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Shear Behaviour of Interfaces in Cemented Carbonate Soil

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ABSTRACT

The problem of the shear behaviour of interfaces between drilled and grouted piles and surrounding carbonate soils is addressed. Results of laboratory shear tests on artificially cemented carbonate soils are presented and the implications of the results for the design of offshore piles are discussed.

INTRODUCTION

In offshore conditions, large structures are often founded on piles which are either driven or drilled and grouted into a weakly cemented soil mass. Piles driven into these soils depend largely on the frictional behaviour of the pile-soil interface to develop their load-carrying capacity, whereas drilled and grouted piles rely on both bonding and the frictional resistance at the interface.

Drilled and grouted foundations are becoming increasingly popular as a means of supporting offshore oil and gas platforms in Australia. For such foundation piles, the interface between the cement grout and the surrounding calcareous soil is subjected to cyclic shear loading as the wind and wave forces acting on the platform are transmitted to the seabed. Understanding the mechanical response of cement-soil interfaces under these loading conditions is therefore of major importance to the design of drilled and grouted offshore piles.

It is well known that calcareous soils may undergo large volume reductions when subjected to relatively moderate stress levels. The application of both shear and hydrostatic stress components can induce these volume changes, which can lead to excessive foundation movements, and can significantly reduce the ultimate load capacity of foundations in these soils. Numerous papers describing these phenomena and other important geological and engineering features of carbonate soils are contained in the conference volumes edited by Jewell and Andrews (1988).

Of particular relevance in the present study is the behaviour of interfaces subjected to either monotonic or cyclic shear stresses. Laboratory shear tests have been carried out to allow an examination of this behaviour under controlled conditions. An artificially cemented soil, consisting of natural carbonate sand particles obtained from the seabed and bonded together with gypsum cement, has been prepared and samples of this material have been subjected to both static and cyclic shear tests under conditions of constant normal stiffness.

In this paper the technique used to prepare the artificially cemented soils samples and the special apparatus used to apply the shear loading are described. A brief comparison of the responses of the artificially cemented soil and the natural carbonate soil from a variety of laboratory tests is presented. The favourable comparisons demonstrate the relevance of the model material to the study of the behaviour of the natural soil. The main emphasis of the paper is then placed on the presentation and discussion of the results of the programme of shear tests, and their application to the design of piles for offshore structures founded in cemented carbonate soils of this type.

MANUFACTURE OF ARTIFICIALLY CEMENTED SOIL

The artificially cemented carbonate soil (ACCS) developed for this study was intended to simulate the mechanical behaviour of a naturally occurring soil described as calcarenite, found at the site of the North Rankin 'A' gas production platform on the North West Continental Shelf of Australia.

The procedure used to prepare the test specimens has been described in detail by Carter and Boey (1989) and only a brief summary is given here. Uncemented carbonate sand was cemented artificially in the laboratory, using a proprietary cementing agent, called Patternstone grout, whose major constituent is gypsum. A mixture of appropriate amounts of the soil, cement and water (typically 20% cement by weight of the dry soil and an amount of water nominally equal to 40% of the combined weight of the dry ingredients) was placed in a cylindrical mould and compacted by the application of an axial load. The axial load was left on the specimen for at least one hour, allowing excess water to drain from the ends of the specimen and the cement to reach an initial set. Due to the quick setting nature of the cement, it was possible to remove the specimen from the mould soon after the axial compaction load was removed. After removal from the mould, the specimen was cured in a plastic wrapper at approximately constant temperature.

COMPARISON WITH NATURAL CALCARENITE

An extensive series of mechanical and chemical tests has been performed to compare the behaviour of the artificially cemented soil with that of the natural calcarenite (Boey, 1990). These comparisons indicate that in many respects the artificial material represents well the natural material. As an example, consider the behaviour of both types of material in drained (CID) triaxial shear tests, as shown in Fig. 1, and during direct shear tests, as shown in Fig. 2. These figures also demonstrate the repeatability of the results obtained using the artificial material.

The major advantage in using artificially cemented soils in the laboratory is that essentially identical specimens can be prepared at relatively low cost. It is very expensive to recover the natural material from the seabed and furthermore the core samples are often highly variable. It is therefore quite difficult to interpret the results of a study on the natural materials because of this sample variability. In contrast, it can be concluded with reasonable confi-

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