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Experimental Study on Ice-Structure Interaction During Earthquakes

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ABSTRACT

This paper describes the effects of surrounding ice sheets on foundation designs of gravity-based structures during an earthquake. Extensive ice tank tests were performed to simulate an offshore structure placed in moving or unmoving ice sheets. We gave a sinusoidal vibration to a model foundation to represent an earthquake. The test results showed that moving ice sheets affect foundation loads and an interaction between structure and surrounding ice sheet may mitigate the foundation loads.

INTRODUCTION

The current design codes for offshore structures do not consider ice and seismic load as combined loads. CSA (1992) regards a seismic load as a rare event, and does not consider an ice load an accompanied load. API (1995) notes that special consideration is given to an effect of ice when an offshore structure is placed in a seismic area. The seismic load governs foundation designs when an offshore structure is located in an earthquake area such as the Sea of Okhotsk. Offshore Sakhalin Island may be the first sea area where both ice and seismic loads have been considered. The offshore Sakhalin area is covered with sea ice approximately half of the year, and it is probable that an earthquake will take place while sea ice surrounds the structure. It is quite important to clarify the effects of surrounding ice sheets to ensure safe operations. While Miura et al. (1989, 1994) considered the effect of a unmoving ice sheet on sliding stability using numerical analysis, little research for the case of a moving ice floe has been done, and the effect of an ice sheet with some velocity is not fully understood. To clarify the effect of surrounding ice sheets, we performed vibration tests in an ice tank as a first step to observing basic phenomena and obtaining verification data for a mathematical model. We assume two scenarios of vertical-sided, gravity-based structures. One is a structure placed in a stable ice sheet such as fast ice; the other, a structure placed in a moving ice sheet such as giant pack ice.

TEST ARRANGEMENTS

Model and Test Equipment

Extensive tests were performed at the Ice and Snow Engineering Laboratory of NKK Corporation. We assumed a vertical-sided, gravity-based structure 40 m wide as a prototype structure and used a 1/50-scale model 800 mm wide. Fig. 1 shows the front view of the model, and Table 1 the main particulars both in full and model. We installed 9 segmented load panels 88 mm wide and 120 mm high where the ice sheet would contact the structure in order to measure both local and global ice loads. In the aft wall, one panel of the same dimensions as on the front side, and 4 double-sized panels (177 mm wide and 88 mm high) were installed. Several pits were made in the front wall to measure hydrodynamic pressures. The surface of the model was treated to have a frictional coefficient of 0.1 with model ice. Fig. 2 shows the test arrangement. The model was connected to a foundation plate through load cells for foundation load. The foundation plate was attached to slide rails affixed to an underwater shaking bed, and disk springs were inserted to the end of the slide rails to represent soil compliance. An accelerator on the towing carriage gives sinusoidal vibration to the shaking bed through a connection rod. The accelerator comprised an induction motor and rotating disks, and frequencies/amplitudes were adjusted by changing revolution rate and disk diameter. This gives a maximum amplitude of 15 mm in

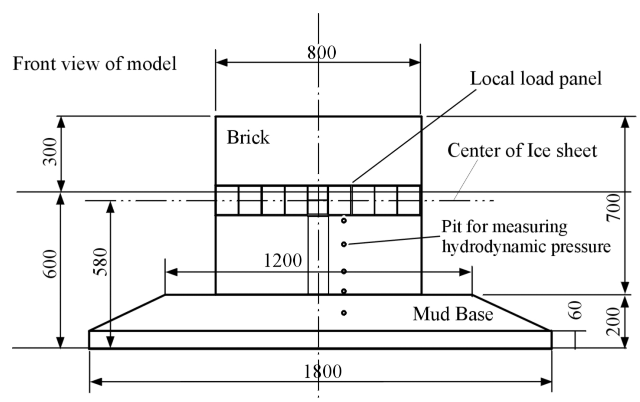

Fig. 1 Front view of structure model

	Full scale	Model
Scale	1 / 1	1 / 50
Width at water surface	40 m	800 mm
Height	45 m	900 mm
Water depth	30 m	600 mm
Total weight	200,600 ton	1.172 ton
Displacement	97,580 ton	0.75 ton
Center of gravity (height)	12.7 m	292 mm

Table 1 Main particulars of model for vibration tests

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KEY WORDS: Offshore structure, earthquake, ice sheet, vibration test, foundation load, ice load.