

# Diffraction Force on a Spherical Structure and Wave Diffraction

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## ABSTRACT

This paper aims at an experimental and analytical investigation of the diffraction forces acting on a spherical structure and wave diffraction. The Source Distribution Method (SDM) is applied to their theoretical estimation. The dimensionless maximum wave force is affected by the relative diameter and submergence of the sphere as well as the diffraction parameter. The nondimensional wave height, however, has little effect on it. The SDM, based on the linear wave theory, is revealed to evaluate well the diffraction force acting on a spherical structure due to finite amplitude waves including the spilling breakers above the submerged sphere. The SDM is useful also in evaluating wave height distribution around the sphere under nonbreaking conditions.

## INTRODUCTION

With increasing utilization of coastal and ocean areas, many coastal and ocean structures will be constructed in these areas. Treated here are structures with spherical shapes, like oil storage tanks, considered to be one of the most suitable shapes for coastal and offshore structures against wave pressure. It is necessary for design of such structures to evaluate wave forces acting on them accurately. The Morison-type equation is useful in estimating the acting wave force on a cylindrical structure whose size is much smaller than the incident wavelength. As the size of structure increases and closes to the order of the wavelength, the Morison-type equation becomes less accurate and the diffraction theory should be introduced in the estimation of wave forces.

The amount of research conducted on the diffraction force acting on the spherical structure is less than that conducted on the cylindrical structures. Havelock (1954) discussed the diffraction force acting on a submerged sphere under deepwater wave condition. His theory, however, was derived without considering the free surface boundary condition. As a consequence, the effects of the bottom and free surface boundaries on the acting wave force cannot be evaluated. Garrison and Rao (1971) and Chakrabarti and Neftzger (1974) discussed the effect of the free surface on the acting wave force in the case of a bottom-seated hemisphere. Both reported that the free surface boundary has negligible effect if its radius is less than half the still water depth. Black (1975) theoretically investigated the diffraction force acting on a sphere with its center on the still water level. He developed the numerical analyzing method using the axisymmetric Green's function and reported that the bottom boundary has little effect on the wave force in a case of depth larger than twice the sphere radius. Similar results were obtained by Fenton (1978).

Concerning the diffraction force acting on a fully submerged sphere in finite water depth, very few analytical investigations have taken the bottom and free surface boundary conditions into consideration. Iwata et al. (1989) discussed this problem using the Hybrid Method and found that the diffraction force is affected by

the relative diameter and submergence of the sphere as well as the diffraction parameter. They graphically showed the range within which the diffraction force cannot be neglected in calculating wave forces. Their numerical research, however, has not been verified through model experiments. Furthermore, no discussion has taken place on the wave diffraction due to spherical structures.

This study aims to investigate the diffraction force and wave diffraction experimentally and theoretically. First, the numerical calculation using the SDM with the axisymmetric Green's function is presented. Next, laboratory experiments conducted in a 3-dimensional wave basin are described. Finally, validity of the numerical calculations is examined through comparison of both results.

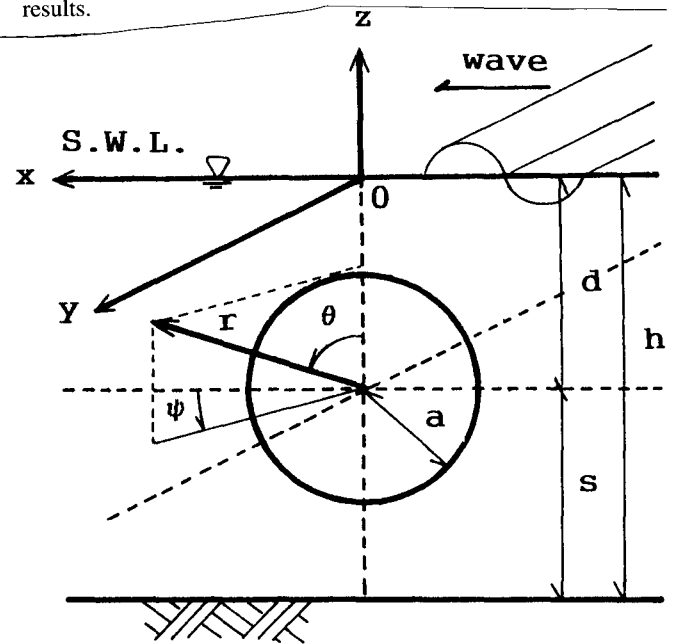


Fig. 1 Definition sketch

## NUMERICAL ANALYSIS

### SDM

As shown in Fig. 1, a sphere with radius  $a$  is fixed at the constant water depth,  $h$ . The center of the sphere is located at  $(x,y,z) = (0,0,-d)$ . The small amplitude wave with wave height  $H_i$  and angular frequency  $\sigma (= 2\pi/T, T: \text{wave period})$  propagates to the positive direction of  $x$ -axis.

Provided that the fluid is inviscid and incompressible, irrotational,

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KEY WORDS: Spherical structure, diffraction force, effective inertia coefficient, source distribution method.