Onr Mine Burial Prediction Science Program

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LONG-TERM GOALS

The ultimate goals are to substantially improve, quantitatively, the U.S. Navy's mine burial predictive capabilities and to provide a strong technical basis for an Office of Naval Research (ONR) science program in mine burial prediction in basic and applied research (Bennett et al., 1999; Bennett and Wilkens, 2000; Bennett, 2000). These goals include technical direction for developing and improving Naval Fleet Aids. The U.S. Navy's capabilities must be substantially improved to meet operational and fleet requirements in mine burial prediction for shallow-water coastal environments. Specific SEAPROBE goals are to 1) implement, coordinate, and assist in the development of the Mine Burial Prediction Science Program (MBP-SP) under the directives and management of ONR science officers and 2) participate in the ONR Field Program and perform *in situ* pore water pressure and liquefaction studies. This effort includes an intensive instrumentation evaluation, study, and reconditioning of the Multi-Piezometer Array System (MPAS). Interaction and coordination with participants in NATO Mine Burial Subgroup has been an important aspect of the long-term goals of the mine burial studies (NATO SG/31, 1999).

OBJECTIVES

The research objectives are to 1) test and evaluate existing models of liquefaction by full-scale field experimentation using the MPAS, 2) evaluate instrumentation performance by limited laboratory and wave-tank testing, and 3) conduct theoretical, analytical, and numerical analysis and computer simulations of existing liquefaction models in cooperation with program participants. Another important aspect of the effort is to coordinate the research program in support of the Office of Naval Research. The Office of Naval Research requires that the technical aspects of the Mine Burial Prediction Science Program be coordinated among participating principal investigators and institutions to provide linkages, cooperation, and sharing of research data and results with the initial development of an ONR Mine Burial Web Site. Thus, an objective of SEAPROBE was to convene several technical workshops that started in April 2000 and to develop a preliminary website for information and data sharing that would later be transferred to a permanent website at a university participating in the MBP-SP.

APPROACH

The technical effort involves two major areas 1) experimental research and 2) science program coordination, with tasks required within each major area.

1) Experimental Research

A. Reconditioning and Modification of the MPAS

Evaluation, repairs, and testing were necessary to upgrade the MPAS for field deployments in the MBP-SP. Improvements, modifications, and testing with the CPU and the piezometers were required.

B. MPAS Testing and Evaluation and Wave Tank Testing

SEAPROBE conducted simple dynamic tests of piezometer probes under controlled conditions with and without mechanical design changes to determine instrument behavior, integrity of signal response, and potential spurious signal response. Tests were conducted in air and saturated sediment. Piezometer probe design modifications were made to test probes under dynamic conditions. Data were analyzed to determine probe response to motion and to assess optimum electronic system design modifications for system reliability. Wave tank tests of the piezometer probes were performed at the University of Illinois in cooperation with Dr. Marcelo Garcia. Data were analyzed to determine MPAS system reliability and potential for field applications.

C. Testing and Evaluation of Liquefaction Models

The thrust of this research effort is to 1) test and evaluate existing models of liquefaction by full-scale field experimentation including instrumentation performance by limited laboratory wave-tank testing and 2) conduct, as required, theoretical, analytical, and numerical analysis and computer simulations of existing liquefaction models in cooperation with program participants. Modeling will be in cooperation with Dr. Chiang C. Mei, MIT, Dr. Horst Brandes, University of Hawaii, Dr. Marcelo Garcia, University of Illinois, and possibly international participants.

2) Science Program Coordination and Web Site

A. Program Coordination

SEAPROBE, Inc. (Richard H. Bennett, P.I.) assisted in the coordination of the science program in mine burial prediction both offshore (field) and shorebased activities under the program management of ONR. This technical multidisciplinary program encompasses the disciplines and expertise of marine geology and geotechnique, climatology and meteorology, shallow-water physical oceanography, bathymetry and morphology, sedimentology, high-resolution geophysical profiling, modeling and statistics, mine physical characteristics and behavior in coastal environments, science and engineering applications and Fleet Aids. The program includes international participants. The ONR science and engineering program in mine burial prediction has included a series of workshops, meetings, and technical assessments and reports.

B. Web Site

The development and maintenance of the ONR Mine Burial Prediction Science Program web site is an important aspect of the program. The web site includes reports from workshops, meetings and ONR announcements, technical data, program participants, etc., and will be a repository for field databases and information exchange as necessary.

WORK COMPLETED

The technical activities completed in FY-2002 included 1) experimental research and 2) program coordination assistance in support of the ONR Mine Burial Prediction Program. Activities are summarized as follows:

1. Assisted in the January 2002 Annual ONR-MBP Workshop at Scripps Institute of Oceanography. We delivered the initial MPAS wave tank test data at the workshop in a poster and oral presentation in a plenary session. The presentation of the data and results was submitted to the University of New Hampshire (UNH) for inclusion in the ONR Mine Burial web site, which is now established at UNH.

2. SEAPROBE worked with the University of New Hampshire personnel to complete the transfer of the temporary MBP website to UNH following an ONR sponsored meeting in FY-2001 at UNH to discuss the development of a permanent web site for the MBP-SP.

3. Completed the major portion of the technical evaluation of the MPAS and repairs (electronic and mechanical components). The repairs and upgrades are expected to be completed in December-January FY-2003. SEAPROBE purchased a permanent container for the MPAS to be used for storage and transportation of the system, associated equipment, and instrumentation to coastal sites for field deployment. Considerable progress was made in FY-2002 and additional work is being done to complete system maintenance, upgrading, and container set-up for MPAS.

4. Wave tank tests of MPAS were conducted in December FY-2002 at the University of Illinois. The objectives were to evaluate the potential dynamic response of the pore pressure probes (piezometers) as a function of wave and current forcing and also to evaluate the pore water pressure response to surface wave-induced bottom pressures. Wave tank testing of the MPAS provided controlled conditions for evaluation of the system and an opportunity to collect wave and current data, pore pressure data, and system performance under controlled conditions and with a range of forcing functions. Probes were tested under wave and current forcing by fastening the probes rigidly to the wave tank to prevent motion (Figure 4). The pore pressure response was then compared to other probes that were tested under the same wave-current forcing but without being restrained.

5. Evaluated the data from an experiment conducted in a laboratory tank for testing dynamic response of the piezometer probes. We measured important sediment (sand) properties of the test tank material and presented these data at the ONR Annual Workshop in January. Laboratory tank tests in sand showed no significant pore pressure response or probe motion from large horizontal forces (up to 50lbs or 220 N).

6. Continuing to upgrade the piezometer probes with reconditioned transducers and new O-rings, etc.

7. The mechanical design of one probe was modified (electronic components decoupled from the probe shaft) and was used for testing the dynamic effects on pore pressure signals in the wave tank at the University of Illinois.

RESULTS

1) Experimental Research

The MPAS was tested in a wave tank (Figure 4) at the University of Illinois (UI) in cooperation with Dr. Marcelo Garcia and in a test tank at SEAPROBE. Sand beds were used in both the wave tank at UI and at SEAPROBE. Typical time series of bottom pressure and pore pressure are shown in Figures 1 (~4.0 s period waves) and 2 (~3.3 s period waves). These data show excellent instrument pore pressure response (≤0.05 PSI, Fig. 1 and ≤0.15 PSI, Fig. 2) to small surface wave-induced bottom pressures. Data reduction of test results is ongoing. Extensive testing was performed at SEAPROBE and at UI to evaluate the MPAS and piezometer probe performance for a range of forcing to assess the potential environmental field conditions and extremes within which the system will provide reliable data. Predicted forcing on an MPAS probe determined from the Morison equations for a range of wave periods and wave heights are depicted in Figure 3. These wave conditions are well within the expected environmental ranges for the field sites at depths of 10 – 12 meters of water. Extensive testing has shown that up to 50 lbs. (220 N) of lateral forcing on a probe only produces noise level pore pressure signals. The reader is referred to additional data sets available on the ONR Mine Burial web site (Bennett and Curry, 2002). We expect the MPAS to be field-worthy and ready for deployment in the scheduled program exercises. Objectives are to complete data reduction of the wave tank tests and analyze additional data for pore pressure response driven by wave-induced pressures. These tests may provide preliminary validation data for liquefaction models under study by ONR Mine Burial program scientists such as the one being developed by Dr. Horst Brandes.

2) Science Program Coordination and Web Site

The workshops are providing the necessary background to give the Navy direction for developing a technical program that encompasses the disciplines of marine geology and geotechnique, climatology and meteorology, bathymetry and morphology, modeling and statistics, and mine physical characteristics and behavior in coastal environments. This includes the science and engineering applications for the Fleet and Operational Navy personnel. Thus, an ONR science and engineering program plan is now being developed with a two-prong effort; one in basic science and one in applied science. Workshop results have determined that the MBP-SP will require expertise in bedform migration, scour and sedimentation, impact burial, geotechnical properties and processes, coastal processes, climatology, numerical and analytical modeling, statistics and probability modeling, instrumentation, geological mapping, and large-scale laboratory studies.

Upgrading and development of new mine burial models requires comprehensive knowledge of seafloor properties and processes as well as mechanisms that drive mine burial in coastal environments. Detailed data on the statistical distribution of sedimentological/geotechnical properties are required. SEAPROBE has developed the initial plans to compile available sediment properties and geotechnical databases for selected coastal areas (domestic and foreign) specifically in support of the development of the Expert System to be a product of the Mine Burial Program and in support of NAVO mine burial work. Well-planned field and laboratory experimentation addressing environmental processes,

seafloor sediment variability, and coupled processes are of paramount importance. Input from the Operational Navy will provide a strong underpinning for the success of the program.

IMPACT / APPLICATIONS

A substantially improved quantitative capability for the U.S. Navy's Fleet and Operational Forces is anticipated. The mine burial predictive capabilities will provide a strong technical basis for enhancing the U.S. Navy's capabilities and fleet requirements in mine burial prediction for coastal environments not only for domestic applications but also for international scenarios. The goals include the improvement of Naval Fleet Aids.

TRANSITIONS

The ONR Mine Burial Prediction Program will integrate field, laboratory, and theoretical modeling with statistical, scientific and engineering contributions, to advance the state-of-the-art in mine burial prediction and support transition of scientific results to applied problems for the Operational Navy.

RELATED PROJECTS

Numerous projects addressing sediment transport processes, marine geology, and oceanography are ongoing that focus on questions fundamental to mine burial. In the USA, the ONR Programs in Geology and Geophysics and Coastal Dynamics support and coordinate basic and applied research in the field of shallow-water sediment transport processes, and geology and geophysics of the continental shelves. Other organizations are collaborating in the ONR programs including coastal geologists from the U.S. Geological Survey, coastal engineers from the U.S. Army Corps of Engineers, and university scientists involved in National Science Foundation research grants. Staff scientists at the Naval Coastal Systems Station (NCSS), Naval Research Laboratory (Stennis Space Center, MS), and Scripps Research Institute are conducting mine burial tests. The mine burial prediction work at NAVOCEANO has included extensive effort in the development of surficial geology maps of selected coastal areas of the world. These maps depict the sediment and other geological material types from the shoreline to water depths of 200 meters. Continuation of U.S. participation in the NATO Mine Burial Studies is presently in discussion with European allies.

REFERENCES

Bennett, R.H., R. Dolan, R.W. Faas, L. Maynard, C. Curry, T. Bath, N. Langhorne and C. Butler, 1999. Mine Burial Assessment State-of-the-Art Science, Technology, and Modeling. A Review of Coastal Research, Modeling, and Naval Operational Needs in Shallow Water Environments with Recommendations. SEAPROBE, Inc. Technical Report No. SI-0099-05, 122p. (Restricted Distribution).

Bennett, R. and R. Wilkens, 2000. Mine Burial Prediction Workshop: Technical Program, Agenda, Background, and References, April 5-7, Metairie, LA. SEAPROBE, Inc. Technical Report Number SI-0000-01, 28p.

Bennett, R., 2000. Mine Burial Prediction Workshop Report and Recommendations. SEAPROBE, Inc. Technical Report Number SI-0000-03, 87p.

NATO SG/31, 1999. Mine Burial Prediction, Subgroup 31 Analysis and Final Report, June, 115p.

PUBLICATIONS / REPORTS

Bennett, R.H. and C.W. Curry, 2002. In Situ Sediment Pore Water Pressure Studies (Liquefaction Potential). Poster Presentation. Annual ONR Mine Burial Prediction Workshop, at Scripps Also available on the ONR-UNH Mine Burial website.

PATENTS

None

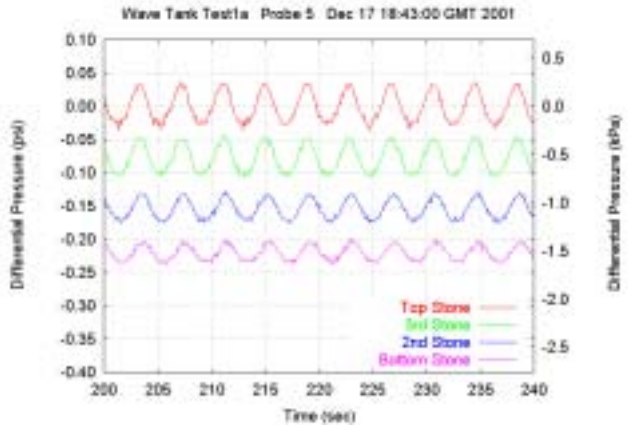

Figure 1. Time series of surface wave-induced bottom pressures and sediment pore pressures in sand bed observed in the University of Illinois wave tank. Top stone is 2 cm above sand bed, third stone is 2 cm below sand bed, second stone is 12 cm below bed, and bottom stone is 22 cm below bed. Note pore water attenuation with depth below bed. Wave period is ~4.0 s.

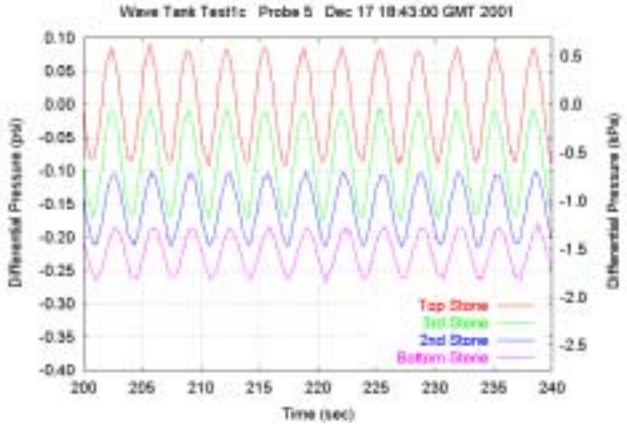

Figure 2. Time series of surface wave-induced bottom pressures and sediment pore pressures in sand bed observed in the University of Illinois wave tank. Stone notation is the same as Figure 1. Note slightly higher wave amplitude with ~3.3 s wave period than in Figure 1 and pore water pressure attenuation with subbottom depth.

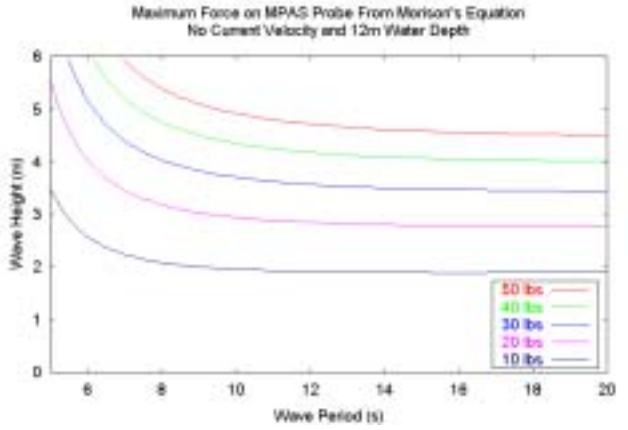

Figure 3. Predicted maximum force on a MPAS probe for a range of wave periods and wave heights at a water depth of 12 m. Tests showed that the pore pressure response to forces of this magnitude is noise level.

Figure 4. Probe 3 with no bracing and plate to enhance forces on the probe and probe 5 rigidly braced from top with steel bars and from behind with support.