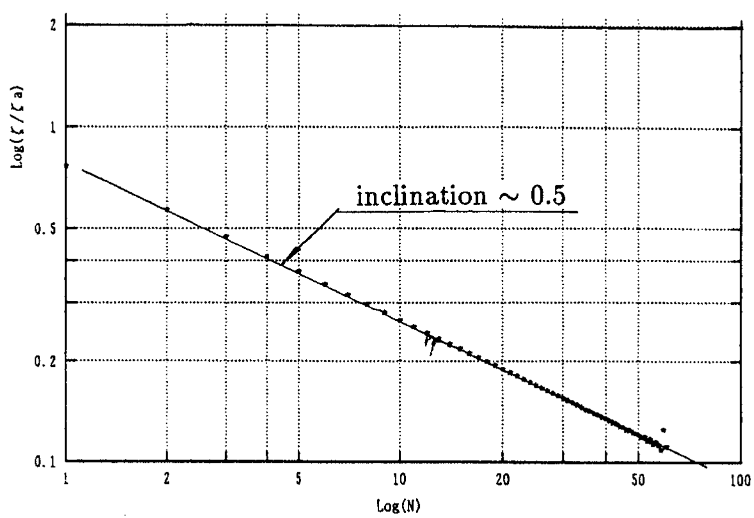


Fig.4 The variation of the amplitude of surface elevation along an array of 1×60 cylinders plotted in a log-log paper(ℓ/λ =1.777)

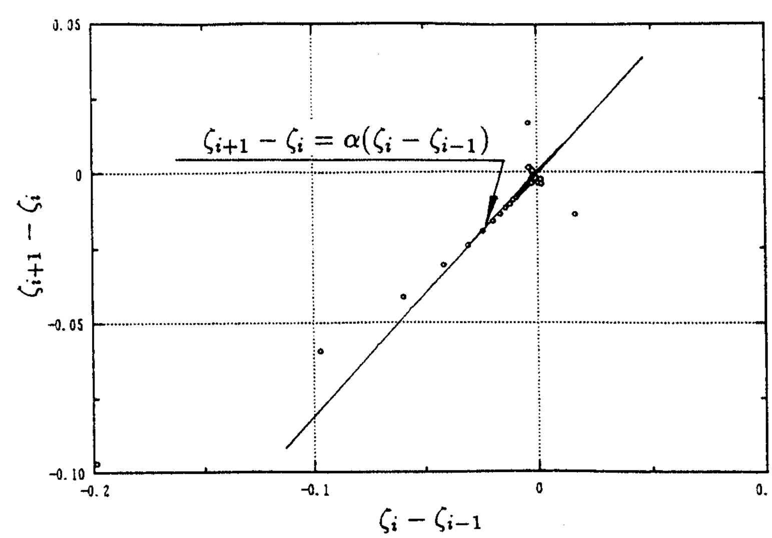


Fig.5 $\zeta_{i+1} - \zeta_i$ vs $\zeta_i - \zeta_{i-1}$ ($\ell/\lambda = 1.777$)