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Research on characteristics of Responses on Floating Structures due to Various Tsunami Wave Profiles

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ABSTRACT

It is the objective of this research to develop practical estimation methodologies for responses of and the mooring force on a floating structure in shallow seas and to clarify the characteristics of responses induced by various tsunami wave profiles. In the present paper, the estimation methodology is introduced. The Tsunami propagation is numerically simulated from the hypocenter to shallow sea after an initial Tsunami elevation around sea area above the hypocenter is predicted by using Manshinha-Smylie's method. The numerical simulation is carried out two-dimensionally. It is assumed that the floating structure is moored by catenary chains in shallow sea around Japanese Island. The two-dimensional boundary integral method is applied to a computation of the Tsunami propagations on a floating structure. The convolution integral method is applied to the prediction of the motion response with the catenary mooring tethers. In the present paper, some tools of parts of system are verified. The analysis method for the Tsunami exciting forces based on the 2-D BEM simulation program code is verified by comparing with the experimental results and another simulation results. The characteristics of responses due to the difference of Tsunami wave profile are discussed.

INTRODUCTION

Tsunami occurring at deep water field is propagated to shallow water field amplifying its height. Therefore, it is very important to investigate the effects of Tsunami for responses of motion and mooring tethers of a floating structure. There are some studies on the responses due to Tsunami. They are studied by, for example, Ikeno et al.$^{1)}$, Masuda et al.$^{2)}$,or Ryu et al.$^{3)}$. However, few parametric studies or few parametric numerical simulations in regard to the responses due to Tsunami were carried out. The cause of that is very hard works,i.e.,

1) An enormous simulation time and hardware capacity for calculation needs.
2) There are many indeterminate parameters. Therefore, it is necessary to develop the practical estimation method for the responses of a floating structure.

By the way, the authors have developed a computer program code for a numerical simulation of the responses due to Tsunami modeled to a solitary wave based on the two-dimensional boundary element method.

In addition, the practical estimation system for the responses of a floating structure due to Tsunami has been proposed by Masuda et al.(2002).

In this paper, the validity of parts of system was confirmed. The validity of computer program code for a numerical simulation of Tsunami elevation and Tsunami exciting forces was confirmed from comparisons between the results of model experiments and numerical simulations. The dispersing waves and the equivalent solitary waves were applied to a Tsunami wave profile and the characteristics of responses due to the difference of Tsunami wave profiles were discussed and also the propagated Tsunami profile were examined.

PRACTICAL ESTIMATION SYSTEM

We propose a practical estimation system for responses of motion and mooring tether force due to Tsunami on a floating structure in shallow water field such as Figure 1.

Sea area of the hypocenter and Magnitude of the earthquake are defined at first. The initial Tsunami elevation and profile are predicted by using Manshinha-Smylie's method$^{4)}$. It can be regarded to apply some simulation methods to prediction of the Tsunami propagation in the near future.

Then, the propagated Tsunami must be numerically simulated by using any calculation method. In this paper, the 2-D BEM is applied to it and the wave profile of the propagated Tsunami is examined

Next step is prediction of time history of the Tsunami excitation forces on a floating structure in time domain by using the 2-D Numerical Wave Tank with VOF method. Input dates for numerical wave tank are primary wave profile and flow velocity of tsunami such as Fig 2. After that, the motion response with a mooring system is solved. Then, the Convolution Integral method (C.I. method) is applied to the equation of motion in time domain. Therefore, interaction between the fluid and structure motion is not directly considered in the numerical wave tank.

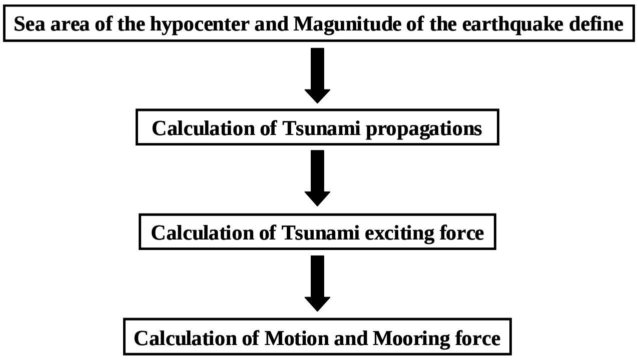

Fig.1 Practical numerical estimation system for Tsunami

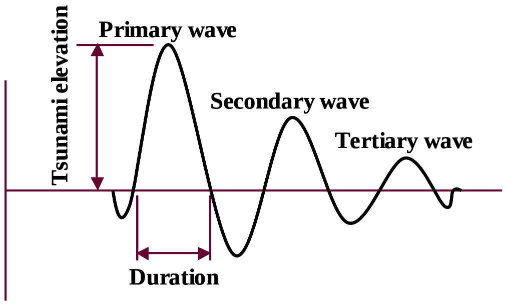

Fig.2 Definitions of Tsunami elevation and duration

VALIDATION OF 2-D BEM

Model test

The model test was carried out at the two-dimensional wave channel with 30.0m in length and 1.35m in width of Department of Oceanic Architecture & Engineering , Nihon University , the Funabashi campus. Figure 3 shows the experimental setup system. The temporary bottom and the separation board in order to narrow the channel width were installed, the width of the channel was 0.8m and the water depth was 0.3m at measurement area. Then, there was a slope with distance of about 4.45m. The model has the breadth of 0.6m, the length of 0.3m and the draft of 0.05m. Therefore, there are gaps of 0.1m between the model and the sidewall of the channel. The wave generator is a piston type.

Simulated Tsunami in the test is dispersing waves. The floating body model was fixed. The wave excitations of sway, heave and roll modes were measured by a load cell with the three degrees of freedom. In addition, the wave heights at three positions front of the model and one position behind the model were measured.

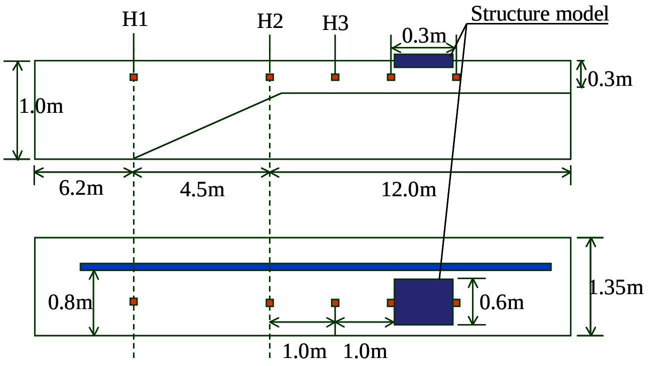

Fig.3 Experimental setup system

Validations

In the numerical simulation, the fluid velocity is given at the wave making boundary. The velocity is transformed from the displacement signal for the wave generator of the wave channel. Therefore, the velocity of the calculation boundary does not necessarily correspond to the actual velocity of the wave maker because there is a transfer function in the wave generating system. The wave maker is moved one-way having any displacement with any times.

The results by the present 2-D BEM are compared with the experimental results and the another numerical simulation results as time series in Figure 4 to Figure 7. Figure 4 shows the time histories of the simulated Tsunami elevation at a model set position. Figures 5 to 7 show each the result of Tsunami excitation forces in sway, heave and roll. Another numerical simulation results are calculated by CADMAS-SURF$^{6)}$. In the Figures, a_0 means the corresponding first Tsunami height. L is body length, and B is body breadth.

In Figure 4, it can found to be difference between the two numerical simulation results and the experimental results. The cause of that is that behavior of the wave making boundary in the numerical simulations differs from the actual movement of the wave maker in the experiment because the boundary is not the moving boundary. Therefore, it seems that the present 2-D BEM. can reproduce the simulated Tsunami.

From the comparisons of the Tsunami excitation forces in Figures 5 to 7, the results by the present method agree with the experimental results although the calculated results are safety side a little from the experimental results.

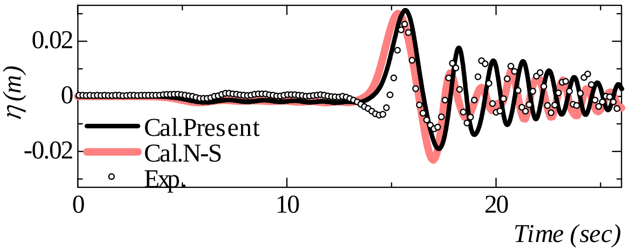

Fig.4 Time series of Tsunami elevation (H3 = 11.65m)

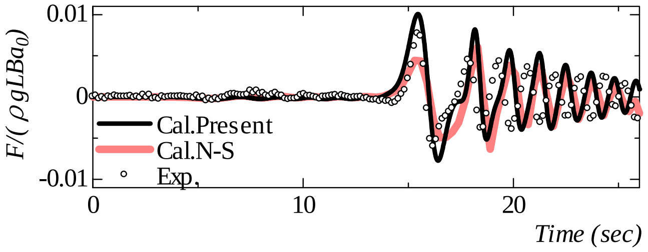

Fig.5 Tsunami exciting force on sway

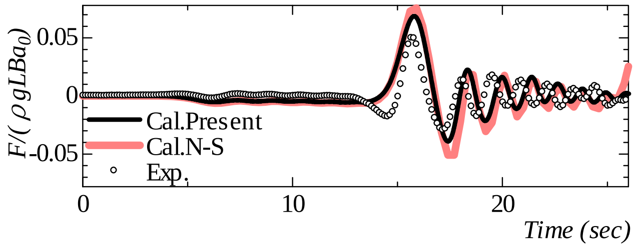

Fig.6 Tsunami exciting force on heave

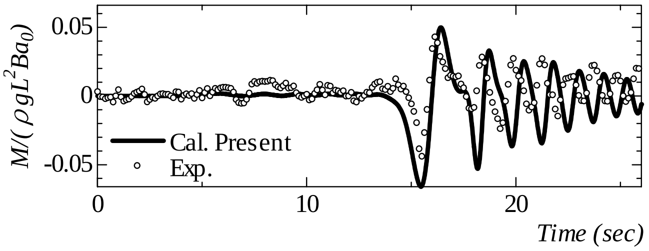

Fig.7 Tsunami exciting moment on roll

VERIFICATION OF TSUNAMI PROFILE

Effect of difference of the simulated Tsunami profile for the responses is investigated. The excitations and motions due to each simulated Tsunami are compared. The setup system for the numerical experiment is shown in Figure 8. The floating body is fixed when the Tsunami excitations forces are calculated. The coordinate system and the mooring system are shown in Figure 9. The model is moored by catenary chains. The principal particulars of the floating model and mooring chains are described in Table 1.

A comparisons of time histories of the simulated Tsunami profile is shown in Figure 10. These time histories are at just front of the fixed floating body. The Tsunami elevations are slightly different at this position. However, both the Tsunami elevations were the same without the floating body. Therefore, the cause of that may be the difference of the diffraction characteristic of the simulated Tsunami. And also, the solitary wave deforms at this position because it goes through over the slope.

Figures 11 to 13 show the comparisons of the Tsunami excitation forces due to two simulated Tsunami that are the solitary wave and the dispersing wave. From these results, the tendencies of the Tsunami excitations due to the primary Tsunami by both Tsunami forms are similar. The maximum values by the solitary wave are lager than that of the dispersing wave. However, the behaviors of the excitations due to the solitary wave are different from that due to the dispersing wave after the primary wave penetrated the floating body. Therefore, a simulation of the Tsunami profile is important in order to predict the excitations in case that effect after the secondary Tsunami may increase.

Figure 14 to 16 show the comparison of the motion of sway, heave and roll due to the two simulated Tsunami. The sway motion due to the solitary wave is larger because there is hardly the secondary Tsunami effect at about 18 seconds of the result due to the solitary wave from Figure 11. The maximum response is dominating regarding the heave motion. The roll motions due to each Tsunami have a similar response qualitatively. Therefore, it may be almost useful to apply the equivalent solitary wave to the prediction of the motion due to Tsunami. However, the strict Tsunami profile and elevation should be considered because it is well known that there are often situations such as the Tsunami incoming continuously.

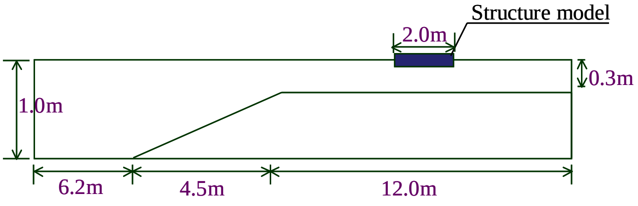

Fig.8 Calculation System

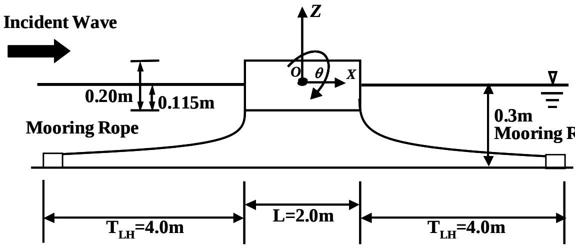

Fig.9 Mooring System

Table 1 Floating Body model

Floating body model		
Length	(m)	2.000
Breadth	(m)	0.960
Height	(m)	0.200
Draft	(m)	0.115
Displacement	(m^3)	0.221
Weight	(kg)	221.000
Area of water plane	(m^2)	1.920
Moment of inertia	(kgm^2)	88.300
Meta center height:GM	(m)	2.060

Table 2 Mooring model

Mooring model		
Length of Mooring	(m)	3.020
Horizontal length	(m)	4.000
Weight per unit length	(N/m)	2.620
Breaking load	(N)	1.000×10^5
Young's modulus	(N/m^2)	3.096×10^8
Section area	(m^2)	7.170×10^5

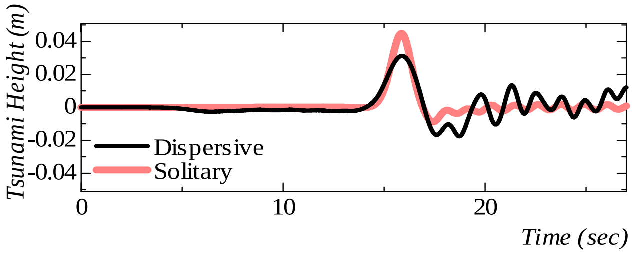

Fig.10 Time series of Tsunami just front of floating model

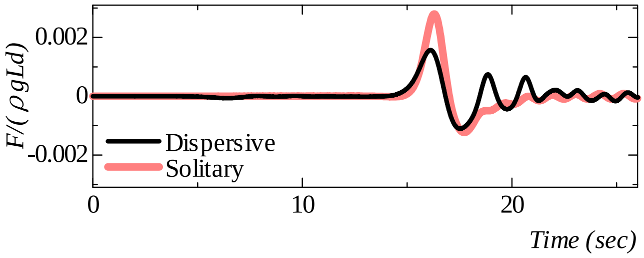

Fig.11 Tsunami exciting force on sway

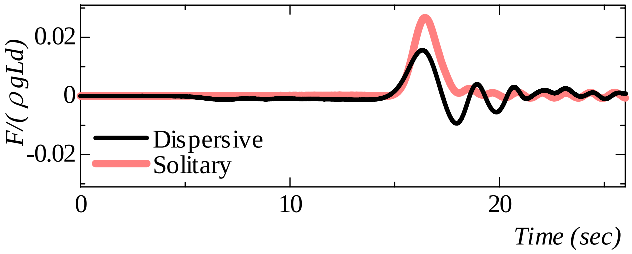

Fig.12 Tsunami exciting force on heave

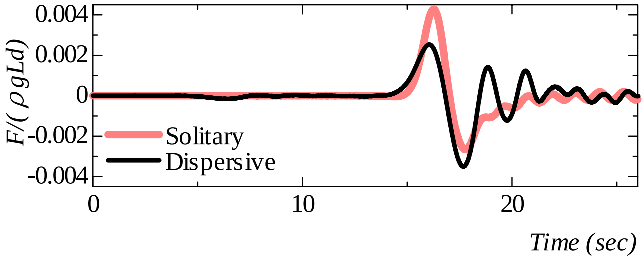

Fig.13 Tsunami exciting moment on roll

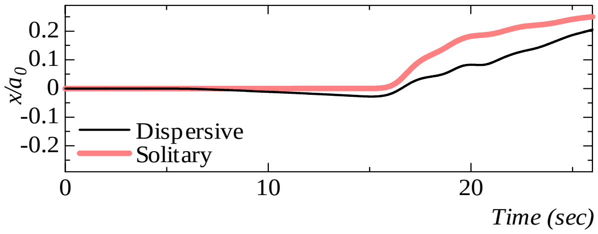

Fig.14 Sway motions due to simulated Tsunami

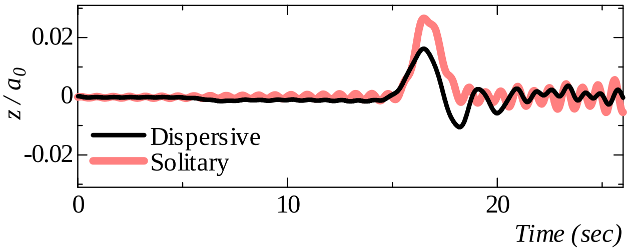

Fig.15 Heave motions due to simulated Tsunami

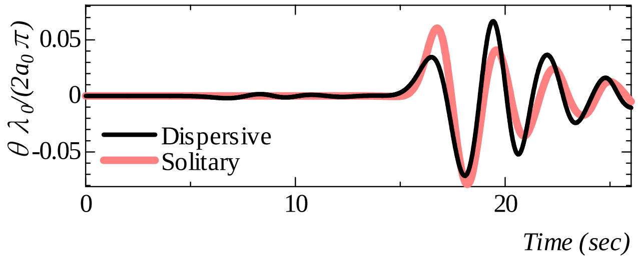

Fig.16 Roll motions due to simulated Tsunami

CONCLUSION

The conclusions of present paper are given as follows:

1) From the comparison of numerical and experimental results on the excitations due to Tsunami, the usefulness of the present numerical method is confirmed.
2) From the comparisons of numerical results on the solitary wave and the dispersing wave, it may be almost useful to apply the equivalent solitary wave to prediction of motion due to Tsunami. In the case of the Tsunami incoming continuously, the strict Tsunami profile and elevation should be considered.
3) From the examinations of the propagated Tsunami profile, it is confirmed that the characteristics of propagated Tsunami profile are almost equivalent to the characteristics of dispersing wave profile.
4) The usefulness of present estimation system with dispersing wave is confirmed.

ACKNOWNLEDGMENT

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