Testing at temperature at Imperial

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Imperial College has been involved in experimental soil mechanics since the Soil Mechanics section was formed in 1946 (Brown, 1985), with A. W. Skempton and A. W. Bishop as key figures in developing the experimental capabilities. Renowned for its development of both testing apparatus and experimental techniques for investigating the behaviour of soil, the close working relationship between the academic, research and technical staff has been crucial to the historical and continuing success of the Geotechnical Laboratories at Imperial College. Over the last 60 years, the testing apparatus has moved from applying deviatoric stress using dead weights (Bishop & Henkel, 1962), hydraulic pressures using self-compensating mercury pots, and with measurements being taken by burettes, proving rings and dial gauges (Bishop & Eldin, 1950) to electronic transducers (Bishop & Wesley, 1975) and the use of computer controlled compressed air supply and automatic logging (Hight, 1983).

Interest into the causes of oilfield subsidence in the central North Sea and subsequently in the Ekofisk Oilfield led to experimental work on the behaviour of chalk under high pressure and temperature (Addis, 1987; Leddra, 1989, Jones et al., 1992), with the experiments for these projects being carried out at the Laboratories at Imperial College. The triaxial apparatus used for these tests tested samples 38 mm in diameter and 76 mm in height, and was able to reach cell pressures of up to 70 MPa (10 000 psi) incorporating a balanced ram, designed by A. E. Skinner, capable of supplying more than 80 kN (Addis, 1987). The cell confining fluid used was oil and the cell was heated using a stainless steel sheathed, ceramically insulated heating cable wound to an elongated sinusoidal shape (Figure 1) which allowed the cell to be heated to 180°C. The radial strains were monitored by a specially designed local radial belt, with the strain gauges able to withstand up to 290°C to allow large strains and high temperature tests within the limited space in the cell.

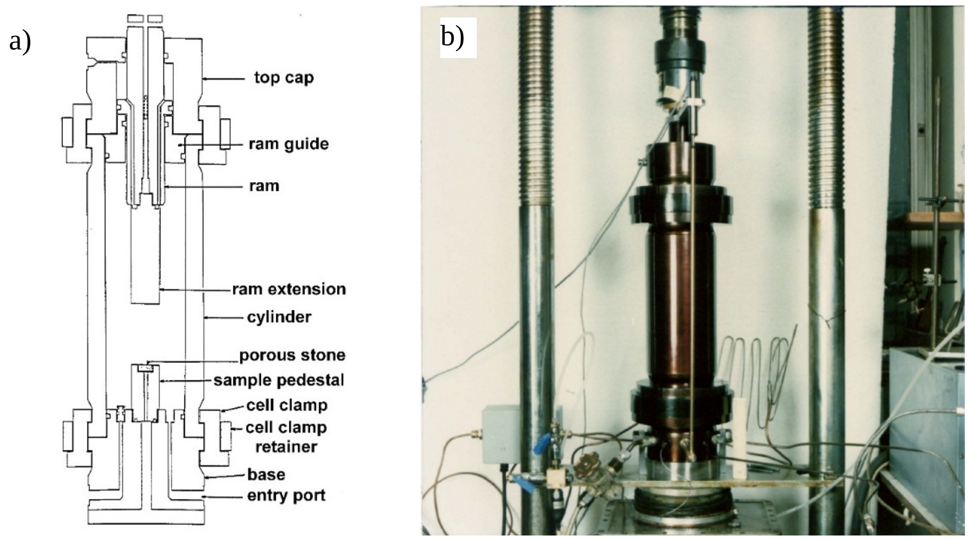

Figure 1 - High pressure, high temperature cell at Imperial College a) schematic, b) photograph of cell and external heating element (Addis, 1987)

Recent renovations to the Geotechnical Laboratories at Imperial College, during the summer of 2013, have overhauled the temperature control of the laboratory space enabling room temperature to be maintained within ±0.5°C. This has coincided with the development of new temperature testing apparatus with the aim of exploring a number of energy applications. Starting with a single temperature controlled triaxial with financial help from an EPSRC small equipment grant, the temperature triaxial mk1 was built in 2013 (Figure 2). The apparatus can test samples up to 50 mm in diameter and 100 mm in height, cell pressures are applied to the sample using de-aired water with the confining cell made of steel with external tie bars designed to withstand more than the maximum 800 kPa of cell pressure the compressed air system can supply. Deviatoric stresses are applied by a 50 kN load frame and load is measured by a high resolution submersible load cell, based on a design by A. E. Skinner (Bishop et al., 1975). Heating of the cell, from ambient room temperature to a modest 80°C, is performed by six 150 W cartridge heating elements with three embedded into top and base plates of the cell respectively. Each heating element has a temperature sensor attached to it which allows computer control and logging and an additional temperature sensor monitors the temperature of the cell water at the mid-height of the cell (Martinez-Calonge, 2013). The volume of drained water leaving the sample is measured by an Imperial College Volume Gauge (de Campos, 1981).

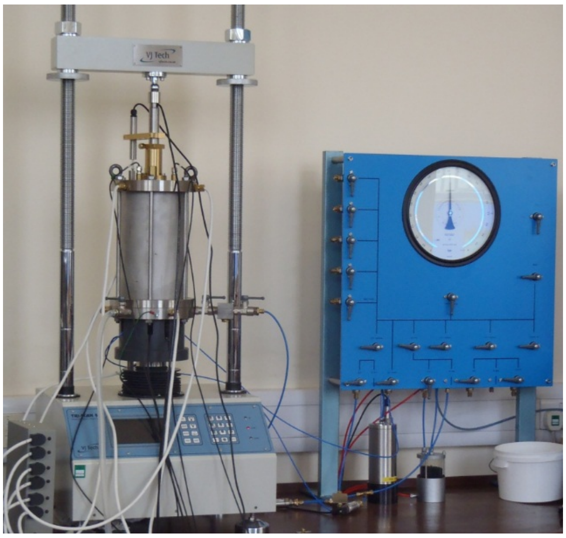

Figure 2 – Imperial College temperature triaxial cell mk 1 (Photo courtesy of D. Martinez-Calonge)

A second more substantial EPSRC Capital Grant has further allowed Dr. D. M. G. Taborda to further expand the thermal testing capabilities at Imperial College with a second generation temperature triaxial (mk 2), a combined thermal and hydraulic conductivity cell, and a temperature controlled oedometer. The temperature triaxial mk2 (Figure 3) is able to test larger specimens, up to 100 mm in diameter and 200 mm in height and in place of heating elements built into the top and base plates of the cell body, heating is provided from circulating temperature controlled fluid in a chamber surrounding the steel confining cell. The confining cell of the mk 2 is designed to withstand cell pressures of up to 5 MPa and has internal tie bars. The heater chiller unit is able to supply a circulating fluid to a non-pressurised chamber surrounding the cell from 5°C to 85°C. Similar temperature control mechanism is provided in the combined thermal and hydraulic conductivity cell, and a temperature controlled oedometer.

Figure 3 – Imperial College temperature triaxial cell mk 2 (Photo courtesy of D. M. G. Taborda)

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