International Journal of Offshore and Polar Engineering
Vol. 9, No. 3, September 1999 (ISSN 1053-5381)

Predicted and Measured Geotechnical Properties of Gas-Charged Sediments

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ABSTRACT

Geotechnical and geo-acoustic characterization of sediments from Eckernförde Bay, Germany, are combined with a theoretical model to predict the influence of gas-bubble concentration on key engineering parameters. These sediments are organic in nature, very soft, and contain variable amounts of dissolved and undissolved methane gas. At the typically low gas volume fractions measured at the study site, on average less than 1%, gas pressure is predicted to be less than 36.4 kPa above hydrostatic water pressure, whereas undrained shear strength is estimated to fall within ±20% of the fully saturated strength. The instantaneous, undrained, elastic shear modulus is expected to decrease very little, whereas the bulk modulus and the compressional wave velocity show dramatic decreases.

INTRODUCTION

Offshore organic sediments, particularly those found in shallow water depths, are often unsaturated due to the presence of gas bubbles. Methane is the most common type of gas present in surface deposits and is derived from bacterial breakdown of organic matter. Organic-rich sediments are found in many coastal areas such as in the North Sea, the Black Sea, and near the deltas of several major rivers. The presence of undissolved gas can have important consequences for the mechanical and acoustic behavior of these sediments, which constitutes the focus of this article.

A recently completed major research initiative, the Coastal Benthic Boundary Layer program (CBBL; Richardson, 1994), included an exhaustive investigation of the soft, organic, methane-rich sediments from Eckernförde Bay, Germany (Fig. 1). The fine-grained sediments near the central basin are relatively uniform in composition in the upper 5 m and consist of a black, silty clay with an average organic content of 11.2% by weight. Near the surface the sediments are characterized by unusually high water contents, plastic limits, compressibility (C_c between 2.7 and 6.8), as well as low permeabilities (average of 4×10^{-6} cm/s in the upper 40 cm), and very low shear strengths (Fig. 2; Silva and Brandes, 1998; Brandes et al., 1996). At ambient pressures the sediments contain variable amounts of methane gas, in solution as well as in the form of gas bubbles. Where gas bubbles are present, they are easily detected in sub-bottom acoustic profiles (Fig. 3), and in fact obscure the structure of the deposits below such horizons. Only where the gas is absent is the underlying sediment structure visible. Note that the acoustic windows adjacent to the pockmark reveal the presence of a layer of glacial till at depth (Lambert et al., 1995).

A comprehensive geotechnical investigation was carried out as part of the CBBL program that included in situ measurements and shipboard and laboratory testing. In addition, the size and distribution of the gas bubbles were determined at a number of locations from gravity cores that were transferred to special pressurized chambers while on the seafloor. These cores were X-rayed under pressure using a Computer Aided Tomography (CAT) system to generate density images, and hence bubble-concentration profiles (Anderson et al., 1998). This technique was intended to minimize disturbance to the sediments and preserve the natural gas character. This data set can be combined with theoretical models to gain further insight into the in situ behavior of the gas bubble-bearing sediments.

The sediments in Eckernförde Bay are nearly saturated at ambient pressures, even where gas bubbles are relatively abundant, so that it is likely that the liquid and solid phases are continuous, but the gas phase is not. This type of structure is thought to behave differently from many land-based unsaturated soils that have a more or less continuous gas phase, corresponding to lower levels of saturation (Wroth and Houlsby, 1985; Wheeler, 1988a). For

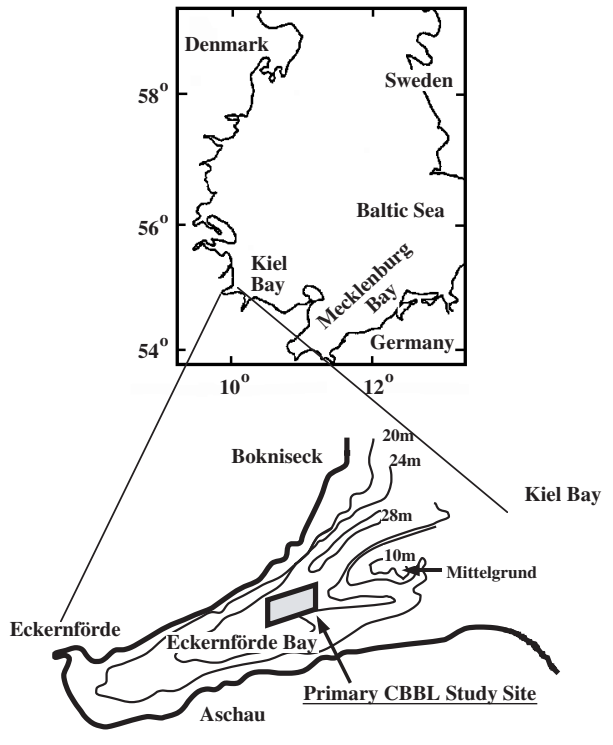

Fig. 1 Eckernförde Bay, Germany

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Received March 10, 1998; revised manuscript received by the editors May 10, 1999. The original version (prior to the final revised manuscript) was presented at the Eighth International Offshore and Polar Engineering Conference (ISOPE-98), Montréal, Canada, May 24-29, 1998.
KEY WORDS: Gas, organic, sediments, geotechnical properties, modeling, testing, acoustic velocity, unsaturated.