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Indian Standard

METHOD FOR MEASUREMENT OF EARTH PRESSURE BY HYDRAULIC PRESSURE CELL

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

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Indian Standard

METHOD FOR MEASUREMENT OF EARTH PRESSURE BY HYDRAULIC PRESSURE CELL

0. FOREWORD

0.1 This Indian Standard was adopted by the Bureau of Indian Standards on 26 August 1987, after the draft finalized by the Foundation Engineering Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 Total pressure at the foundation of earth fill dams and embankments as well as earth pressure on retaining walls are required to be monitored to evaluate their post construction behaviour and taking timely remedial measures for the structures showing distress.

0.3 Different types of earth pressure cells are used for the measurement of such *in-situ* stress. They are generally of two types:

a) Flexible diaphragm type, and

b) Stiff cylinder type.

The flexible diaphragm type cell consist of a flexible circular or rectangular diaphragm attached to a rigid stiff case where the pressure is measured due to continuous displaced shape of the flexible diaphragm, whereas in the second type, the axial compression of the stiff prismatic element, usually enclosed within a case to isolate it from the lateral stresses of the surrounding soil mass is used to sense the total pressure.

0.4 Some of the other systems adopted for measuring earth pressure are:

i) Electrical resistance strain gauge,

ii) Semiconductor strain gauge,

iii) Vibrating wire system,

iv) Closed fluid system (usually called Gloetz or hydraulic pressure cell), and

v) Pneumatic system where air pressure is used to balance the stress on the cell.

0.5 Out of the above systems, the strain gauge type, vibrating wire type, and the closed fluid system, that is, the hydraulic pressure cell are the most accurate and are most commonly used. Resistance strain gauge types are easy to use and have linear rapid response. But they are susceptible to damage and are affected by the moisture of the fill material in long use. Vibrating wire type are more durable but have non-linear response. More rugged and durable are closed fluid systems or hydraulic pressure cells which are universally adopted for measuring the earth pressure. This Indian Standard covers the use of such type of pressure cell.

0.6 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

*Rules for rounding off numerical values (*revised*).

1. SCOPE

1.1 This code deals with measuring the total pressure in earthfills, dams, embankment as well as pressures on the surface of retaining walls, bridge abutments, etc, by using the technique of balancing the fluid pressure in the cell by a pressure applied to the reverse side of the transducer diaphragm. The same method may also be utilized with slight modification for measuring the magnitude of stresses on tunnel linings rock and concrete masses and other structures inclusive of hydraulic ones.

2. TERMINOLOGY

2.0 For the purpose of this standard, the following definitions shall apply.

2.1 Total Pressure — Total pressure at a given location is the sum of effective soil pressure and pressure due to ground water or air pressure.

2.2 Pressure Change — Pressure change is the difference between total pressure at any given time and the total pressure value at the time of cell installation.

2.3 Balancing Pressure — It is the pressure applied to the reverse side of the transducer diaphragm to balance the fluid pressure built up in the cell.

2.4 Cell Fluid — Hydraulic fluid used for filling the cell.

2.5 Measuring Fluid — Hydraulic fluid used in transducer and read out unit.

3. EQUIPMENT

3.1 It consists of (a) pressure cell, (b) fluid reservoir, (c) a pump with pressure gauge to measure the applied pressure, and (d) a detector to indicate the fluid return from the cell.

3.1.1 The pressure sensor consists of a flat jack of suitable size filled with hydraulic fluid and connected to the pressure measuring transducer. The flat jack is usually made from two flat sheets of steel, welded around the periphery. They can be circular or rectangular in plan, its size depending upon the measuring location. The choice of cell fluid depends on actual requirements. Liquid of low viscosity is usually used for higher pressure and also for long delivery lines.

3.1.2 The pump should be capable of applying a pressure at least 20 percent in excess of the maximum pressure to be measured. It should be able to increase/decrease the pressure gradually and to hold up the pressure for several minutes as per the requirements.

3.1.3 The return flow indicator system should be capable to detect a flow of less than 10 percent of the maximum flow possible through the cell transducer and tubing and a measuring accuracy better than $\pm$ 2 percent of the measured pressure throughout the range.

4. SELECTION OF PRESSURE CELL

4.1 The stiffness of the cell should be similar to that of the material in which it is to be embedded to ensure smooth stress transfer. The gap between the plates forming the cell should not exceed 1 mm, and the ratio of the cell diameter/side length to the cell thickness should be greater than 20 : 1.

4.2 The material of the cell, transducer, and all ancillary components, should be so selected as to resist corrosion due to surrounding materials, ground water, cell fluid and measuring fluid.

4.3 The design and material of the transducer should be such as to ensure minimum diaphragm inertia so that the pressure in the measuring fluid corresponds closely with that in the cell fluid at the time of balancing.

5. CALIBRATION OF EQUIPMENT

5.1 The cell should be checked in a compression testing machine for its range, to determine the edge-effects and to evaluate proper correction factor. The equipment needs to be calibrated for temperature effects at the cell location.

5.2 The complete assembly should be checked to determine diaphragm inertia and the effects of delay between pumping and fluid return.

5.3 The read out pressure gauges should be calibrated using a standard dead weight pressure gauge tester.

6. ACCURACY

6.1 Overall accuracy requirements should be specified. Generally, it should be better than $\pm$ 5 percent of the pressure to be measured, inclusive of the combined effects of inaccuracies due to lag, temperatures, tube pressure losses and gauge calibration errors.

7. INSTALLATION

7.1 Selection of Locations

7.1.1 Cells are generally installed in pairs or clusters to measure pressure in different directions at the same location. Adjacent cells should be separated by a distance of at least 1 cell diameter in such a way as to prevent the presence of a cell affecting readings on adjacent cells.

7.1.2 The distribution of the cells should be such that each cell should represent a particular type of material.

7.1.3 The cell should be in complete contact with the surrounding material which should not have any protrusions or non-uniform material that may result in stress irregularities on the cell.

7.1.4 The cells should not be installed in locations exposed to appreciable temperature changes due to exposure to direct sunlight or cold wind. They might have to be insulated in such cases.

7.2 Installation in Soils

7.2.1 When the cells are to be installed in natural soil or fill embankment, an overall excavation of stabled slopes and of sufficient dimensions is to be made to accommodate the cell cluster. Then individual pockets, each being of size approximately twice that of the cell to be installed, are hand dug at the correct locations and at correct inclination taking utmost care not to disturb the surrounding soil strata.

7.2.2 Rock fragments greater than 1/10 cell diameter or size, except in cases of rock fill embankments, are to be removed and replaced by fine grained material, and compacted into the voids. The cells are then fixed in position, taking care to see that they are fully in contact with the underlying material. Each pocket is then back filled with fine grained material, hand compacted to a density similar to that of the original fill.

7.2.3 In case of rock fill embankment, the pocket should be larger and the pocket back fill should be graded, with the finer material placed adjacent to the cell and the coarser adjacent to the embankment.

7.2.4 The cluster excavation is then back filled and compacted with natural embankment material, having removed the big rock fragments. Three layers of 10-20 cm each, should first be placed and hand compacted before completing the back fill with light mechanical equipment. No heavy vibratory rollers should be used until at least 2 m of fill has been placed on the cells through controlled compaction.

7.3 Installation at the Interface Between Soil and Concrete or Rock

7.3.1 When placing cell adjacent to piers, piles, retaining walls, culverts and other structures, the cells may either be attached to the form and placed in the structure, or fastened to the structures, prior to the back filling, or embedded in the back fill, a short distance away from the structure. The contact between the cell and the back fill material should be effected by means of a layer of fine grained material as indicated in 7.2.2.

8. CONNECTING, FILLING AND CHECKING THE CELLS

8.1 Connection

8.1.1 The terminal equipment is to be fixed securely, either nearer to the cells on a wall or remote from them in an instrument house. The terminal panels should be prechecked for proper functioning of the valves and for leakage in the system.

8.1.2 The labelled tubing is to be connected to the appropriate terminals and secured in place. A test should be made on each cell while accessible, for repair and replacement to ensure proper functioning of the completed hydraulic system.

8.2 Filling

8.2.1 The cells, with liquid as measuring medium, may be filled with the measuring fluid by the read out unit pump but usually, it is more convenient to fill them by gravity from a fluid reservoir. While filling the system, care should be taken to see that the delivery tubes are also completely filled up. Bleed points should be provided at positions where air entrapment is likely.

8.3 Checking

8.3.1 Each connecting tube in the systems should be temporarily disconnected from the cell and the complete system tested to a pressure of at least 120 percent of the anticipated maximum use, reconnected, refilled and checked for leakage along all the tube lengths.

8.3.2 After installation of the cells and back filling, the cell pressures should again be recorded and back pressured to ensure a small positive reading after compensation and for the fall in pressure or any negativc pressure developed during installation.

9. PROCEDURE FOR TAKING READINGS

9.1 After proper calibration and functional checking of the read out unit, it is connected to the cell delivery and return tubes, taking care to avoid entrapment of air in the delivery tube.

9.2 The supply pressure is increased gradually until a return flow is recorded. The return flow should be maintained for a period of at least 4 minutes to ensure removal of air bubbles and to establish steady conditions. An approximate reading of the delivery pressure is then noted.

9.3 The pressure is released and again increased at a very slow and constant rate (usually 3-4 cm^3/min until return flow is observed, which is noted. There is usually a characteristic peak in the pressure flow curve due to the inertia of the diaphragm valve. This should be ignored and the steady pressure taken as the reading.

9.4 Further, readings are taken and recorded until a consistent reading, P_r, is established which would be the average of a minimum of three readings.

9.5 Delivery line pressures should preferably be maintained between the readings, at a level that will avoid the entry of air, yet well below the long term burst pressure of the tubing.

9.6 The procedure is repeated for all other cells whose readings are required to be taken.

10. CALCULATIONS

a) The cell pressure, P, is estimated from the reading, P_r, by applying the corrections as follows:

$$P = (P_r - P_i - P_h - P_f) \times E$$

where

P_r = pressure reading,

P_i = initial cell pressure applied during first installation, and/or other factors subsequently adjusted by compensation for shrinkage,

P_h = static head correction for the pressure due to difference in between the cell and read out unit (liquid only; for gas $P_h = 0$),

P_f = correction for frictional losses in the fluid delivery line, and

E = multiplying factor (less than 1·0) to compensate for edge effect of the cell

b) In most applications, only changes in pressure are of interest. In most cases, an initial readings, P_i, is taken after completion of the installation and it includes the effect of P_h and P_f which remains constant for a particular set of cells. In these cases,

$$P = (P_r - P_l) \times E$$

c) The elevation correction, P_h may be calculated as follows:

$$P_h = r(h_1 - h_2)$$

where

r = unit weight of measuring fluid, g/cm^3 (for gas, this unit weight is zero), and

$h_1 - h_2$ = difference in elevation (cm) between read out unit and cell (positive when the cell is below the read out unit).

P_h is then obtained in g/cm^2 and can be converted to P_a by multiplying by 0·098 1.

d) The tube friction correction P_f should be measured during installation, before connecting the cell, and is the pressure required to maintain a steady flow through the tubing at a flow rate similar to that obtained during measurement. Under normal conditions, with unobstructed and correctly selected tubing, this correction should be small.

e) The edge effect correction, E, should be established on the basis of control tests in a compression machine.

f) In addition, a temperature correction may be required in some specialized applications. The correction P_t to be subtracted from the readings may be expressed as

$$P_t = K_t(t_r - t_1)$$

where

$(t_r - t_1)$ is the temperature increase (°C) from the time of the initial reading P_1 and K_t is a coefficient expressing the response of the system (cell, fluid and surrounding material) to temperature. The actual value of K_t will depend on the size of the cell.

11. REPORT

11.1 Result should be presented in two forms of reports:

a) Installation report, detailing basic data on the instrumentation system at the time of installation, and

b) Monitoring report, submitted periodically, giving the results of routine observations.

Frequent monitoring report is very essential to minimize delay between the detection of adverse behaviour and the remedial measures that may be necessary.

11.1.1 Installation Report — Installation report should include the following:

a) A description and diagram of the monitoring equipment installed, including their detailed performance, specifications and manufacturer's literature;

b) A location plan showing details of the pressure cell location, details of methods used for installation, calibration and monitoring;

c) A location plan showing details of the pressure cell locations with respect to the structural configuration and the surrounding soil, rock or concrete conditions; and

d) For each cell, a report giving the initial installation pressure and wherever applicable, the pressure after compensation for shrinkage. Details of calibrations and correction factors should be included, alongwith details of any problems. encountered during installation of each cell.

11.1.2 Monitoring Reports — Monitoring Reports should include the following:

a) An up-to-date field data sheet with results and graphs;

b) A brief commentary, drawing attention to significant pressure changes and all instrument malfunctions occurring since the preceding report; and

c) The result of any calibration or checking of instruments carried out since the preceding report.

12. PRECAUTIONS

12.1 Edge effects occur due to the presence of the weld around the circumference/periphery of the cell. They are greatest when the cell is small and rigidly constructed. The thickness of flange around the cell periphery partially affects the transfer of stresses to the cell from the surrounding material. Edge effect is difficult to estimate but may be determined experimentally by embedding the cell in a large block and then subjecting it to uniaxial compressive stress under controlled laboratory conditions.

12.2 The most reliable method for temperature correction is to provide an additional cell that is exposed to the ambient temperature at the location, but not subjected to any pressure. Any pressure increase/decrease noted in this control cell due to temperature variation, may then be deducted from the pressure indicated by the adjacent cells installed in the structure.

12.3 Various other sources of error are due to (a) inadequate matching of the cell and surrounding material stiffness, (b) placing the cell at an unrepresentative location in the structure, and (c) installation of an inadequate sized cell which can be avoided by proper planning of the instrumentation programme before the start of the work.

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BUREAU OF INDIAN STANDARDS

Headquarters:

Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110002
Telephones : 323 01 31, 323 94 02, 323 33 75

Telegrams: Manaksanstha (Common to all offices)

Regional Offices:	Telephone
Central : Manak Bhavan, 9 Bahadur Shah Zafar Marg NEW DELHI 110002	323 76 17 323 38 41
Eastern : 1/14 C. I. T. Scheme VII M, V. I. P. Road, Maniktola CALCUTTA 700054	337 84 99, 337 85 61 337 86 26, 337 86 62
Northern : SCO 335-336, Sector 34-A, CHANDIGARH 160022	60 38 43 60 20 25
Southern : C. I. T. Campus, IV Cross Road, CHENNAI 600113	235 02 16, 235 04 42 235 15 19, 235 23 15
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