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Properties of Foam/Sand Mixtures for Tunnelling Applications

Summary

This thesis presents experimental work on foam/sand mixtures carried out in the Civil Engineering Laboratory at Oxford University, as well as the findings associated with it. This research represents the preliminary stage of a research project on Soil Conditioning Agents in Pipe Jacking and Mechanised Tunnelling, sponsored by the Pipe Jacking Association (PJA) and three water companies. The experimental work was carried out in order to evaluate the fundamental soil properties of foamed sand, in particular its compressibility, permeability and shear strength.

The first chapter deals with the basic aspects of soil conditioning agents and their application to tunnelling, and provides an understanding of the fundamentals of foam behaviour. An introduction to the problems encountered in tunnelling is given. A brief study of foams and their properties is presented and the role of foams as soil conditioning agents is described.

In the second chapter, a description of the foam generator used is provided. Two types of sand (fine and coarse), four types of foaming agents and a specific polymer mixture were employed for the testing. In some cases, sodium bentonite was used alone or in combination with foam and polymer. The sample preparation method, together with the results from measuring the reduction of the power input required to mix sand with foam, are presented.

The third chapter presents the compression tests performed in a 75 *mm* Rowe cell. Results are presented as volume changed variation with the applied vertical stress. Quality control was carried out on the test results in order to evaluate the likely inconsistencies during the preparation and measurements. The most notable outcome was that for fine sand even at high pressure the final voids ratio of foam/sand mixtures after the compression remained higher than the maximum voids ratio of dry sand. Some measurements of the foam/sand mixtures permeability were also performed in the Rowe cell. Tests were carried out using the constant head principle with a "Marriotte bottle". Permeability values determined from testing are compared with indirect evaluation from the compression tests.

In the fourth chapter direst shear tests in a standard shear-box are presented. Fine and coarse sand mixed with foam were test in shear under seven different vertical loads. Results are presented as plots of shear strength against horizontal deformation. Very low values of shear strength for foamed sand tests are recorded. The shear strength is plotted against the relative density index along with the experimental results from Bolton's correlation. Foamed sand shear strength values are scattered within a range below that of Bolton's Correlation. Finally, the conclusions form the test results are discussed.