IN-SITU CLASSIFICATION OF PORT JEFFERSON HARBOR SEDIMENTS USING A DYNAMIC PROBE PENETROMETER

Heather M. Bittner
Roger D. Flood
Marine Sciences Research Center
State University of New York
Stony Brook, NY 11794-5000

Robert D. Stoll
Lamont-Doherty Earth Observatory
Palisades, NY 10964

Abstract

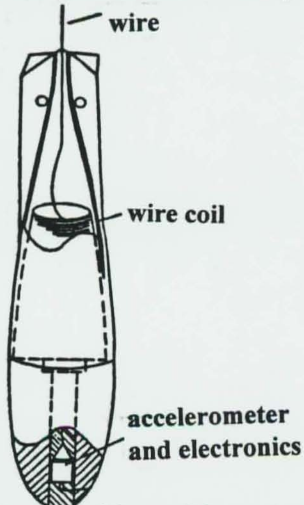
Classification of marine sediments in an efficient and accurate manner can be a tedious and difficult task. At present, there is need for a system to provide rapid, in-situ assessments of seafloor geotechnical and geoacoustic properties for initial environmental characterization and to target more detailed sedimentological, biological, and contaminant studies. A dynamic penetrometer has recently been developed that is particularly effective for rapidly characterizing surficial sediments and is easily employed in shallow water. The usefulness of this device for nearshore environmental analysis is being evaluated in Port Jefferson Harbor through the study of co-located penetrometer records and grab samples at a number of sites. Initial evaluation of these data suggest that the probe records successfully distinguish between fine-grained, muddy sediments and coarser sands and gravels. Our results confirm that the probe penetrometer is able to assess seafloor sediments quickly and accurately and suggest that it may become a very useful tool in the environmental community.

Introduction and Background

The type and physical properties of seafloor sediments are generally determined through analysis of sediments recovered by core or grab sampling. However, collecting and analyzing enough samples to characterize complex environments can be tedious and expensive, and the sampling process tends to disturb the sediment and provides poor samples for laboratory analysis. This long-standing problem has led to the development of a number of approaches, primarily acoustic, that attempt to remotely determine sediment characteristics. Recent work has resulted in the introduction of a new system for remote sediment classification using a dynamic penetrometer that is particularly well suited for studying the upper 0-10 cm of the sediment column and is effective in shallow water. A dynamic penetrometer is essentially a falling body instrumented with an accelerometer. The deceleration of the body on impact with the sediment surface, especially the maximum deceleration (termed maximum g), is recorded and analyzed. In this study, a dynamic penetrometer is being evaluated for usefulness in a complex, shallow-water sedimentary environment (Port Jefferson Harbor) through analysis of impact records and co-located sediment samples.

The dynamic penetrometer being used in this study was developed in a cooperative program between the Lamont-Doherty Earth Observatory and the SACLANT Undersea Research Center. The probe (termed an expendable benthic penetrometer, or XBP) is approximately 20 centimeters in length, weighs about 1.5 kilograms (Figure 1), and is based on a standard expendable bathythermograph (XBT) currently used by oceanographic researchers and the Navy. The primary difference between an XBT and the XBP is that an accelerometer in the nose of the XBP replaces the thermistor in the XBT. The signal from this accelerometer is carried to the surface ship either on a thin wire in an expendable version of the probe or on a thicker wire that can also be used to recover the probe when used in shallow water. The accelerometer combined with shipboard electronics and computer logic are used to record impact and penetration into seafloor sediments and to classify the sediments (Stoll & Akal, 1995).

Figure 1. Schematic of the probe



The XBP impact records have been calibrated in terms of seafloor physical properties such as undrained shear strength and dynamic shear modulus, as well as an indication as to whether the sediment is granular or cohesive in nature, through a series of laboratory experiments and field studies where sediment properties were known through separate analysis. Field areas included New York Harbor, the Mediterranean Sea, Eckernforde Bay in Germany, and the Black Sea. Stoll and Akal (1995) suggest that there is now enough data in the probe database to justify using the dynamic expendable probes as a reliable means of classifying marine sediments. However, for nearshore work, a recoverable version of the probe is preferred to the expendable version, and similar studies are needed to demonstrate how probe records should be interpreted. The present experiment in Port Jefferson Harbor, Long Island, New York, investigates whether or not the probe penetrometer is capable of classifying sediments in-situ in a rapid and accurate manner and also adds additional data to the existing database in this heavily used estuary.

Study Area

Port Jefferson Harbor is located on the northern shore of Long Island and is approximately 3.4 km long, 1.3 km wide, and 4.4 m deep on average. The harbor is an embayed section of the Atlantic coastal province and is connected to Long Island Sound by a narrow mouth. Port Jefferson Harbor was chosen as the study area because of its accessibility, water depth, and variety of background information (including a side-scan sonar study reported by Flood and Sun, 1996). This background data showed that the estuary provided a number of sediment types in close proximity, thus making it suitable for the kind of assessment study planned.

Methods

Side-scan sonar maps of the area were studied to determine the distribution of different bottom sediment types, and a grid of 94 stations spaced approximately 170 m apart was designed to provide sufficient detail to allow boundaries between adjacent sediment types (i.e. clay and sand) to be determined.

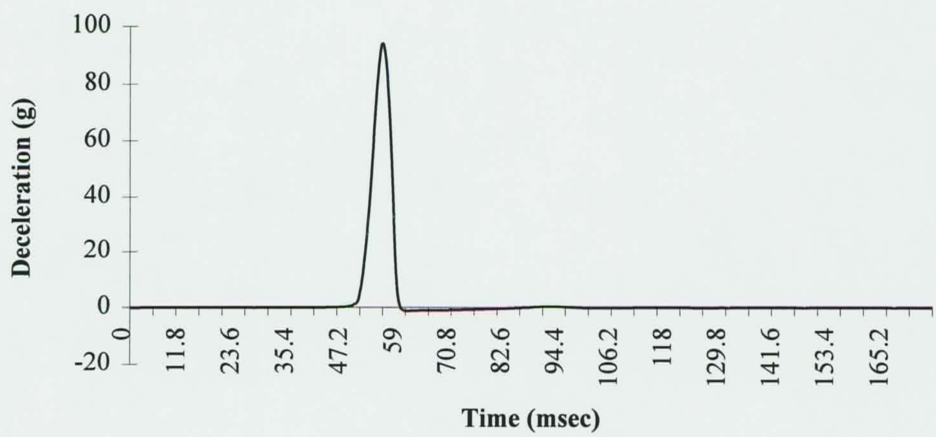
Three cruises have been conducted (1) to use the XBP probe at 56 stations in the northern portion of Port Jefferson Harbor where there is suitable sediment variability, (2) to collect sediment samples at probe drop stations in order to calibrate the physical properties of the sediment samples with the probe data, and (3) to collect additional sediment samples and to obtain simultaneous probe drop, cone penetrometer, and core data at a more limited number of stations with varying sediment types. Differential GPS was used to determine station locations. During the first cruise, about 76 penetrometer drops were made at 56 stations over a 4.5 hour period, demonstrating that the method is indeed rapid.

Sediment samples have been described and analyzed for water content (% wet weight), sediment content, porosity, dry bulk density, and void ratio. Analysis for percent organic carbon (CHNS) and grain size are underway. Initial results of our studies are presented here.

Results

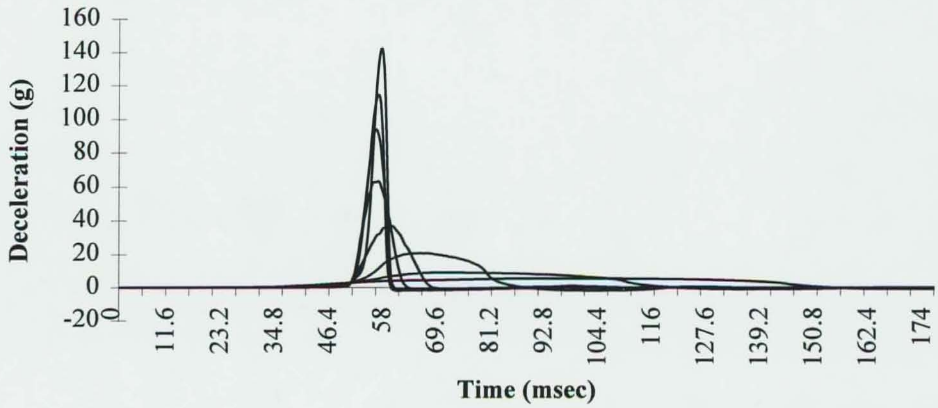
Figure 2, an individual deceleration record for station 23 which is located in a sandy region, shows features characteristic of all the penetrometer records. As the probe falls through the water column, it attains a terminal velocity after falling only a few meters. While it is falling at terminal velocity, the probe experiences no acceleration. At the moment when the probe impacts with the sediment and starts to slow down, the deceleration starts to increase above 0 g (acceleration is given in terms of the gravitational acceleration at the Earth's surface, 1 g = 9.81 m/sec^2). A maximum deceleration (maximum g) occurs part way through the record, and the deceleration goes to zero when the probe comes to rest in the sediment.

Figure 2. Individual deceleration record for station 23



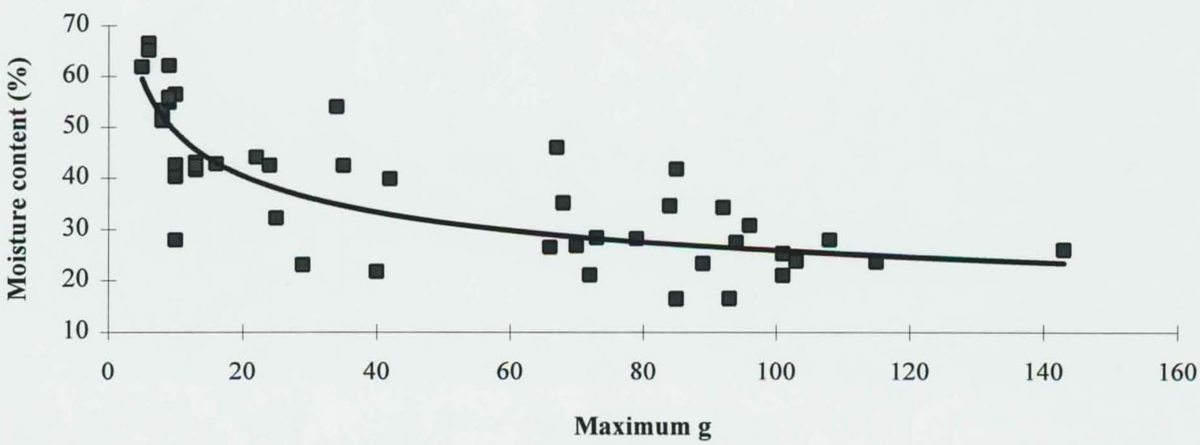
Impact records can be characterized by parameters such as the maximum deceleration or the distance that the probe goes into the sediment. Figure 3 shows the impact records for eight chosen stations. For fine-grained sediments, plastic deformation occurs as the probe penetrates into the sediment and decelerates more slowly. For coarse-grained (sandy) sediments, the probe stops abruptly because of the dilatational behavior of the sediment. From these records it is evident that there is a great deal of variability in the form of the impact, with some probe deployments displaying high g values and stopping quickly while other probe deployments display low g values and stop more slowly. It is also important to note that even though different records have different deceleration times, the area under each curve is similar because the total energy dissipated is the same in all cases.

Figure 3. Impact records for 8 stations



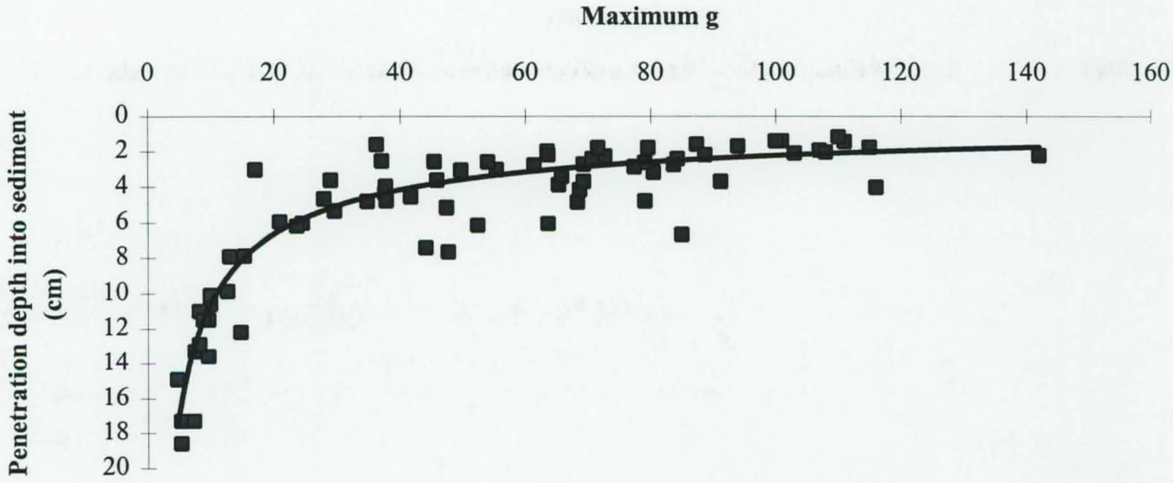
Analysis of sediment samples demonstrates that this variability in impact record is related to variability in sediment types found in Port Jefferson Harbor. Typically, sediments with a low maximum g value are muddy with a smaller grain size, higher percentage of organic carbon, and higher moisture content than sediments with a high maximum g value. Figure 4 shows that sediments with higher moisture contents (muds) typically display low maximum g values and sediments with lower moisture contents (sands and gravels) have higher maximum g values.

Figure 4. Moisture content vs. maximum g for all stations



The distance that the probe penetrates into the sediment can be determined by double integration of the acceleration record. Figure 5 shows penetration depth versus maximum g for all Port Jefferson Harbor stations. For fine-grained sediments with low maximum g values, plastic deformation occurs as the probe penetrates deeply (up to 19 cm) into the sediment. For coarser sediments with higher maximum g values, the probe stops abruptly and only penetrates a few centimeters into the sediment due to the dilatational property of the sediment.

Figure 5. Penetration depth vs. maximum g for all stations



Conclusions

From the work completed thus far, the probe penetrometer has proven to be a very useful tool in the rapid and precise determination of sedimentary parameters in a complex environment. Predictive relationships between maximum g values, grain size, moisture content, organic carbon content, and penetration depth into the sediments are being developed. This tool should thus be of interest and use to the environmental community because of its ability to asses seafloor sediment characteristics in-situ accurately and efficiently.

References

Akal, T. and R.D. Stoll (1995) An Expendable Penetrometer for Rapid Assessment of Seafloor Parameters, In: Proc. IEEE Conference 'Oceans 95,' San Diego, 1995.

Flood, R.D. and J. Sun (1996) Side-Scan Sonar Study of Port Jefferson Harbor, Long Island, New York, In: Geology of Long Island and Metropolitan New York, April 20, 1996, Stony Brook, NY, 53-55.