Simulation of Wave-Dissipating Mechanism on Submerged Structure using Fluid-Structure Coupling Capability in LS-DYNA

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ABSTRACT

Understanding the wave-dissipating mechanism of seashore structures is important to design effective seashore protection system against high waves. From the engineering point of view, wave dissipation with seashore structures is considered as a kind of fluid-structure interaction (FSI) problem. Recently constructing a submerged structure "flexible mound" is increasing for some advantages. The flexible mound is made of rubbery material and is deformable. Authors tried to apply the ALE (Arbitrary Lagrangian Eulerian) capability in an explicit finite element program LS-DYNA to this problem and compared the behavior of conventional "rigid mound" (breakwater) and flexible mound. Through this preliminary study authors showed that the FSI analysis using LS-DYNA could widely be used to design shore structures.

INTRODUCTION

Seashore protection against high waves is a serious problem for the countries which have long coastline. There are many types of seashore structures for this purpose. Most conventional structure may be a rigid breakwater in these structures as we can see them anywhere beside the sea. Although indeed conventional breakwater is very useful to protect seashore from high wave attack, this sometimes disturbs shipping traffic. In resent years another type of wave-dissipating structure called as flexible mound has been used to overcome some disadvantages on conventional breakwater. Flexible mound is a submerged structure constructed inshore. Typical flexible mound consists of a half-piped or domed rubber bag, fluid inside the bag and foundation fixed on the seafloor. When waves pass above flexible mound, it absorbs and scatters kinetic energy of waves and wave is weakened. Major advantages of flexible mound comparing with conventional mound are as follows;

(1) Compact and simple structure
(2) Short construction period and cost effective
(3) Don't spoil the beauty of seashore
(4) Safe for ship transportation (folded when not in use)

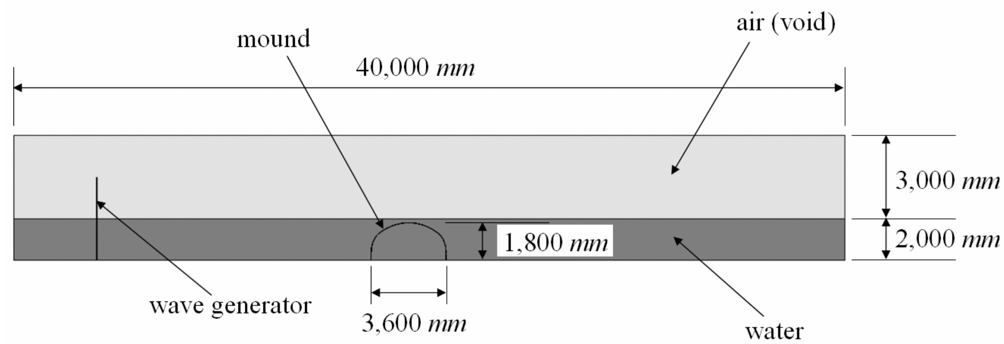
The wave-dissipating capability of flexible mound is depend on its geometry, material properties, characteristics of infused fluid and so on. In the paper preliminary investigation for modeling the interaction between mounds and waves using LS-DYNA FSI capability is presented and behavior of wave dissipation is compared between conventional rigid mound and flexible mound. In addition possibility to use LS-DYNA to design effective mound structure against high wave attack on seashore is shown.

Analysis Model

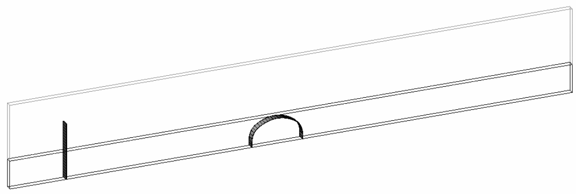
We modeled a wave generation equipment to simulate a similar experiment. The model contains the mound, fluid and wave generator which is defined with rigid shell elements. The geometry and dimensions of analysis model is shown in Fig.1 (a)-(d). Since this problem is considered in 2-Dimensional plane strain field, the fluid region was made of one layer solid elements through depth as shown in Fig.1 (b) and (c). We prepared two types of geometry for the mound. One is the elliptic model and another is the rectangular model. The number of solid elements in fluid region is 6,000.

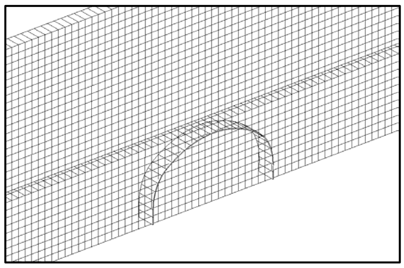
The elliptic model is elastic with Young's modulus = 1,000 N/mm^2, Poisson's ratio = 0.48 and density = 1.2 x 10^{-9} ton/mm^3. The rectangular model is rigid. Fluid is modeled using null material (LS-DYNA keyword = *MAT_NULL) and equation of state (LS-DYNA keyword = *EOS_LINEAR_POLYNOMIAL). Properties for fluid (water) region are as follows; density = 1.0 x 10^{-9} ton/mm^3, cut-off pressure = -1.0 x 10^{20} N/mm^2, viscosity = 1.0 x 10^{-9} Nmm/s and bulk modulus = 2,300 N/mm^2 as C1 in *EOS_LINEAR_POLYNOMIAL. Proper boundary condition is defined to model pseudo-2D state.

Prescribed displacement (*BOUNDARY_PRESCRIBED_MOTION_RIGID) is applied to the wave generator to generate solitary wave. The stroke of the wave generator is adjusted so

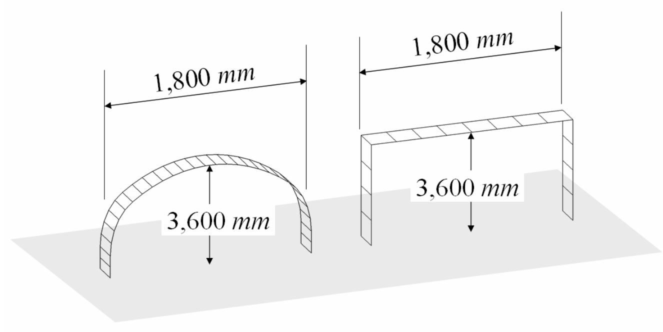


(a) Side view





(b) Oblique view (c) Close-up around mound



(d) Mound geometry (left ; ellipsoid model, right ; rectangular model)

Fig.1 Geometry and dimensions of wave generator tank model

as to generate about 1,200 mm high wave from the sea level. The prescribed displacement curve is depicted in Fig.2. Zero gravity loading is applied at time 0.0

second and increased linearly to 1.0 G by 0.5 seconds. The penalty coupling was used to define fluid-structure interaction.

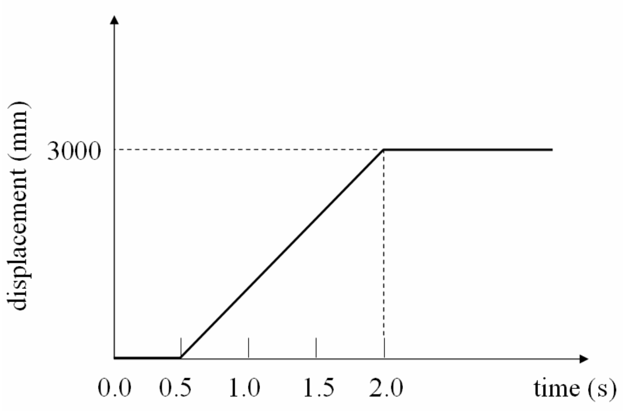


Fig.2 Prescribed displacement curve applied to the wave generator

Analysis Results

The wave propagation is shown in Fig.3 for rigid mound and in Fig.4 for flexible mound. The incident wave has about 1,200 mm height and about 10,000 mm length. When the wave pass above the mound, wave shape is changed and the height is shortened. Both mounds show similar wave-dissipating capability in this simulation.

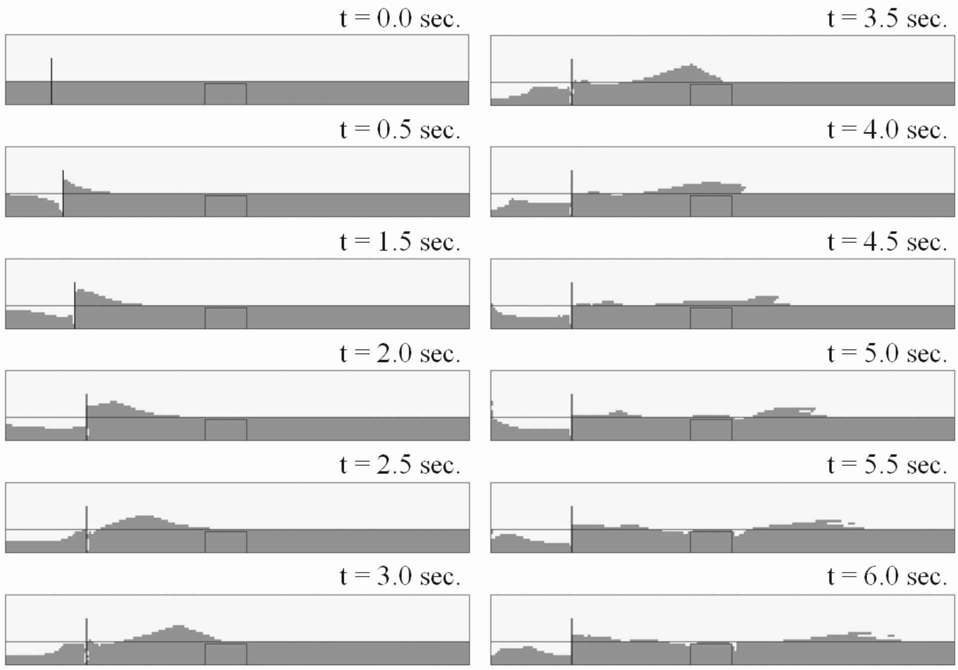


Fig.3 Wave propagation passed above rigid rectangular mound

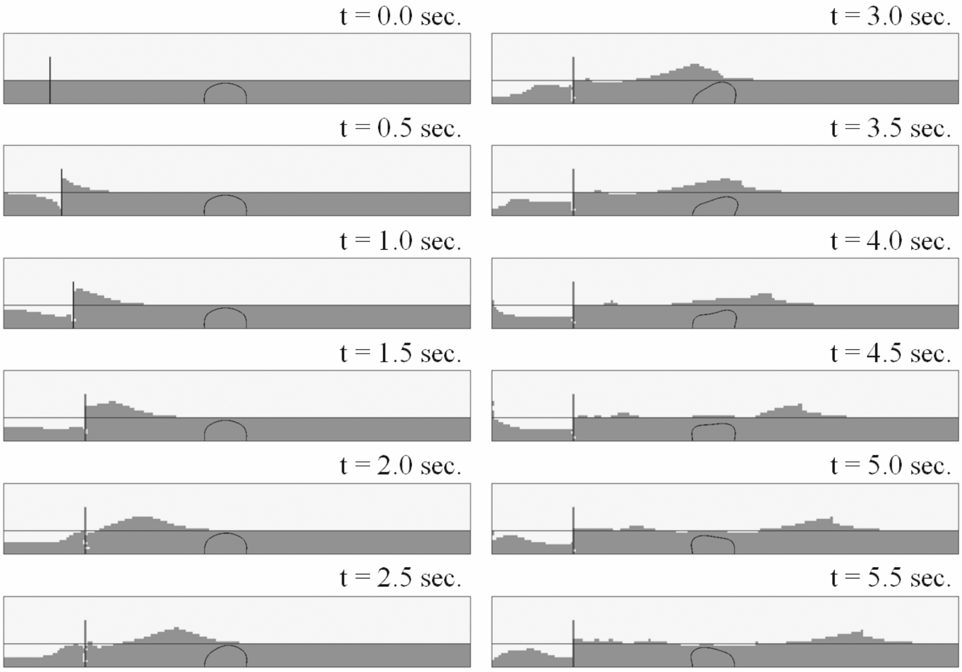


Fig.4 Wave propagation passed above flexible elliptic mound

For the flexible mound, the time step was 1.4 x 10^{-4} seconds determined by the shell element on the mound. In case of rigid mound, the time step was 3.14 x 10^{-4} seconds determined by the solid element in the fluid region. The time step scale factor, TSSFAC on the control card *CONTROL_TIMESTEP was set to 0.8 for numerical stability. The analyses were performed for 10 seconds to simulate real event. CPU time was about one hour for flexible mound and 30 minutes for rigid mound on an Intel Pentium M 2.0 GHz processor mounted PC.

Summary and Conclusions

To design seashore protection system fit to individual environment is very important. Since the performance of the protection system including flexible mound and similar equipments should be influenced by many parameters such as material properties and geometry, useful and cost effective technique is required to design these systems in addition to use of experimental equipments. This paper suggested effective and easy way to design seashore protection system using numerical simulation based on FSI capability in LS-DYNA.

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