Pressure Control for Long Term Triaxial-Cell Tests

Régulation de la pression pour des essais triaxiaux de longue durée

by S. SEROTA B.Sc.(Eng.), A.C.G.I., M.I.C.E.
T. R. M. WAKELING M.Sc.(Eng.), A.M.I.C.E.
and
P. FARRINGTON D.I.C., Foundation Engineering Ltd 111, Westminster Bridge Road, London S.E.I.

Summary

The paper describes some techniques which have been developed in a commercial soil mechanics laboratory where it is necessary to carry out pore water pressure testing on a large scale in a routine fashion. The apparatus and procedure developed by BISHOP and HENKEL, at Imperial College have been used with the exception of their system for controlling water pressures. The authors' system uses compressed air which is controlled by commercial regulating valves and applied to air-water syphons. A number of tests for which this system is particularly suitable are described.

Sommaire

Dans ce rapport les auteurs décrivent certaines techniques étudiées dans un laboratoire de mécanique des sols à caractère commercial, où l'on a à faire en série des mesures de pression interstitielle. Ils utilisent les appareils et les méthodes mises au point par BISHOP et HENKEL à l'Imperial College à l'exception des dispositifs de mesure de la pression de l'eau. Pour cela ils emploient de l'air comprimé contrôlé par des vannes d'un type courant et agissant sur des siphons air-eau. Ils décrivent un certain nombre d'essais auxquels cette technique convient particulièrement.

Introduction

In recent years the measurement of pore-water pressures both in the laboratory and the field has become increasingly important. No important earthworks can be properly designed without it. Therefore, the authors, charged with the job of setting up a new commercial soils laboratory in London, decided to equip it to carry out pore-water pressure testing on a large scale in a routine fashion.

It was decided to adopt the apparatus and procedures described by BISHOP and HENKEL [1] of Imperial College but alternative methods to their's for pressure-control had to be devised. At Imperial College pressures are controlled by using spring-compensated mercury manometers, which require a good deal of wall-space and are somewhat cumbersome to use. Furthermore, they suffer from the disadvantage that every so often an accident occurs which broadcasts mercury around the laboratory.

This paper describes the alternative system of pressure control adopted by the authors in which the water-pressures are maintained by controlled air-pressures applied to water syphons. The system is very compact, reliable and convenient. Its salient features are :

(1) The apparatus can sustain comparatively large leakages without affecting the applied pressures. This is very useful in long term tests.

(2) It can supply *flows* of water at any desired constant pressure. This is particularly useful in high-pressure permeability tests.

(3) All pressure gauges are permanently connected to a mercury manometer so that any or all of them can be calibrated in a few minutes.

(4) The system, being dependant upon a compressed air supply is fitted with twin compressors, one taking over if the other fails. In four years of operation this has worked without hitch and virtually without stopping.

(5) Air pressures are controlled by commercial, but very accurate regulators which maintain constant pressures within a variation of about 0·1 lbs. per sq. in.

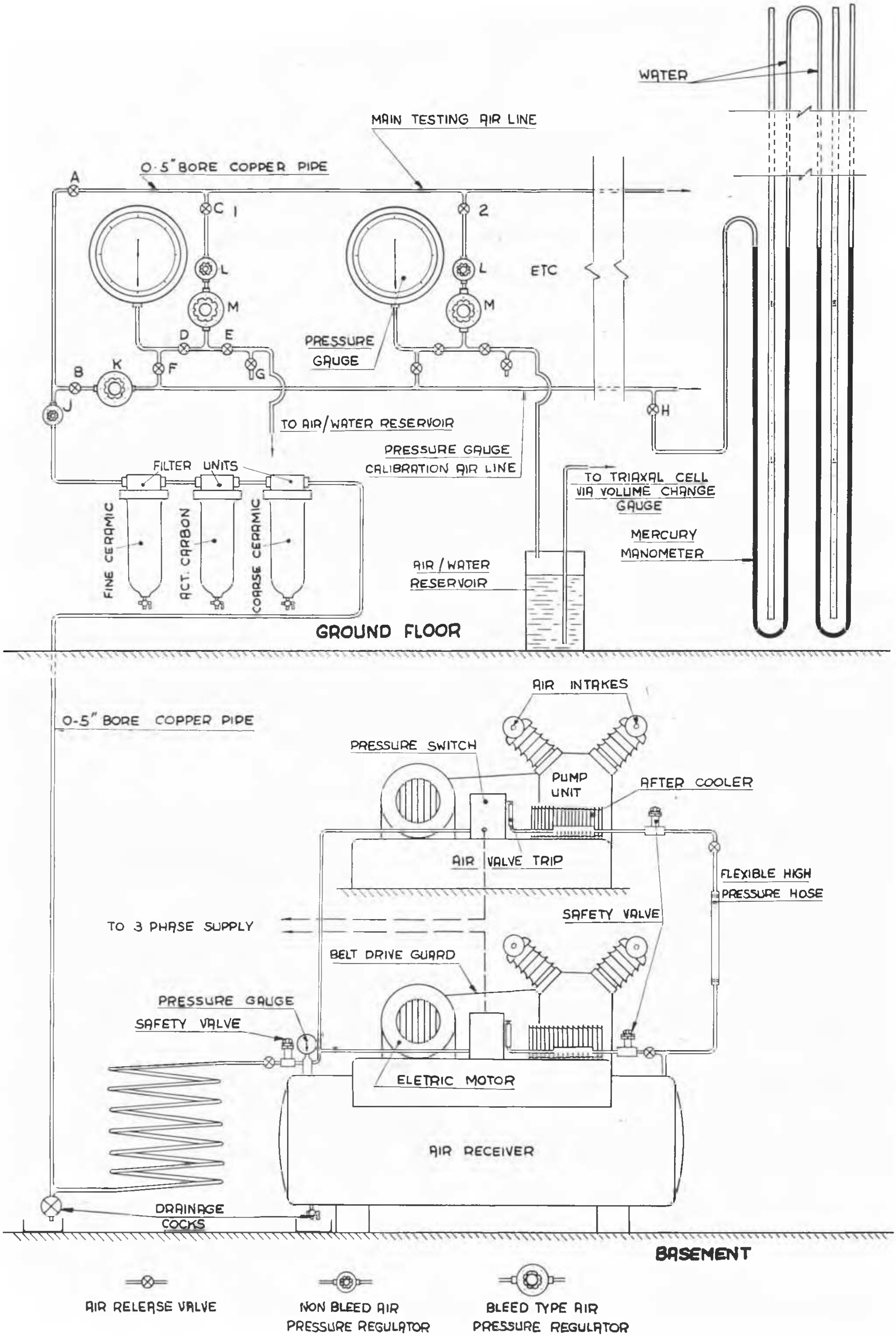
(6) The de-aired water in the triaxial cell is solated from the water in the syphon, which contains dissolved air, by a manometer which is also used for measuring volume changes during test.

Général Layout

Fig. 1 shows diagramatically the general arrangement of the equipment for maintaining constant pressure up to 150 lbs. per sq. in. and also the system for making check calibrations of the Bourdon pressure gauges. The individual components are as follows :

(a) *Air Compressors*—A pair of identical electrically driven compressors each of 7 cub. ft. per min. displacement supply air to a common receiver of 6 ¼ cub. ft. capacity. The normal running compressor is set to work between 200 and 170 lbs. per sq. in. and the second unit acts as a stand-by only coming into use should the first machine fail. In the event of an electrical supply failure affecting both compressors, the air receiver will generally maintain the air supply for about a quarter of an hour. In this respect it is important to ensure that the electrical switch gear is of a type which will automatically re-engage when the electricity supply is restored. This system has given adequate maintenance against electricity failure in London, but if failures of longer duration are likely a compressed air cylinder controlled by an automatic regulator can be inserted.

(b) *Air Cleaning*—The functioning of the pressure regulating valves is seriously upset by particles of oil or dust in the air stream, and it is necessary to interpose an efficient air cleaning system between them and the compressors. This


WATER
MAIN TESTING AIR LINE
0·5" BORE COPPER PIPE
A
C 1
2
L
M
ETC
D
E
B
K
F
G
J
H
PRESSURE GAUGE
TO AIR/WATER RESERVOIR
PRESSURE GAUGE CALIBRATION AIR LINE
FILTER UNITS
TO TRIAXAL CELL VIA VOLUME CHANGE GAUGE
FINE CERAMIC
ACT. CARBON
COARSE CERAMIC
MERCURY MANOMETER
AIR / WATER RESERVOIR
GROUND FLOOR
AIR INTAKES
0-5" BORE COPPER PIPE
PRESSURE SWITCH
PUMP UNIT
AFTER COOLER
AIR VALVE TRIP
FLEXIBLE HIGH PRESSURE HOSE
TO 3 PHASE SUPPLY
SAFETY VALVE
BELT DRIVE GUARD
PRESSURE GAUGE
SAFETY VALVE
ELETRIC MOTOR
AIR RECEIVER
DRAINAGE COCKS
BASEMENT
AIR RELEASE VALVE
NON BLEED AIR PRESSURE REGULATOR
BLEED TYPE AIR PRESSURE REGULATOR

comprises a condenser coil and length of vertical rising main which effectively removes the major proportion of oil and water, followed by three filter units, two having ceramic elements and one a carbon element.

(c) *Constant Pressure System*—The characteristics of a large number of commercially available pressure regulators were studied and eventually one was found with the required accuracy and reliability. This is of the "bleed" type in which a small pilot jet is used to control the operation of the valve. The amount of air being bled off through the pilot jet increases with the pressure difference across the valve and in order to minimise air losses, the regulator is worked in series with a less accurate non-bleed spring controlled regulator. The non-bleed regulator has an accuracy of about + or — 2 lbs. per sq. in. and is set about 10 lbs. per sq. in above the required pressure, the difference being controlled by the sensitive regulator.

In the laboratory, the fluctuating output from the conpressors is controlled at approximately 160 lbs. per sq. in by a coarse non-bleed regulator "J" set immediately downstream of the filters. From here, stop valve "A" leads to a supply main which extends the full length of the laboratory. At each constant pressure outlet, stop valve "*C*" leads to the coarse and fine regulator valves "*L*" and "*M*" followed by stop valves "*D*" and "*E*" which connect to the pressure gauge and air water reservoir respectively. "*G*" is a release valve exhausting to atmosphere.

(d) *Gauge Calibration*—Stop valve "*B*" leads through a sensitive "bleed" type regulator "*K*" to a second supply main extending through the laboratory. Each pressure gauge can be connected to this main by closing the respective valve "*D*" and opening "*F*". A calibration pressure is selected by the sensitive regulator "*K*" and is measured on the multiple mercury manometer connected into the system via valve "*H*". It is then a matter of simple routine to check simultaneously the calibration of all gauges in the laboratory.

Test Procedures

It is not proposed to describe routine procedures which are equally capable of being executed by normal laboratory systems but to confine this section to descriptions of tests in which the use of this apparatus is particularly suitable.

(1) *Permeability Tests*—The triaxial cell is one of the most convenient means of carrying out constant head permeability tests. Water from one constant pressure supply is passed through the sample and the lateral pressure in the triaxial cell is made high enough to keep the rubber membrane tight against the samples so that surface leakage of the permeating water is prevented. If it is so desired, the permeability test can be carried at an elevated pore-water pressure either for the purpose of reproducing conditions deep within an earth dam or to saturate the sample by causing all the air to pass into solution. For this test constant pressure water supplies from syphons are applied to the ends of the sample, a pressure difference being maintained to induce the flow, and a third higher pressure is applied to the cell. The quantity of water flowing through the sample is measured by a volume gauge. Saturation has been attained when further increase in the pressures produces no corresponding increase in the coefficient of permeabiliy.

These tests can be carried out with controlled flows of water at pressures approaching 150 lbs. per sq. in. By any method other than using syphons regulated by controlled air pressure, this test would be exceedingly cumbersome.

(2) *Tests involving consolidation under conditions of water-seepage*—When testing samples of filling material for an earth dam it is necessary to reproduce the conditions which will prevail after the dam comes into use. These generally entail the soil consolidating under seepage conditions and eventually becoming fully saturated. In the authors' laboratory these two conditions can be reproduced very easily. For the seepage conditions the cell pressure will represent the overburden pressure and water can be passed through the sample at the relevant mean pore-water pressure. In most cases the sample is considered to have attained equilibrium when volume changes cease.

The saturated condition is attained by raising the pore-water pressure until all the air in the soil voids passes into solution. A constant water pressure is applied to the top of the test specimen while at the same time, the cell pressure is maintained at a slightly higher value in order to preserve the water-tightness of the rubber membrane. Pore water pressure measuring equipment is connected to the other end of the test specimen. At various stages during the elevation of the pore-water pressure, the connection at the top of the test specimen is closed and the pore pressure response, to a change of cell pressure is measured. When the change in pore pressure becomes equal to the change in cell pressure then the sample is saturated.

Where it is necessary to consolidate the soil in the saturated condition, the consolidation pressure is applied in excess of the datum represented by the pore pressure necessary for saturation, and the excess pore pressure is allowed to dissipate down to this datum. It has been found that compacted clay samples become saturated at pore pressures of 60 to 90 lbs. per sq. in. and this was one reason for selecting the maximum safe pressure that the triaxial cells can withstand, namely 150 lbs. per sq. in., as the upper limit for the constant pressure system.

Acknowledgments

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Reference

[1] Bishop and Henkel (1957). The Measurement of Soil Properties in the Triaxial Test, London.