Short Communications

A Transducer for Measuring Vertical Load Inside a Tri-Axial Cell

by

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Introduction

When the axial load is measured in a tri-axial test with a proving ring fixed outside the cell, a correction is necessary due to the water thrust on the loading ram and the friction between the ram and the bushing of the cell. For a perfect cell in which the dimensions of the ram and the bushing are correctly maintained, this correction is constant for a particular cell pressure, and can be easily evaluated (Bishop and Henkel, 1962). But unfortunately, the cells, that are commonly available in India, do not possess constant frictional characteristics along the full length of travel of the ram. This may introduce serious error in the measurement of strength and especially, the stress-strain modulii of soft clays from tri-axial tests. Furthermore, for special tests like Ko consolidated undrained tests or stress-path duplicated tests, where cell pressure is to be continuously changed along with the application of vertical load, evaluation of ram friction becomes difficult even for perfect cells.

One way of eliminating the effect of ram friction is to measure the vertical load inside the cell by means of a transducer. The design and use of such a transducer are reported herein.

Ram Friction of a Typical Indian Tri-Axial Cell

The details of the top of a typical tri-axial cell, commonly used in India, are shown in Figure 1. In order to make the cell water-tight, an 'O'-ring sealing is provided between the ram and the bushing, and as a result, the ram friction is also dependent on the cell water pressure. The variation of friction with the ram movement of a typical cell was studied at Jadavpur University, for a length of travel of ram that is usually encountered in a tri-axial test with free ends (Rowe & Barden, 1964; Gangopadhyay et. el. 1972). The results for a particular tightening of the gland, and for three different cell pressures (1.75, 3.50 and 7.00 Kg/cm^2), are shown in Figure 2. It is seen from Figure 2, that during downward movement of the ram, i.e. loading in a compression test, friction varies from about 0.795 to 2.02 Kg, 1.13 to 2.34 Kg, and 2.47 to 3.18 Kg for cell pressures of 1.75

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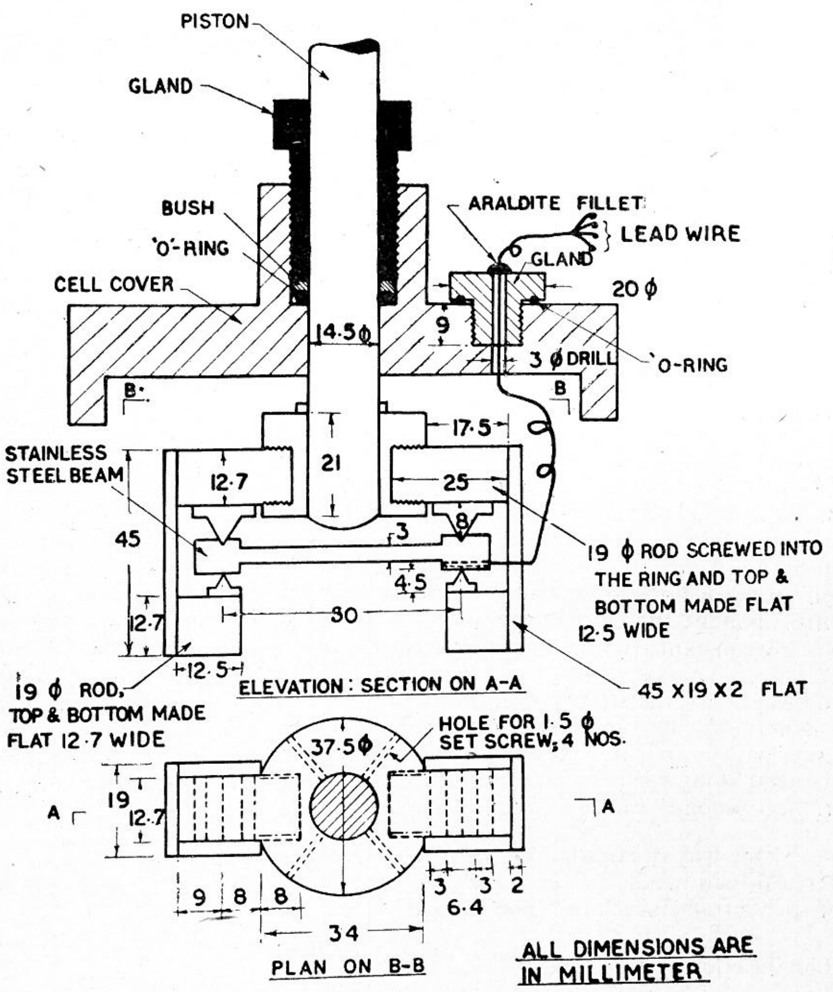

FIGURE 1. Details of transducer and top of triaxial cell

3.50 and 7.00 Kg/cm^2 respectively. The extent of variation is comparatively less during upward movement or unloading. This is from about 0.45 to 1.23 Kg for cell pressures of 1.75 and 3.50 Kg/cm^2, and 0.34 to 1.05 Kg, for a cell pressure of 7.00 Kg/cm^2. In terms of vertical stress on a standard soil specimen with a diameter of 3.8 cm, the maximum range of variation of ram friction amounts to about 0.107 Kg/cm^2 during loading and 0.069 Kg/cm^2 during unloading of a typical tri-axial compression test.

Design of Transducer

Figure 1 shows the details of the transducer (capacity 35 kg), which essentially consists of a stainless steel beam, freely supported between knife edges provided in a brass housing, that is connected to the lower end of the ram by set screws. A ball contact is provided between the beam and the top cap of the soil specimen.

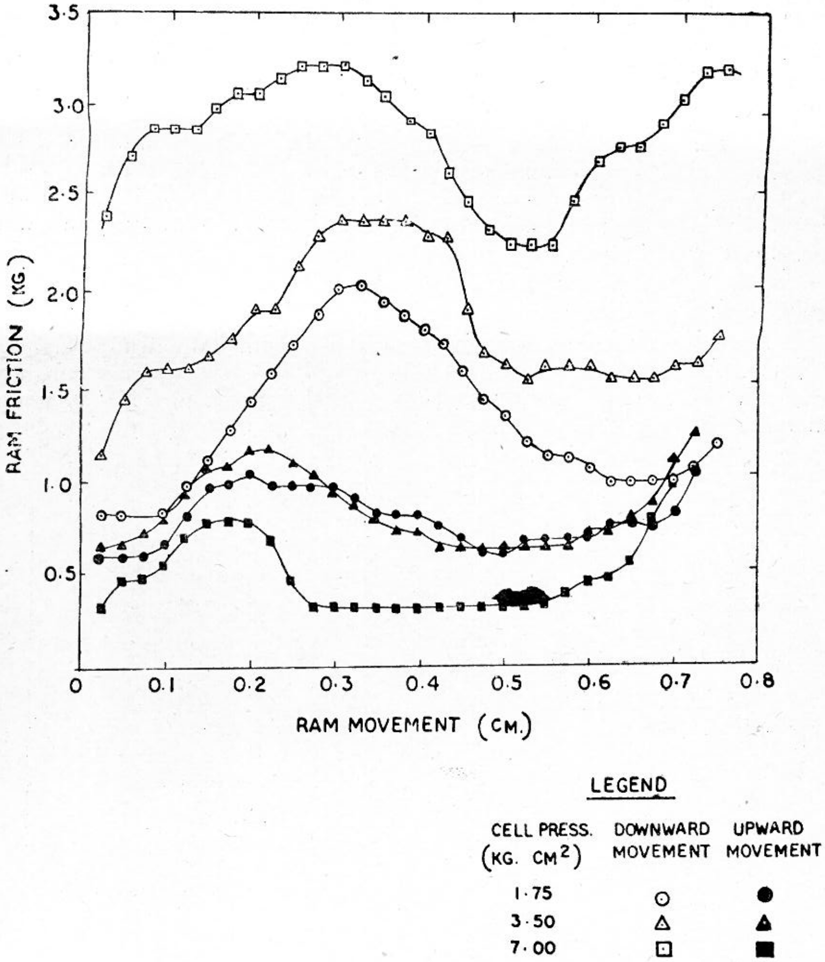

FIGURE 2. Variation of friction with ram movement

The vertical load is measured by the strain of the beam sensed by electical resistance strain gauges. The thickness of the beam was so designed that the output in terms of strain is the maximum, and the stresses under the design load are well within the elastic limit so that a sensibly linear calibration with negligible hysteresis is obtained. For a span of 5cm. of the beam, a thickness of 3.2 mm and width of 12.7 mm were found to be most suitable. The maximum stress under the design load of 35 kg would be 2020 Kg/cm^2 (yield stress = 2500 Kg/cm^2) and the maximum central deflection would be 0.0013 cm. and thus the measurement of soil deformation is not disturbed by the deflection of the beam. In order to increase the output and at the same time to provide builtin temperature compensation, two strain gauges were fixed side by side at the centre on the tension side, and two at 1/4th span on the compression side, and they were connected to form a four-arm bridge circuit. EA-09-250B6-120 strain gauges, manufactured by M/S Micro Measurement (U.S.A.) were used for long term stability and they were cemented to the beam by type R.T.C. Epoxy adhesive after adequate surface preparation. Short lengths of 4-cored, teflon coated lead wires were connected to the strain gauges through terminal strips and they were taken out of the cell through a gland at the top, which was made completely watertight by an 'araldite' fillet. Suitable lengths of 4-cored shielded wires were then soldered to these short lead wires and the shield was connected to the body of the cell. The strain gauges and the terminal strips were made completely water proof by a thick coating of 'Gage Kote No. 5', manufactured by W.T. Beam Inc. (U.S.A). The resistance to body under a cell pressure af 7 Kg/cm^2 were more than 10 Megohms.

Calibration of Transducer

The calibration was done by loading the beam with dead weights in an anisotropic consolidation frame (Gangopadhyay, 1970). Figure 3 shows the mean calibration curve for loading and unloading. No significant difference between the loading and unloading was noticed upto the design load of 35 Kg. The calibration with a strain measuring bridge type RZ 003, manufactured by ORION-EMG (Hungary), showed that 1 Kg is equivalent to 72 micro strain. Since the readability of the measuring bridge is 10 microstrain (5 microstrain by estimation), the transducer may be considered to be sufficiently sensitive for testing 3.8 cm, diameter soil specimens.

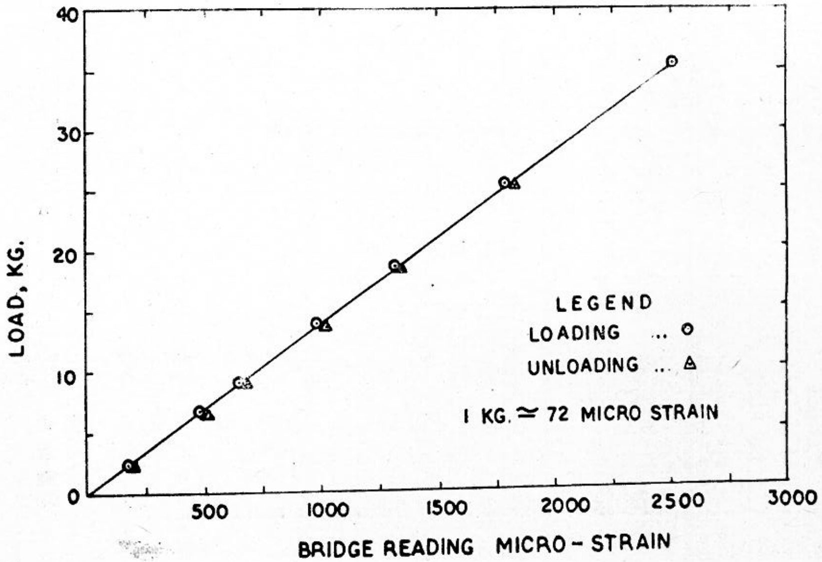

FIGURE 3. Transducer calibration curve

Performance of Transducer

The beam-type transducer, shown in Figure 1 has been used with success in several research programme carried out at Jadavpur University (Gangopadhyay, 1970; Dutta, 1971). To illustrate the performance of the transducer relative to that of proving ring outside the cell, the result of the shearing stage of our anisotropically consolidated undrained test is shown in Figure 4 and Table 1. The sample was an artificially sedimented normally consolidated Kaolinite which was consolidated to a vertical pressure of 0.453 Kg/cm² and a lateral pressure of 0.226 Kg/cm² in a tri-axial cell. The details of sample preparation and testing technique are described by Gangopadhyay (1970).

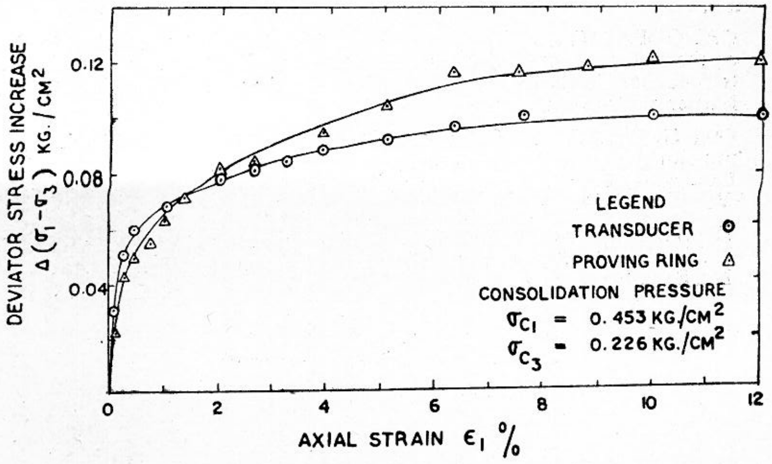

FIGURE 4. Stress-strain curve from anisotropically consolidated undrained test

It is seen from Figure 4 that the proving ring measurement is rather erratic while a very smooth and a regular curve is obtained from transducer measurement. Also data from Table 1 suggest that transducer measurement gives more consistent result. It is observed that the proving ring measurement overpredicts undrained strength by about 7% and underpredicts undrained secant modulus (at axial strain = 0.1%) by about 40%.

TABLE 1 : Comparison of Undrained Test Data from Transducer and Proving Ring Readings

Type of Measurement	Undrained Shear Strength Cu (Kg/cm^2)	Secant Modulus E at $\epsilon_1 = 0.1\%$ (Kg/cm^2)	Effective Stress Parameter ϕ'	Pore Pressure Coefficient A_f	C_u/σ_{c1}*
Transducer	0.158	35	32°	0 962	0.345
Proving ring	0.169	21.6	33°	0.778	0.374

*σ_{c1} = Major Principal stress at consolidation = 0.453 Kg/cm^2

Conclusion

It may be concluded that with the tri-axial cells presently available in India, the measurement of vertical load outside the cell may introduce serious error in testing of soft clays, which can be eliminated by using the beam-type transducer within the cell.

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