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The micromechanical behaviour of a biogenic carbonate sand

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Abstract

An experimental investigation of the micromechanical behaviour of a biogenic carbonate sand from the Philippines was conducted. Mechanical parameters of sands at the micro-scale are required in order to simulate the particle interactions in numerical analyses carried out using the Discrete Element Method (DEM). The tests were performed on particles obtained from the sedimentation of coral fragments and they were carried out by means of a custom-made inter-particle loading apparatus that enabled the investigation of both the normal and tangential loading behaviour at the particle contacts. The normal loading tests showed a reversible behaviour after the first loading, while the tangential loading behaviour of this sand appears to be dependent on the vertical confinement and mainly reversible for small displacement cycles. Also, the inter-particle friction coefficients at larger displacements are substantially higher than those calculated for other sands using the same experimental procedures.

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Keywords: carbonate sand; micromechanics; contact behaviour; friction; stiffness

1. Introduction

Carbonate sands are soils that have a sedimentary origin. Calcium carbonate is the predominant mineral in these materials and they are usually the result of the deposition of the skeletal bodies of small organisms (e.g., shells, elements of coral reef, etc.) or chemical precipitation from carbonate-rich water. In recent decades, interest in these

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materials increased because of their unusual mechanical features, such as high friction angles and high compressibility, which is related to particle crushing [1].

The mechanical behaviour of geomaterials at the micro-scale started to be studied during the 60's of the 20th century by means of custom-made apparatuses [2,3,4], but it gained more interest after the increase in popularity of the Discrete Element Method [5]. New experimental methodologies were developed, in order to study the strength of particles [6] and the contact behaviour of grains [7,8]. Cavarretta et al. [9] studied the effects of environmental conditions on both glass ballotini and particles of quartz sand, highlighting an increase of friction coefficient for relative humidities higher than 40% and for water saturated conditions. Senetakis et al. [10] presented the results of inter-particle shearing tests on a quartz sand, underlining the effect of the normal confinement on the tangential behaviour and showing that water had no clear influence on the frictional behaviour of soil particles.

2. Experimental equipment

The experiments were carried out by means of a custom-made inter-particle loading apparatus that was designed and built at the City University of Hong Kong [8]. The original version of the apparatus was upgraded in order to improve the accuracy of the displacement measurements and increase the variety of testing conditions [11].

The apparatus consists of a stainless steel loading frame, three loading arms and a stainless steel sled (Fig. 1). One loading arm is oriented along the vertical direction while the other two are in orthogonal horizontal directions. Each of them was assembled connecting a micro linear actuator (a), a high resolution load cell (b) and the sled by means of stiff mechanical elements and quasi-frictionless linear bearings. The sled (c) is placed on a polished piece of stainless steel by means of a bearing system made up of three chrome steel balls and can be moved along the horizontal plane by means of the linear actuators. Each load cell has a capacity of 100 N.

During each test, one particle is connected to the vertical arm and another one is mounted on the sled (d) and they can be tested after placing them in contact using the linear actuators. The displacements are measured through three non-contact eddy current displacement sensors (e) having a measuring range of 3mm and a resolution of 10^{-5}mm. The whole apparatus is located inside a Perspex chamber and the relative humidity inside this can be regulated using a humidity controller within the range 15-85%. Also, the particles can be tested under fluids installing a small aluminium and Perspex water bath inside the apparatus.

The apparatus is capable of performing tests applying combinations of either forces or displacements along three directions. A custom-made software is used to send the input commands to the apparatus and to record the test data. Also, two digital micro-cameras (f) are installed inside the chamber in order to determine the correct location of the contact between the particles and to record pictures during the tests.

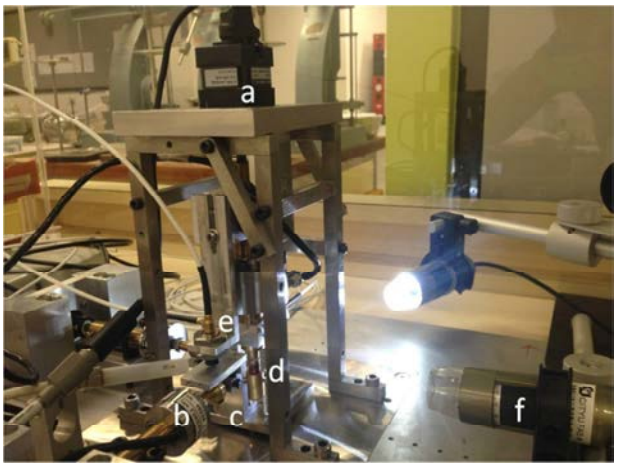

Fig. 1. Inter-particle loading apparatus: a) linear actuator; b) load cell; c) stainless steel sled; d) soil particles during a test; e) eddy-current displacement sensor; f) digital micro-camera.