DEVELOPMENT OF A NEW APPARATUS FOR HOLLOW CYLINDER TESTING

Volume 1 of 2

by

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Preface

This thesis describes original work that has not been submitted for a degree at any other university.

The investigations were carried out at the Department of Civil Engineering, University College Dublin, during the period from September 1994 to September 2000, under the supervision of Dr Tom Widdis.

The main part of this thesis describes the development of a new automated hollow cylinder apparatus which facilitates accurate measurement of soil constitutive behaviour, from its quasi-elastic region, to failure, during stress path testing. A complementary sample preparation apparatus was developed to reconstitute hollow cylindrical test specimens of sand, to a prescribed density.

This thesis is presented in two volumes. The first volume contains the body of the text and is 126 pages long. The second volume contains ninety A3 size component and assembly drawings for the new *HCA* and its sample preparation apparatus.

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DEVELOPMENT OF A NEW APPARATUS FOR HOLLOW CYLINDER TESTING

The Hollow Cylinder Apparatus (*HCA*) is the only soil test device that can facilitate independent control of both the magnitudes and directions of the principal stresses. The stress history and loading conditions at a point in a soil deposit can be reproduced on a Hollow Cylindrical (*HC*) specimen, and its constitutive behaviour and pore-pressure response measured. However, shortcomings in the equipment, instrumentation and the procedural approaches can potentially invalidate the test results obtained from existing *HCA*s. Measurement and process control limitations confine their operation to static testing over the strain range from 10^{-4} to 0.20. Many of the existing *HCA*s are incapable of generalised stress path testing.

A new HCA that can simulate the complex loading conditions at a point in a soil deposit, on a hollow cylindrical test specimen, was developed. It facilitates accurate measurements of the specimen's constitutive and pore-pressure responses over the complete strain range during stress path testing or displacement-controlled loading. Test specimen dimensions, which limit the stress non-uniformity during testing to an acceptable level, were identified. A sample preparation apparatus was also developed and a technique was perfected to reconstitute saturated sand specimens in the new apparatus.

The research and development of the new *HCA's* cell, its pressure systems, the servo-mechanisms, which displace and rotate the loading piston, their instrumentation and ancillary equipment, are described. Linear actuators control the hydraulic systems, which apply the inner and outer confining pressures and the back-pressure to the specimen. Innovative servo-mechanisms, which induce an axial force and a torque across the specimen, are mounted beneath the cell so that it can be readily assembled and disassembled by an operator. The cell's tie bars are located inside its acrylic cylinder and the load path through it is extremely stiff. The servo-mechanisms can quasi-statically or dynamically load specimens of all soil types, weak rock and pavement base materials in direct compression, extension or pure torsion, to failure. They can also apply tensile normal stresses to the test specimen to facilitate investigations into the engineering properties of materials other than soil. The mechanisms have a low inertia, zero backlash and insignificant compliance values.

The axial force, torque and the confining pressures that are applied and the specimen's polar deformational, pore-pressure and volume change responses can be accurately measured. Its static deformational response can be measured over the specimen's zone of uniform stress, near its mid-height using instruments located inside the cell. These instruments can be remotely relocated during a test to accommodate the specimen's deformational response. The control sensitivity of the pressure systems and servo-mechanisms and the instruments' resolution and accuracy values are sufficient to facilitate low amplitude cyclic testing in order to determine the soil's quasi-elastic constitutive properties. The specimen's boundary displacements can also be measured using instruments located outside the cell. They facilitate dynamic measurements over

the reduced strain range from the order of 10^{-4} strain, to failure. A hollow-shaft type encoder was uniquely incorporated in this instance to measure the specimen's twist. The servo-mechanisms can readily produce the high-speed response, which is necessary to facilitate accurate dynamic testing. A complementary control system was integrated in the new *HCA* with the aim of developing a fully automated stress path and displacement-controlled test device.

Test specimens of 71 mm inner diameter, 100 mm outer diameter and 200 mm high were selected in view of theoretical and practical considerations. These dimensions also facilitate the testing of undisturbed samples. The development of the sample preparation apparatus and the technique, which employs the wet-pluviation method followed by tapping that was perfected, is described. This technique can consistently reconstitute specimens with a uniform controlled density and their dimensions have excellent repeatability.

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