Sediment Liquefaction Around an Object on the Seafloor

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LONG-TERM GOALS

The long-term goal of the project is to correlate the generation of wave-induced liquefaction to wave and current conditions, to estimate the scale of liquefied sediment in seafloor, and finally to predict the sinking of heavy objects, *e.g.* mines into seafloor.

OBJECTIVES

The effective earth and dynamic pore pressures will be measured in order to identify the scale of liquefaction in seabed and estimate the sinking of heavy objects into seabed. The effective earth pressure and pore pressure fluctuations will be discussed by correlating with the measurements on the shear wave velocities in near surface sediment, water wave and current conditions under stormy weather. To complete the objectives described above, the full scale field verification of probes composed of the units of effective earth pressure transducer or dynamic pore pressure transducer and the laboratory examination on the units of each sensors should be conducted.

APPROACH

The past studies indicated that wave-induced liquefaction causes the sinking of heavy objects *e.g.* mines, concrete blocks and vessels and the surfacing of light objects. Maeno *et al.*(1996,1999) investigated the mechanism of wave-induced liquefaction by conducting the field measurements on effective earth

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14. ABSTRACT
The long-term goal of the project is to correlate the generation of wave-induced liquefaction to wave and current conditions, to estimate the scale of liquefied sediment in seafloor, and finally to predict the sinking of heavy objects, e.g. mines into seafloor.

15. SUBJECT TERMS

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pressure and pore pressure fluctuations in seafloor, sea surface elevation, water wave and near shore current velocities, wind velocities, underground water level and tide. Their observations showed only large steep waves induce the fluidization of sediment. And there is some difference on mechanisms of liquefaction between outside and inside surf zone. Outside surf zone, the phase shift of pore pressure from wave pressure at seabed surface causes the fluidization of sediment. Inside surf zone, wave breaking plays an important role on liquefaction. The depth of liquefaction reached up to three feet from seabed surface at the water depth of 6 to 7 meters with the wave height of 3 meters. The strong near shore currents transport the liquefied sediment. Since the breaking point of waves depends on wave height and the water depth that changes with tide, the seafloor is eroded during ebb and low tides and deposited during flood and high tides.

The probes employed in this study should be customized to the project purpose. The probes are composed of the units of effective earth pressure and pore pressure transducers, which had developed and improved to operate in deep water by Maeno & Yabe (2001). The units of transducer should be inspected and examined in laboratory, to obtain the linear calibration between force (pressure) and output (micro strain or voltage) and the relationship between the output and the thickness of sediment. The probes also should be verified by preliminary field measurements at full scale.

The final field measurement at Martha's Vineyards Coastal Observatory (MVCO) will be scheduled to begin September 27, 2003. The effective earth and pore pressures will be discussed with the shear wave velocities, waves and currents measured by Dr. Michael Richardson (NRL, Code 7341, Stennis Space Center) whom the PI works in collaboration with.

Figure 1 In-situ probe composed of three effective earth pressure transducers, a dynamic pore pressure transducer and a tide gage.

WORK COMPLETED

Maeno, Yabe and Toyoko Elmes Co. Ltd. customized the *in-situ* probes composed of three effective earth pressure transducers, a dynamic pore pressure transducer and a tide gage to operate under severe hydrodynamic conditions (bottom currents and surface wave conditions) as shown in Figure 1. The linearity of calibration between pressure and micro strain (output) was confirmed. The correlation between the output (pressure) of earth pressure transducer and the thickness of overburden sediment above and around transducer was examined by the laboratory tests. Figure 2 shows the calibration of earth pressure with the thickness of overburden sediment. There is a good agreement between the measured earth pressure and the theoretically estimated earth pressure.

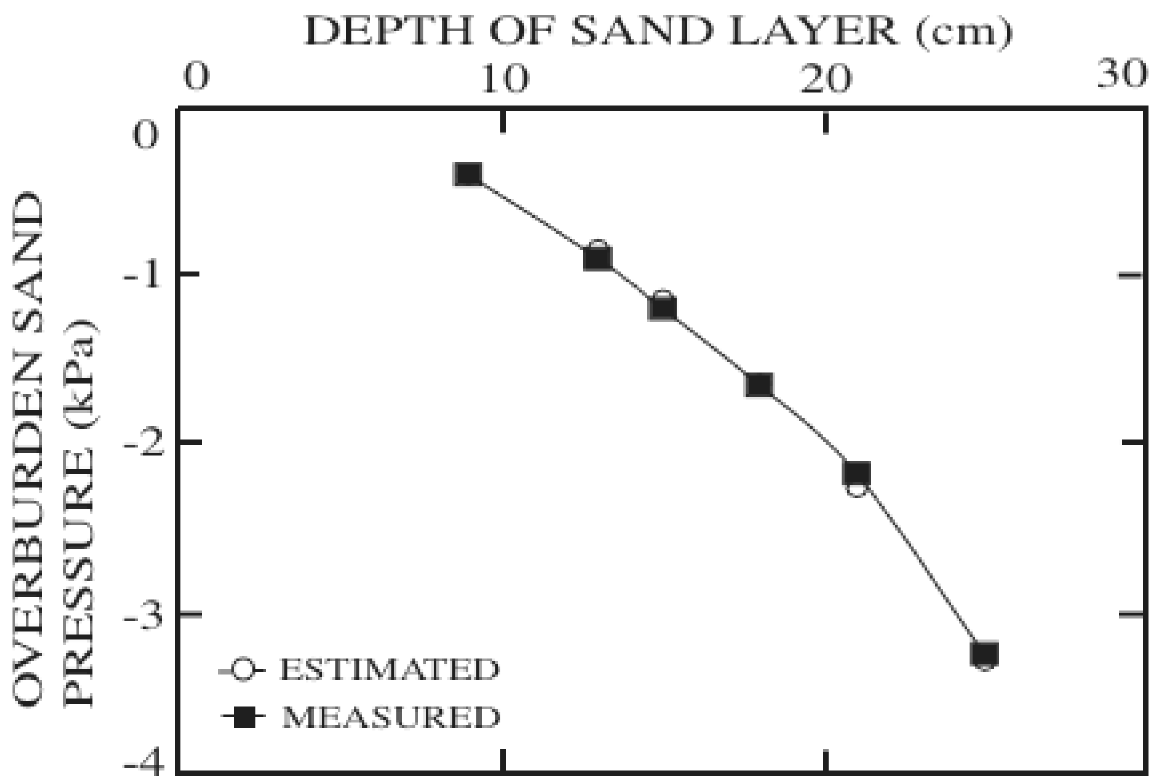

Figure 2 Relationship between the thickness of overburden sediment and that estimated by the measured earth pressure shows a good agreement.

RESULTS

The preliminary *in-situ* verifications of probes were conducted at Hazaki Oceanographical Research Station (HORS) of Independent Administrative Institution Port and Airport Research Institute (PARI), Japan.

Figure 3 shows the changes in effective earth pressures at the top, middle and bottom of connected three units of transducer during the period of the field observation, from 05/15/03 to 07/30/03. The Typhoon Linfa was approaching and affecting the Pacific coast of Japan during 05/29/03 and 05/30/03. In this period the earth pressures considerably decreased because of the erosion of seafloor. There are some differences in the time courses of earth pressures. The curves of each earth pressure separately varied, while they varied parallel with each other without this period. Since the deeper earth pressure transducer was affected by much wider area than that for the near surface transducer, the deeper transducers were more influenced by lager scale bathymetric changes such as the migration of dune and ripples as described above. It is implied from the result that Figure 3 shows that the earth pressure by the deeper transducer is larger than those of top and middle transducers. The curves of effective earth pressures and pore pressure are required to examine in relation to tide, bottom currents, sediment transport and scour.

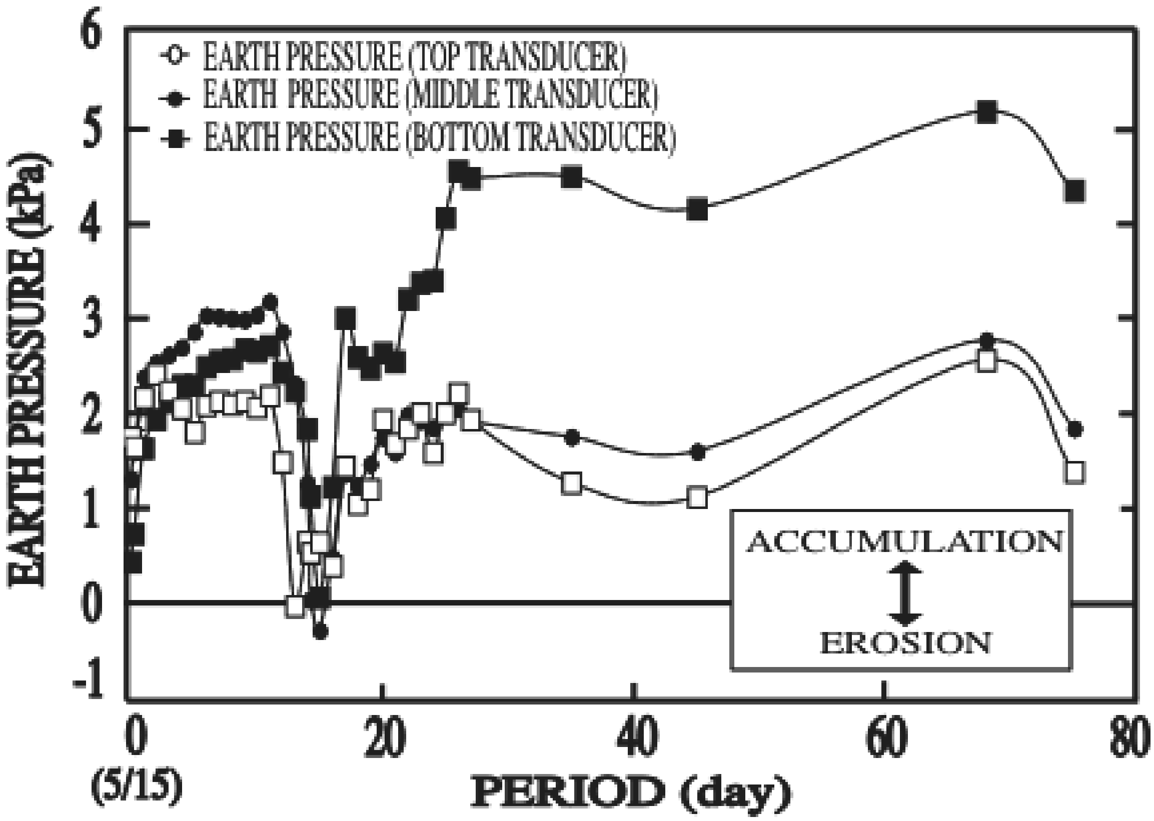

Figure 3 The changes in earth pressure at various depth below seabed surface.
[There are some differences in effective earth pressure among three depths (top, middle and bottom)]

IMPACT/APPLICATIONS

The *in-situ* probes could quantify the depth of liquefied sediment around mine-like heavy objects. The improved probes could be applied to the measurement of the rate and scour around a vertical pipe and larger scale bathymetric change such as the migrations of dune and ripple. It also could be applied for predicting the initiation of seabed slide and mudflow by measuring the buildup of pore water pressure and the sudden reduction of effective earth pressure in seafloor. The explication of each mechanism of liquefaction, seabed slide and mudflow and their interactions is required to predict mine burial in seafloor.

TRANSITIONS

The sophisticated *in-situ* probe is improving to apply the prediction of landslide which possibility is in high potential. Installing the *in-situ* probes into slopes, the effective earth pressure and pore water pressure will be monitored. When the buildup of pore water pressure or the sudden reduction of effective earth pressure is beyond the critical level, a landslide warning will be issued. The field experiences at various locations should be gained to raise the accuracy of prediction.

RELATED PROJECTS

We are working in collaboration with Dr. Michael Richardson (NRL, Code 7341, Stennis Space Center、MS) to investigate the relationship between the wave-induced liquefaction of seafloor and the deformation of soil skeleton by correlating the effective earth pressure to the shear wave velocity.

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