Earth Pressure and Friction Cells for Laboratory and Field Observations

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Introduction

Laboratory models and a field model of well fundation were proposed to be tested under combined action of vertical and horizontal loads. Observations of distribution of pressure and friction on faces and base of these well models were planned so as to obtain an insight into the nature of normal and frictional forces which affect the behaviour of a well foundation. Since a well model is comparatively a rigid structure, direct method of measuring the soil reaction was employed by using boundary earth-pressure cells. Friction cell was used for observing frictional forces. These transducers were designed and fabricated in the laboratory.

A transducer which could measure normal pressure and friction at the same point (Arthur and Roscoe 1961) would have been ideal but it was not found feasible under the prevailing conditions.

Boundary Earth Pressure Cells for Use in Labortrory Models

Choice of Cell

A deflecting diaphragm type earth-pressure cell was chosen due to its simple design and construction and convenience of use in well models. The primary requirement of a cell for measuring pressure in granular materials is to produce a system that gives linear calibration characteristic so that any departure from linearity should be associated with stress distribution within the sand material. It has been shown by Trollope and Currie (1960), that if the ratio of the central deflection to the diameter of the diaphragm of the cell is restricted to less than 1 : 2000, a reasonable linear calibration curve may be obtained. For deflection ratios in excess of this amount, the calibration takes the form of a convex curve owing to the the effect of arching in the sand material over the diaphragm. It was therefore decided to design the cells with deflection to diameter ratio of 1 : 2000 at maximum pressure.

It was desirable to use a cell of small diameter in order not to alter the characteristics of the face of model in which it was used. The base of smallest well model was of square crose-section with 15 cm size. The 15 cm wide faces, a small cell with 3 cm diameter was possible with a 1.8 cm

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diaphragm. The diaphragm size of 1.8 cm diameter was decided since it would accommodate two resistance type electric strain gauges for working of cell with a half bridge. The smallest available gauges were Rohit KWR-1A having Resistance = 120 Ohms, Gauge factor = 2.8 ± 1 per cent, Grid size = 1.5 mm × 0.5 mm, and Base size = 8 mm × 4mm.

Range of Pressures

In designing a cell, the range of pressure must be known (WES 1955). In the present case, pressures were required to be measured on the faces and base of a 15 cm square model embedded in dense sand with maximum depth to width ratio, D/B, equal to 2. For 20 cm square model the maximum D/B ratio was 1.5. Both models were thus to be embedded upto a depth of 30 cm. The models were to be treated as prototype wells and were to be tested under vertical and lateral loads.

Current design practice for a field well (IRC 1971) subjected to combined action of vertical and lateral loads provides that the maximum pressure at the toe should not exceed the allowable bearing capacity of soil. It was thought proper to apply the same condition in model testing also in order to simulate the behaviour of large field wells. Dense sand which was chosen as the soil medium for testing, had an ultimate bearing capacity of about 8 kg/cm^2 and the safe vertical load that could be applied on this sand was about 4 kg/cm^2, because beyond this load the sand near the edge of the base could have a tendency to go plastic due to parabolic distribution of pressure caused by a rigid base on elastic soil. Moreover, if besides the vertical loading, the foundation was made to tilt, the edge pressure would be higher thereby increasing the chances of plastic failure. It was decided to keep a safety of 3 on 4 kg/cm^2 for tilted well. This provided a safe bearing pressure of about 1·5 kg/cm^2 at the edges. Since the cells could not have been fixed at the edge itself but would be sufficiently inside the edge due to its size, a maximum pressure of 0.1 kg/cm^2 was adopted for design of base pressure cells.

The design pressure for the face cells was fixed in the following manner. It was decided that the lateral loads and tilts would be kept below those required for ultimate failure in the horizontal direction, and a factor of safety of 3 with respect to the ultimate pressures on face was used as for the base.

Assuming the well to rotate about the base the maximum passive pressure at failure would occur at about mid-height as in case of rigid bulkheads (Terzaghi 1943). In these case the maximum passive pressure, p_{max}' would occur at the depth z equal to about 15 cm and its magnitude would be

$$P_{max} = K_p \, \gamma \, z \qquad \ldots(1)$$

where K_p = coefficient of passive earth pressure and γ = unit weight of sand. Assuming the unit weight of dense sand as 1.65 g/cm^3, the angle of internal friction $\Phi = 40°$ and the angle of wall friction $\delta = \Phi/2$, K_p was calculated as 10.38 from tables of passive earth-pressure values (Singh 1967). Thus P_{max} = 0.341 kg/cm^2. Using a factor of safety of 3, the design pressure worked out as 0.114 kg/cm. A maximum value of 0.14 kg/cm^2 was therefore adopted.

Design Data

For the purpose of design, diaphragm was treated as a thick circular plate fixed at its perimeter and subjected to a uniform surface load (WES 1955).

The following data were used in designing the thickness of diaphram and working out the sensitivity of the transducer.

(*i*) Design pressure (P_{max}) for (*a*) face cells $= 0.15$ kg/cm^2

(*b*) base cells $= 0.1$ kg/cm^2

(*ii*) Ratio of deflection of centre to diameter under P_{max} $= 1/2000$

(*iii*) Radius of diaphragm '*a*' $= 0.9$ cm

(*iv*) Young's Modulus of diaphragm material '*E*' (Berrylium copper) $= 1.34 \times 10^6$ kg/cm^2

(*v*) Poisson's ratio of diaphragm material (ν) (Hetenyi, 1960) $= 0.355$

(*iv*) Length of grid of strain gauge $= 1.5$ mm

(*vii*) Sensitivity of strain recording instrument $= 1\ \mu$—strain

Thickness of Diaphragm

Maximum deflection w_{max} of the centre of the diaphragm due to a uniform pressure p_{max} when treated as a thin circular plate fixed at its perimeter is given by (Timoshenko and Woinowsky-Krieger 1959).

$$w_{max} = \frac{3}{16} \frac{p_{max}\, a^4\, (1-\nu^2)}{Et^3} \qquad \ldots (2)$$

where t is the thickness of diaphragm. Using deflection to diameter ratio adopted for maximum pressure 1 in 2000, w_{max} will be limited to $1.8/2000 = 0.9 \times 10^{-3}$ cm.

For the pressure cells for well faces, p_{max} was 0.14 Kg/cm^2. Using the various data in Equation 2 thickness of the diaphragm should be .0233 cm or more. A diaphram thickness of 0.23 mm was adopted. Similarly for the pressure cell as base of well using $p_{max} = 0.8$ kg/cm^2, the required thickness works out as 0.0414 cm. A diaphragm thickness of 0.42 mm was adopted.

Sensitivity of the Cells

Sensitivity of cells can be worked out if the positioning of the gauges on the diaphram and the sensitivity of the strain recording instrument is known. The positioning of the gauges is shown in Figure 1(*a*). One gauge is placed on the centre of the diaphragm and the other at a distance of about 0.75 mm from it. The strain output can be worked as follows :

The general equation of radial strain (ϵ_{a_1}) produced at any radial distance 'a_1' from the centre of a fixed circular plate of radius 'a' acted upon by a uniform pressure (b),

$$\epsilon_{a_1} = \frac{3}{8} \cdot \frac{pa^2(1-\nu^2)}{Et^2} \cdot \left(1 - \frac{3\,a_1^2}{a^2}\right) \quad \dots (3)$$

The radial strain curve in shown in Figure 1(b). Average strain (ϵ_{ac}) on the stratin gauge located at the centre will be

$$\epsilon_{ac} = \frac{2.98}{8} \cdot \frac{pa^1(1-\nu^2)}{E} \quad \dots (4)$$

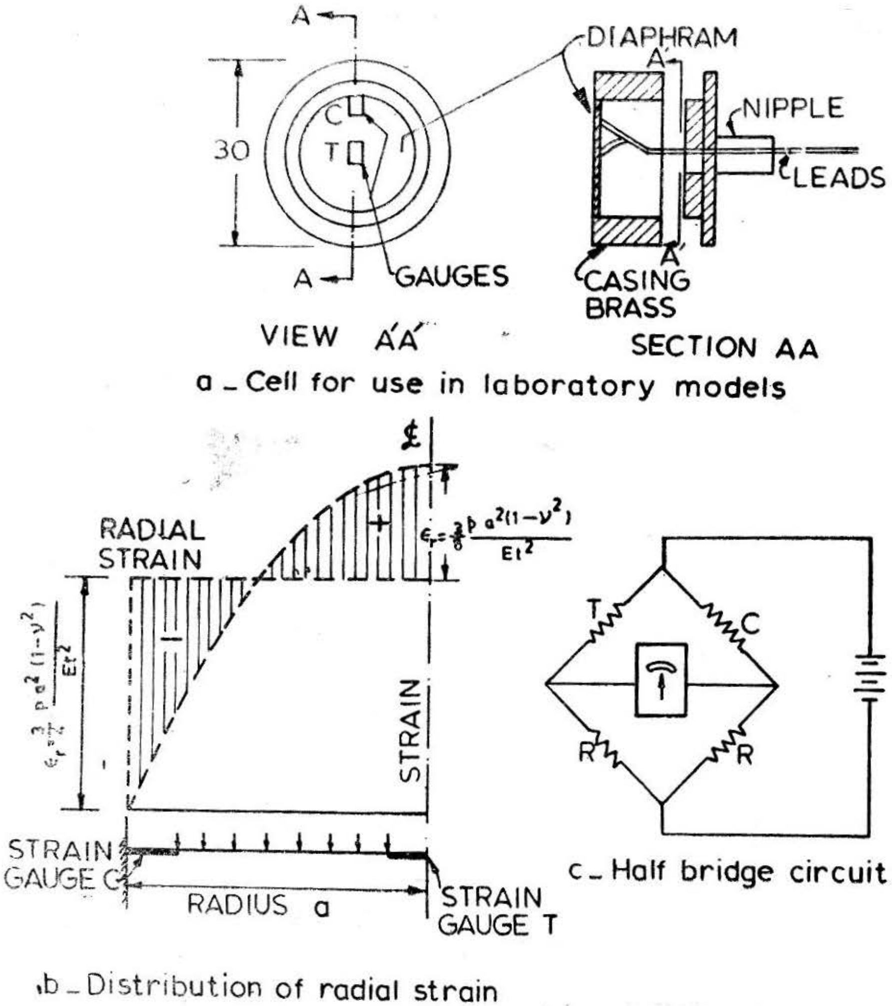


FIGURE 1 Boundary earth pressure cell

Similarly average strain (ϵ_{ae}) produced by strain gauge located near the fixed edge at a distance of 0.75 cm from centre will be

$$\epsilon_{ae} = -\frac{3.24}{8} \cdot \frac{pa^2 (1-\nu^2)}{Et^2} \qquad \dots (5)$$

In a half bridge circuit, the total strain indicated will be

$$\epsilon_{ac} + \epsilon_{ae} = \frac{6.23}{8} \cdot \frac{pa^2 (1-\nu^2)}{Et^2} \qquad \dots (6)$$

Equating this strain to the minimum recordable strain.

$$\frac{6.23}{8} \cdot \frac{p_{min}\, a^2 (1-\nu^2)}{Et^2} = 1 \times 10^{-6} \qquad \dots (7)$$

or

$$p_{min} = \frac{8\, Et^2 \times 10^{-6}}{6.23\, a^2 (1-\nu^2)} \qquad \dots (8)$$

For face pressure cells, the sensitivity is obtained as 1.37 g/cm^2 per microstrain and for the base pressure cells, it is 4.16 g/cm^2 per microstrain.

Fabrication

Figures **1** (*a*) and 2 show the details of a typical pressure cell. Circular brass casing of 3cm outer diameter and 1.8cm inner diameter was machined out of brass rod. Circular disc of 2cm outer diameter and thickness equal to that of designed diaphragm was cut out from beryllium copper sheet. The disc was carefully soldered flush with one of the faces of the casing to form a 1.8cm size diaphragm, by placing them in a peripheral slot of the same thickness and diameter as the disc. Gauges were carefully pasted with araldite and then connected in a half bridge circuit. A coating of araldite was applied over the Gauges for water proofing. The leads were taken out of a nipple provided in a threaded brass cap at the outer end of the cell casing. The leads were subsequently fixed in the nipple with araldite as a precaution against damage to the strain gauge connections due to any accidental disturbance to the leads.

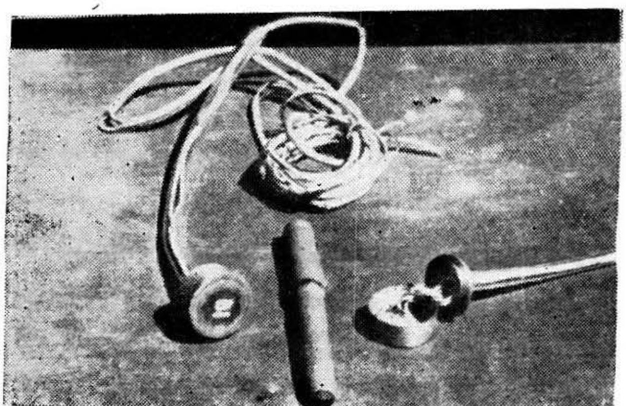


FIGURE 2 Typical pressure cell

In All, six cells were fabricated to have 0 to 0.14 kg/cm² pressure range. These are designated as cells $B-1$ to $B-6$. Two cells were prepared to have the range 0 to 0.8 kg/cm² and are designated as $C-1$ and $C-2$.

Calibration

Water pressure was used for calibrating the cells. The complete calibration assembly is shown in Figure 3. It consists of a small calibration chamber, a water pump and a pressure measuring unit. The calibration chamber shown in Figure 4 was machined out of brass rod. The base of

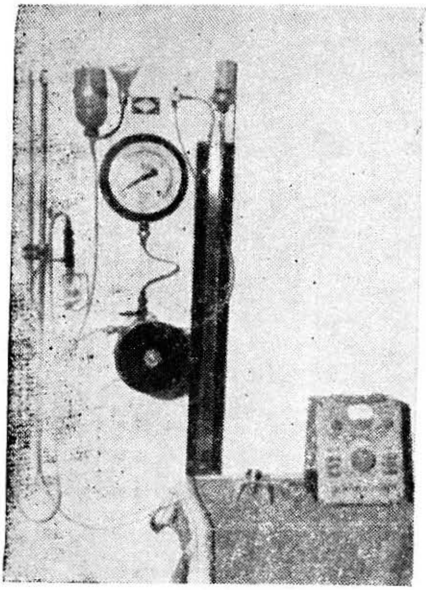


FIGURE 3 Assembly for calibration of cell

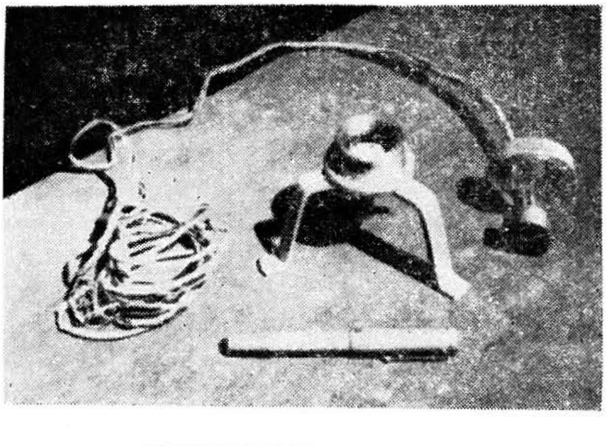


FIGURE 4 Calibration chamber

the chamber had an opening to allow water and bleeder hole to expell air. The cell could be pressed against a circular rubber seal on a peripheral offset in the chamber near its bottom with the help of a threaded cover at the top of chamber.

For calibration, the cell was put into the chamber with the lid pressing it against the rubber seal. The chamber was connected to water pump and manometer. The complete system was de-aired by operating water pump and bleeder holes in the chamber and the pore pressure apparatus. Water pressure was applied in suitable increments. Strain readings for each incremental loading and unloading of pressures were recorded by SR—4 strain indicator.

The water calibration curves for typical C—type and B—type cells are shown in Figure 5. Calibration factors for various cells are given in Table I.

Precautions were taken that no leak occurred in the calibration system during testing. Cells were subjected to a check if substained load altered the characteristics of the diaphragm. No change was discernible.

Friction Cell

Design of the Cell

The cells were designed to function in the range of 0 to 0.20 kg/cm² shear stress and to measure reversible force only in one direction. The cells worked on the principle that strains produced at fixed end of a cantilever are linearly proportional to the tangential force applied at its free end (Perry and Lissner 1962).

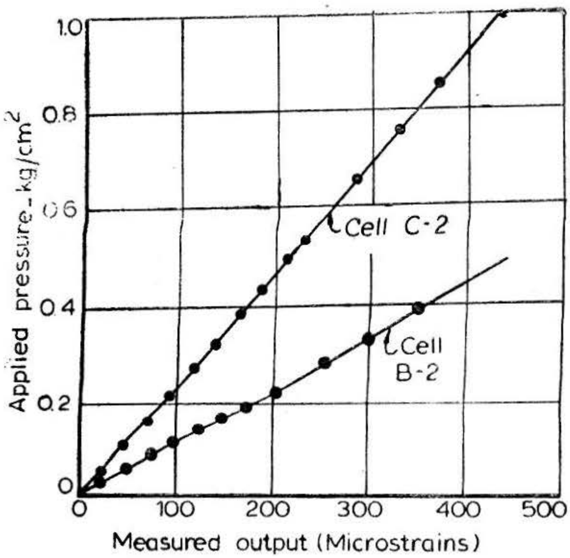


FIGURE 5 Typical calibration curve for laboratory earth—pressure cell

TABLE I

Calibration Factors for Earth Pressure and Friction Cells

Cell for laboratory model	Calibration factor kg/cm² per u strain $x\ 10^{-3}$	Cell for field model	Calibration factor kg/cm² per u strain $x\ 10^{-3}$
B—1	0.99	P—1	2.36
B—2	1.09	P—2	1.54
B—3	1.09	P—3	2 00
B—4	1.10	P—4	3.30
B—5	1.09	P—5	2.50
B—6	1.10	P—6	2.00
C—1	4.09	P—7	2.00
C—2	2.36	P—8	1.82
F—1	0.792	P—9	2.20
F—2	0.823	P—10	2.20
F—3	0.823	P—11	2.20
F—4	0.823	P—12	2.20
F—5	0.891	S—1	4.50
F—6	0.713	S—2	6.60
F—7	0.668	S—3	5.00
F—8	0.763	S—4	6.60
F—9	0.713	S—5	5.00
F—10	0.763	S—6	6.60
		S—7	5.70
		S—8	5.70
		S—9	5.50

An account of design of a cell that could measure friction was given by Arthur and Roscoe in 1961. It was suggested that for a satisfactory performance of a friction cell deflection of the free end of the cantilever should not exceed .025mm. This criteria was adopted in designing the cell.

After several trials with the size of the cell in view of the size of the model well which had a 20 cm wide face, an overall size of 47 mm $\times$ 47mm $\times$ 69 mm was finally adopted (Figure 6*a*). The cantilaver length was fixed at 55 mm. The section of cantilever was designed in the following manner.

The deflection 'W' of the free end of a cantilever of length 'L' due to a concentrated load 'T' at its end is given by

$$W = LT^3 \mid 3EI \qquad (9)$$

where I = the moment of inertia of the cross-section of the cantilever and E = modulus of elasticity of its material. Taking the design frictional stress as 0.20 kg/cm², and the area of the sensitive face as 10 cm², the maximum force at the cantilever end worked out as 2.0 kg. Making the cantilever of aluminium (Arthur and Roscoe, 1961), its $E = 7.1 \times 10^{-5}$ kg/cm². Using a width of 1.5 cm for the cantilever for accommodating two strain gauges of 7.5 mm width, taking the maximum tip deflection as

.025 mm, the depth of cantilever section is determined from Figur (9) as 0.79 cm. A cross-section of 1.5 cm × 0.8 cm was adopted.

Sensitivily of the Cell

Assuming that the cantilever in Figure 6(c) was loaded with a concentrated load 'T' at its end, the bending moment at the gauge point 'M_A' is given by

$$M_A = (L - L_g/2) \qquad \ldots(10)$$

where L_g = length of gauge.

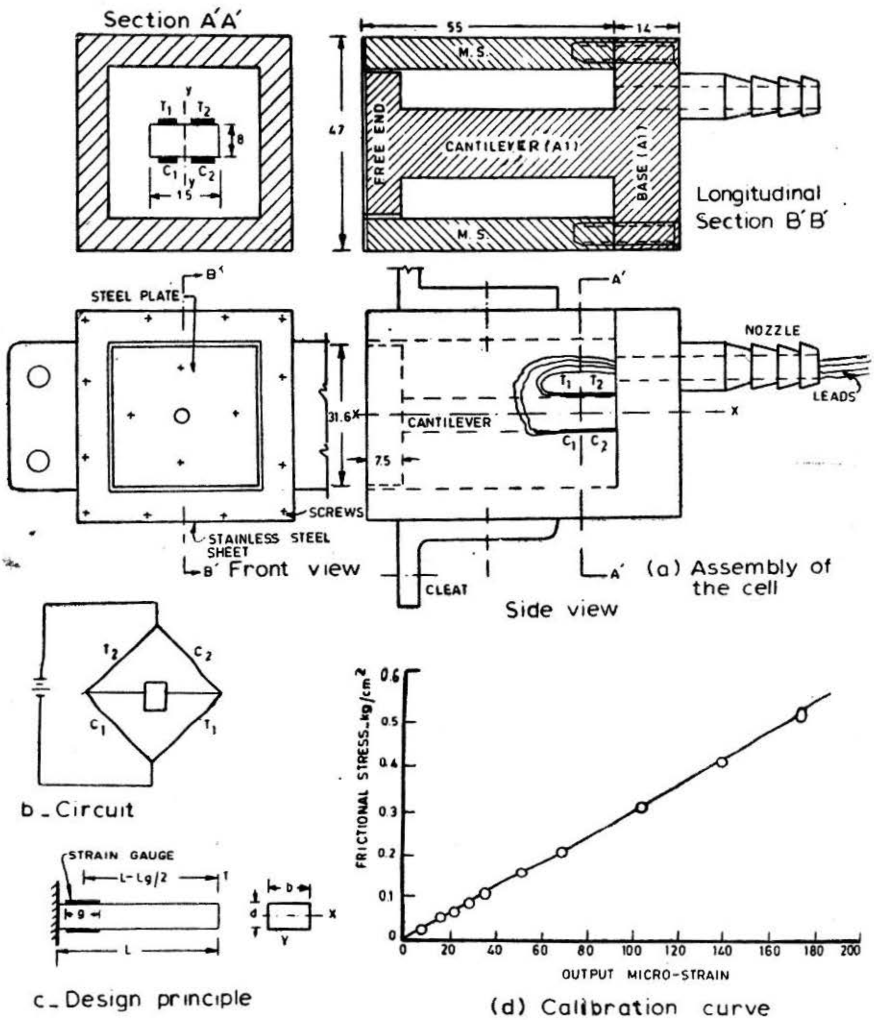


FIGURE 6 Friction cell

Strain on the top and bottom fibres of a rectangular section $b \times d$ due to M_A would be

$$\text{Strain} = \frac{6T\,(L - L_g/2)}{E.bd^2} \quad \ldots(11)$$

Substituting $L = 5.5$ cm, $L_g = 1.0$ cm, $E = 7.1 \times 10^5$ kg/cm², $b = 1.5$ cm, $d = 3.8$ cm, we get, Strain at $A = 4.4 \times 10^{-6} T$

Four strain gauges were located at postitions as shown in section at A' A' of Figure 6(*a*), Due to their connection in a full bridge circuit Figure 6 (*b*) they produce an augmental strain output equal to 4 times the strain in a single gauge. The strain measuring instrument was sensitive upto 1 microstrain. Therefore, the sensitivity would be worked out as $T_{min} = 5.68$ g or frictional stress as 568×10^{-3} kg/cm²

Fabrication

The cell shown in Figures 6 (*a*) and 7 consists of a cantilever 5.5cm long with a cross-section of 1.5cm ×0.8cm fixed to a square base of 5cm × 5cm × 1.4cm size. Its free end is made to have a square face of area 10 cm². These sizes were machined out accurately on a milling machine from a single aluminium casting. The cantilever block was encased into a hollow square shape casing such that the square face at free-end leaves an all round gap of 1mm width within the inner face of the casing for allowing deflection of the cantilever when acted upon by a frictional force. A thin rubber membrane is stretched to cover the entire working end of the assembly, including the gap, for stopping entry of water or soil particles into the gap, during functioning of the cell. The sand grains if allowed to enter the gap would cause obstruction to the deflection of cantilever. The membrane was held in place by a thin steel lining screwed to the perimeter of the casing-end and a thin square steel sheet covering the free-end of cantilever. The surfaces of the lining on the casing and the square sheet on the cantilever-end were in the same plance, and did not obstruct the functioning of cantilever in any way. The square steel sheet formed the face on which frictional force was received.

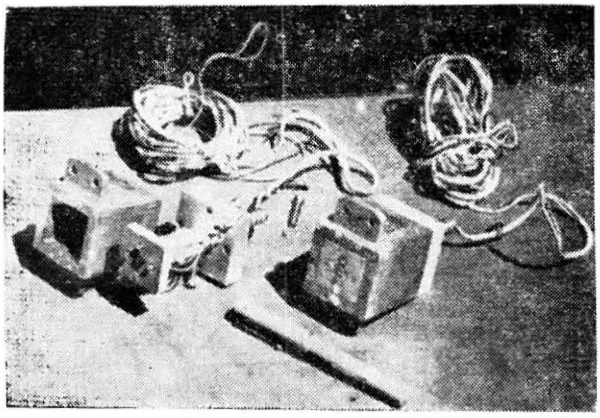


FIGURE 7 Friction cell

Four gauges of Mahavir L—10 type having 120$\pm$ 0.5. hm resistance and gauge factor of 2.8 $\pm$ 2 per cent and grid 10mm$\times$4 mm with 15 mm $\times$7.5 mm base, were used for measuring strains. On pair of gauges i.e. (T_1 and T_2) in Figures 6 (a) was pasted symmetriclly and parallel to the long axis of the cantilever onits broader face and as near as possible to the fixed end. The second pair of gauges i.e. C_1 and C_2 was pasted on the opposite face on a mirror image of the first pair. The gauges were connceted in a full bridge ciecuit, as shown in Figure 6*b* to achieve the desired performance that is, four times the strain to be recorded for bending in xy plane, zero for bending in a plane at right angles and zero for strains arising out of axial thrust. The temperature compensation was also automatically effected in the same manner in the full bridge.

Calibration of the Cell

The calibration arrangement used is shown in Figure 8. The cell was clamped horizontally in a vice with sensing width of the cantilever beam remaining horizontal. Transverse load was applied with slotted weights at the centre of cantilever-end in suitable incremental loading and the strains produced in the cantilever were measured correspoding to each loading. The readings were obtained for both loading and unloading. Figure 6*d*, shows a typical calibration curve of a friction cell. The same method was employed to check the effect of forces in another tangential direction. It was found that no unbalance of bridge occurred due to this type of loading.

In all, ten friction cells were prepared. These were designated as F—1 to F—10. Calibration factors for these cells are given in Table 1.

Boundary Earth-Pressure Cells for Field Model

Choice of Cell

The size of the field model of well-as decided to be a square with 1.5m sides. A deflecting diaphragm type cell with 9cm overall diameter was found convenient for fabrication within the Earthquake Engineering Department workshop and also for placing it on faces and base

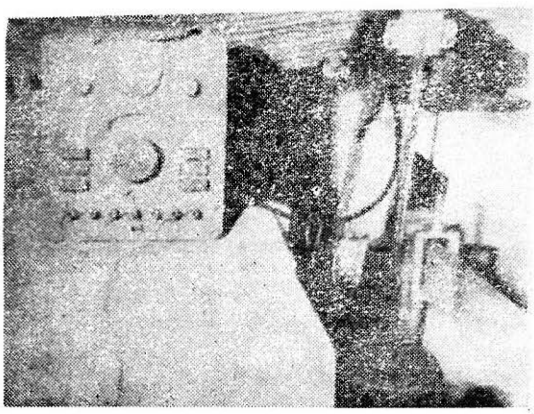


FIGURE 8 Calibration arrangement

of the model during its construction. A 5cm diameter, diaphragm was found suitable for accommodating locally available Mahavir K—5 strain gauges of flat grid type with a grid size of 6mm$\times$1.5mm, resistance 120 ohm and gauge factor 2.84$\pm$ 2 per cent.

Range of pressures

After due consideration of the conditions of testing of the model in the field, it was arrived at that the maximum earth pressures of 0.35 kg/cm^2 and 0.5 kg/cm^2 should be adopted for designing the cells for well faces and base respectively.

Design of cells

For design purposes the diaphragm was treated as a thin circular plate fixed at its perimeter subjected to a uniform surface load (WES Bulletin 1955). The design criterion used in this case also was that the ratio of the deflection at centre to the diameter of the diaphragm should not exceed 1/2000 at maximum pressure. Phosphor bronze was selected as the material for face pressure cells and non-magnetic stainless steel for base pressure cells. Use of stainless steel pres sure cells at the base was desirable due to conditi ons of higher pressures and proximity of the water table near the base. Stainless steel cells would have been desirable for use on faces also but could not be produced in large numbers mainly because of difficulty in machining the metal.

The following data was used to obtain the thickness of the diaphragms of phospher bronze and stainless steel cells. Radius of diaphragm = 2.5 cm; For phospher bronze $E = 10^6$ kg/cm^2, $\nu = 0.335$; For stainless steel $E = 2\times10^6$ kg/cm^2, $\nu = 0.305$ (Hetenyi 1960) Using the above data in the procedure for pressure cells for laboratory models, the thickness of the diaphragm worked out as 0.967 mm for phospher bronze and 0.863 mm for stainless steel. A thickness of 1mm was adopted in each case.

Sensitivity of the Cells

A half bridge circuit with two strain gauges of 5 mm grid length was used for measuring strains in the diaphragm. The positioning of the gauges is shown in Figure 9. Using the procedure adopted in section 2.5, the sensitivity was determined as 2.53×10^{-3} kg/cm^2 per μ—strain for phospher bronze disphragm and 5.16×10^{-3} kg/cm^2 for stainless steel cells.

Fabrication

A typical field pressure cell is shown in Figure 9 and 10. The cells were formed by machining out 9cm diameter casings from 100 mm diameter phospher bronze and non-magnetic stainless steel rods. A 5cm diameter diaphragm of 1mm thickness was machined coaxially out of the casing to form as integrated part of the cell. The back cover for the cell was made from 100mm diameter aluminium rod. Phospher bronze cells were electroplated from outside to protect them from corrosion. Gauges were pasted in position as shown in Figure 9. These were connected in a half bridge circuit and made water proof as in case of

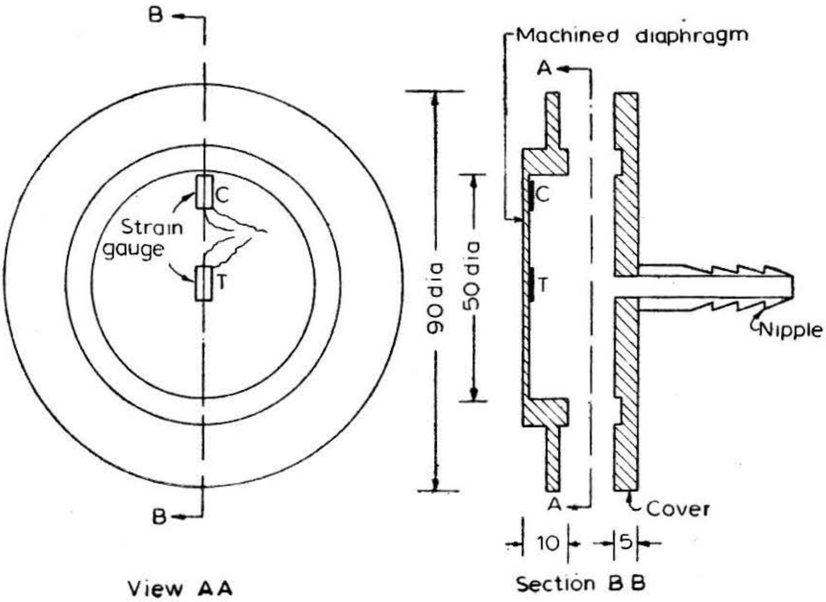


FIGURE 9 Earth pressure cell for field model

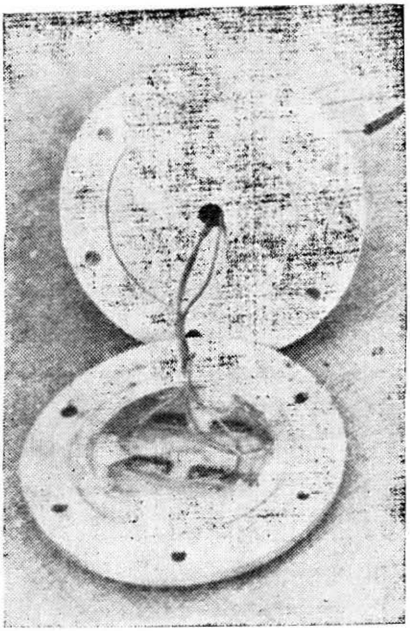


FIGURE 10 Field pressure cell

small earth-pressure cells. The water proofing was tested by keeping a cell under water for 24 hours.

Calibration

The cells were calibrated under water pressure. A calibration chamber was fabricated as shown in Figure 11. The complete calibration setup is shown in Figure 12. Calibration was done in the same manner as for small laboratory earth-pressure cells. Typical calibration curves of a phospher bronze and a stainless steel cell are shown in Figure 13.

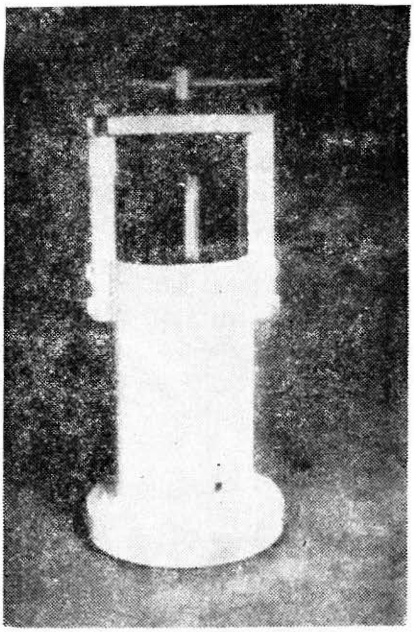


FIGURE 11 Chamber for calibration

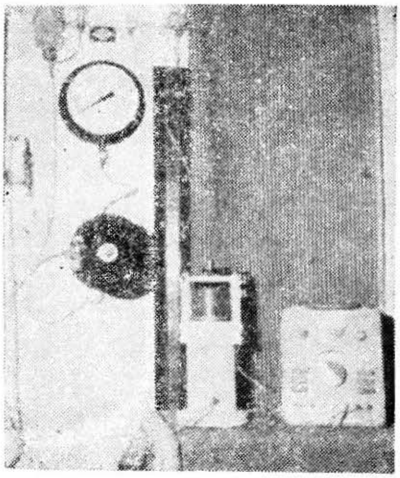


FIGURE 12 Calibration set-up

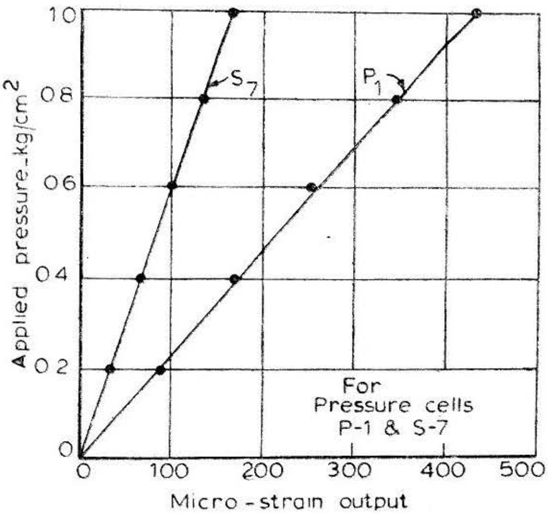


FIGURE 13 Calibation curves for field pressure cells

In all 21 cells were fabricated for use in the field model. of these 12 were of phospher bronze and have been designated as $P-1$ to $P-12$. The 9 stainless stell cells have been designated as $S-1$ to $S-9$. The calibration factors for these cells are given in Table 1.

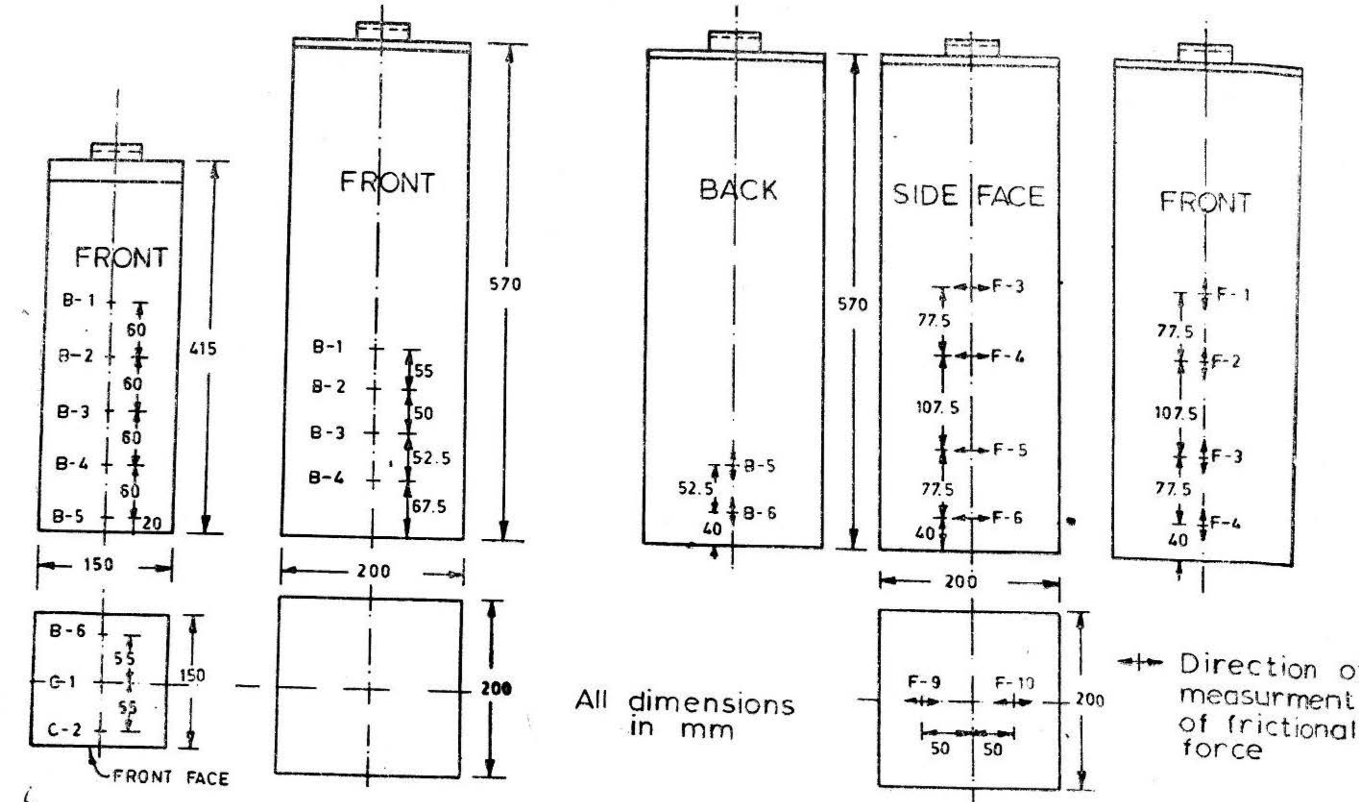
Performance of Earth Pressure Cells and Friction Cells with Laboratory Well Models

Two sizes of well models with 15cm and 20cm square base were used in the investigations. These were prepared from thick wooden plunks. The positions at which the soil pressures were to be measured were hollowed out suitably so that the pressure cells could be fitted with their faces flush with the model surface

For observing the frictional forces a 20cm square base model made of mild steel plates was used. Suitable openings were provided on the faces and base of the model such that the friction cell could be screwed to the surface of the model with its sensitive face flush with model faces. These models with the positioning of pressure cells and friction cells are shown in Figure 14.

Typical pressure distribution curves as obtained from pressure cells on faces and base of a 15 cm model embedded to a depth of 22.5 cm in dense sand of dry unit weight=1.658 g/cm³ under the action of lateral loading are shown in Figure 15. The pressure distribution is seen to be curvilinear on the vertical faces as well as the base. The more or less parabolic distribution on the compressed face tends to support the modulus of subgrade reaction theory.

Figure 16 shows the magnitude of frictional stresses and their direction as obtained from a typical test on 20 cm mild steel model. In this case. a substantial vertical load was applied before hand. The frictional stresses



a_ Wooden models with pressure cells

b_Mildsteel model with friction cells

FIGURE 14 Models with pressure and friction cells

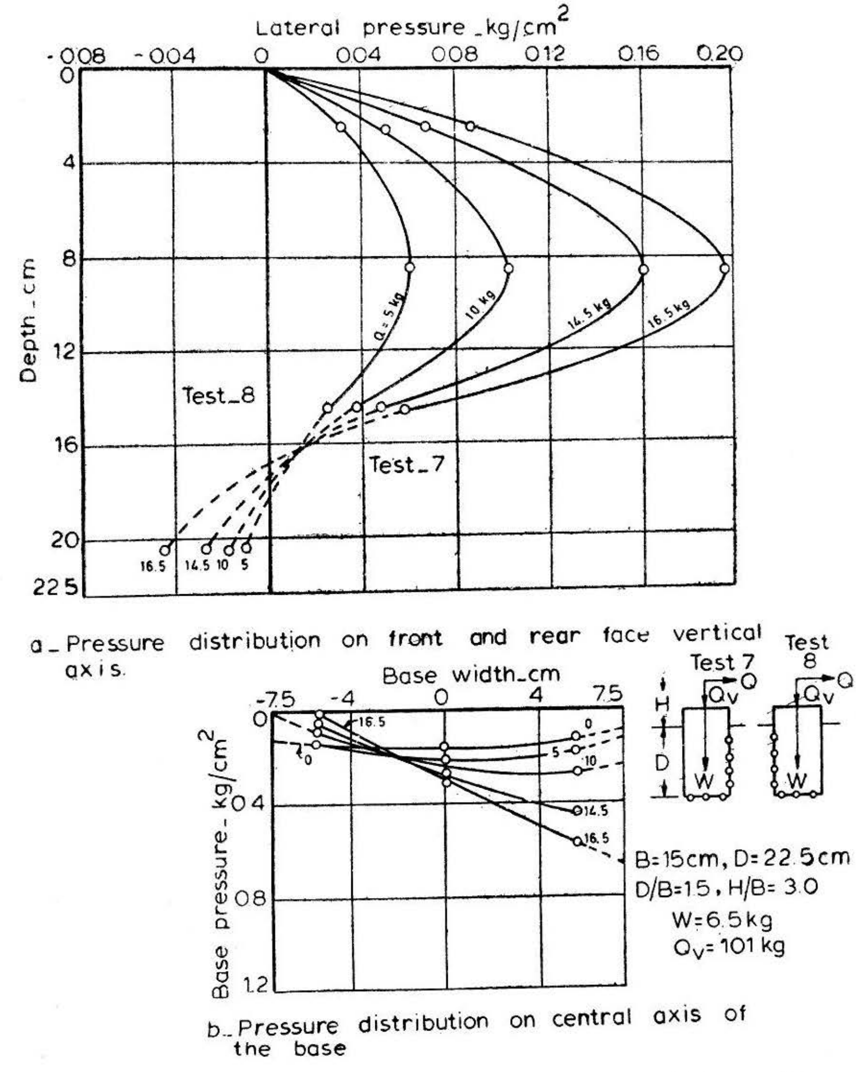


FIGURE 15 Pressure distribution curve on faces and base of 15 cm model

were measured for various values of lateral load O. These are drawn [by firm lines for front face and by dashed lines on the rear face. It is seen that large frictional forces do act on front and rear faces of a well when lateral load is applied. The direction of the frictional force is such as to a oppose the rotation of the well and the magnitude goes an increasing with increasing lateral load. The curvilinear distribution of frictional stress with depth seems to be in conformity with the observation of lateral pressures on front face also being curvilinear as seen earlier in Figure 15 since frictional force is a product of normal pressure and the coefficient of friction.

Figure 17 shows the mobilization of horizontal friction on side faces and base of the 20 cm mild steel well model. For the sides it is observed

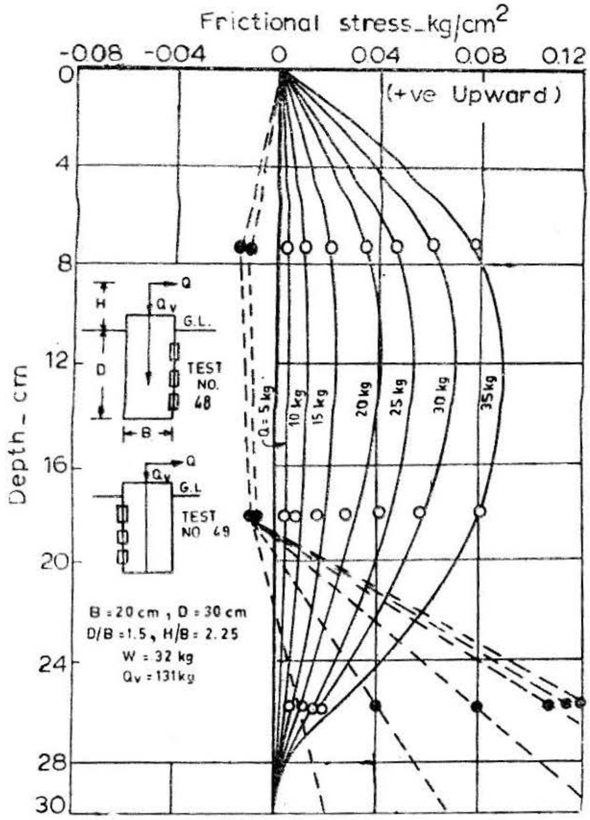


FIGURE 16 Frictional stress on front and rear faces of 20 mm mild steel model

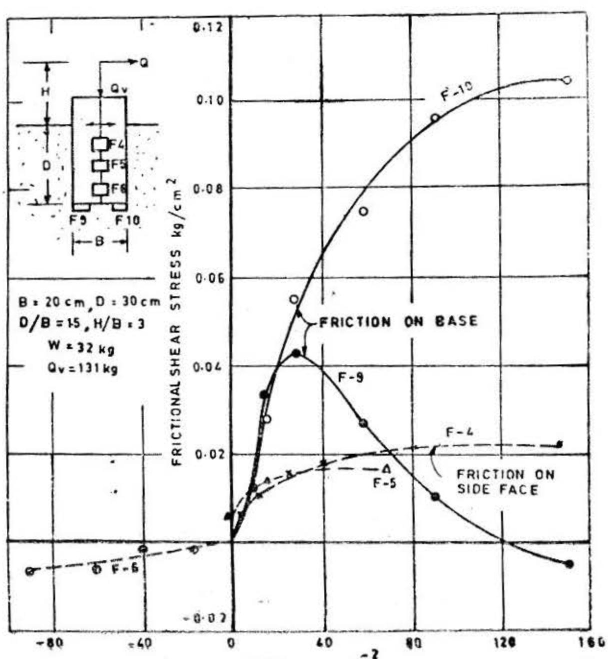


FIGURE 17 Mobilization of friction on side face and base

that as the lateral load is increased friction is fully mobilized at the points of large movements whereas it is only partly mobilized near the point of rotation. Also the direction of frictional force is opposits to the direction of lateral force in the portion above the point of rotation whereas it is in the same direction as the applied force Q below this point. It is also seen that frictional stresses recorded by cells F-5 and F-6 show somewhat erractic variation with lateral load. This may be due to changing position of the point of rotation with the increasing load and adjustment of soil particles during the movement of the well.

Curves F-9 and F-10 represent the mobilization of friction at the base of the well near the toe and the heel respectively obtained with the help of friction cells. The location of the curve above the x-axis (displacement) is indicative of frictional force being in the same direction as the lateral load whereas points below the displacement axis represent friction acting in the opposite direction. It is seen that in both the cases, the friction near the toe is in the same direction as the lateral load. The friction near the heel (curve F-9) is first mobilised in the same direction as that for the toe and then it starts reducing to zero. In fact the curves F-10 and F-9 are seen to coincide in the initial stages of the tilt of the well. This suggests that in the initial stages the mobilization throughout the base is uniform and as the tilt increases the heel has a tendency of lifting up accompanied by a reduction in normal pressure whereas the toe pressure goes on increasing thereby increasing of friction with its movement. The horizontality of the curve at the end suggests that full frictional force is mobilized near the toe at a displacement of the base of about 1.2 mm.

Performance of Field Pressure Cells and Friction Cells in Field Well Model.

A lateral load test was performed on a 1.5 m square section R.C.C. well with 2.25 m af embedment in natural saturated soil. Field pressure cells and friction cells described earlier were fixed in various positions on faces and base of well as shown in Figure 18 for making an attempt to measure lateral earth pressure and friction.

The usual method of fixing pressure cells on the face of a retaining well or base of a footing is either to embedded them in masonry or concrete with *their sensitive* faces flush with the surface, or fix them with their sensitive faces projecting on the surface. The advantage of the embedment technique is that the sensitive face is flush with the surface which is desirable for good results but the disadvantage is that it is difficult to retrieve the cells either for repairs or for use in other tests. The advantage of fixing the cells on surface is that these cells possibly could be retrieved after the test is over but the disadvantage is that the projection is not desirable for good results.

In the present case the cells were fixed by an arrangement in which the cells could be placed with their sensitive faces flush with the surface yet they could be retrieved easily when required. The arrangment its shown in Figurh 18(b). 'A' is a mild steel pipe 100 mm inner diameter and 200 mm long. A' is an 8 mm thick mild steel square plate with sides slightly longer than 100 mm. This plate has a machined opening of appropriate shape to accommodate either a pressure cell or a friction cell with its sensitive face flush with plate's outer face. This plate is welded to one of the ends

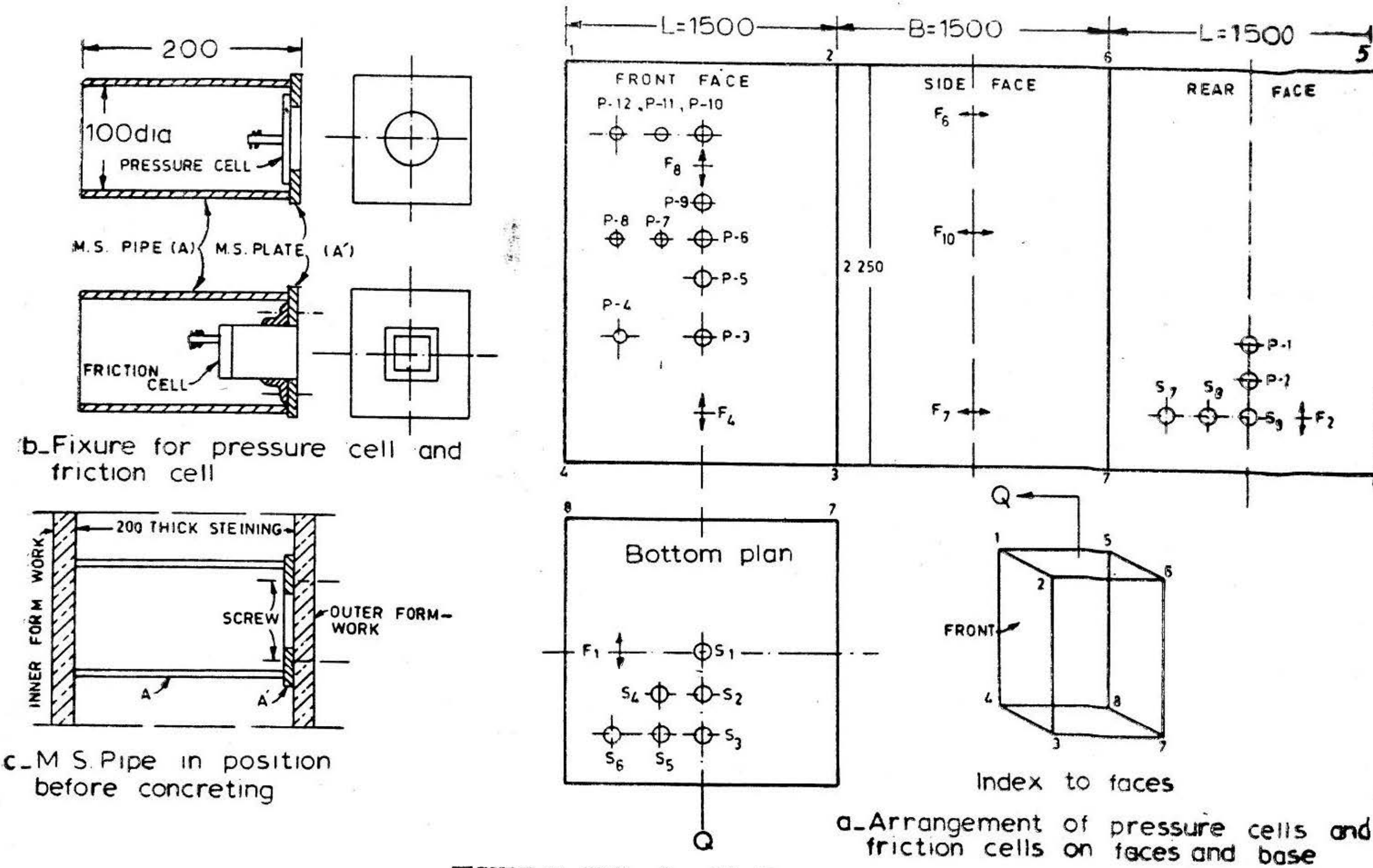


FIGURE 18 Field well model with pressure and friction cells

of A. The transducers can be fixed to A or removed from it from the open end of pipe A. The pipe assembly is placed between the inner and outer formwork before concreting is done, as shown in Figure 18(c). For this, plate A is screwed to the outers huttering from within the pipe A. The pipe assembly gets embedded when concreting is done. The screw holding the pipe assembly with the outer shuttering are accessible after the inner shuttering is removed. The opening thus formed in the concrete steining can now accommodate transducers by operating from inside the well.

Desired number of pipe fixtures were embeded in walls and bottom plug of the well for fixing pressure cells and friction cells at various locations indicated in Figure 18(b). Transducers on faces were put in position before sinking operation was under-taken. The tranducers at bottom were placed after the concreting of the plug, alongwith the pipe fixtures had been done. The leads of the transducers were taken to a strain measuring unit through plastic tubes with one of their ends fixed to the nozzle of the transducer. The space left in the pipe after fixing the cells was filled with grease as a precaution against any leakage of water into the well through these pipes.

Figure 19 shows the pipes with their plates screwed to the outer form-work before the first stage of concreting, and Figure 20 shows the outside face of the well with openings for fixing cells from inside in the first stage of well construction and Figure 21 shows the cells in position on rear face and side face.

Figure 22 a shows the lateral pressure distribution as observed in Test No. 124 on front and rear faces and Figure 22 b shows the base pressures The pressure, on sides show the usual trend of pressures as obtainted in modulus of subgrade reaction theory except for variations due to local soil conditions. The base pressure abtained only on half the width show the trend of changing from trapezoidal to triangular as the Lateral load increases. The point of rotation of the well is about 0.30 D above the base.

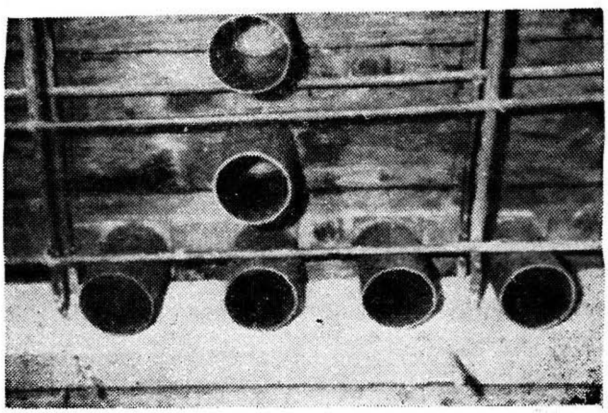


FIGURE 19 Arrangement of pipes with their plates

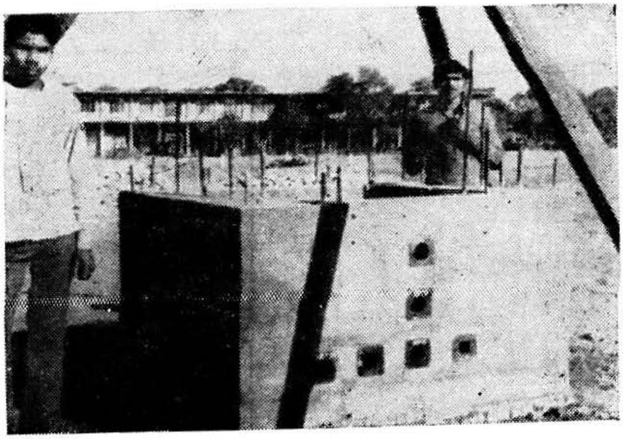


FIGURE 20 **Outside face of the well and openings for cells**

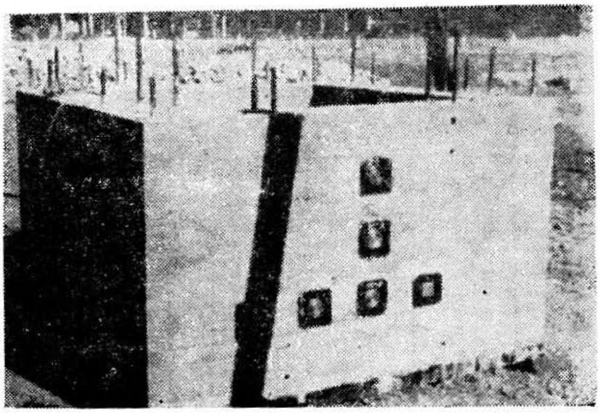


FIGURE 21 **Side face of the well with cells in position**

Figure 23 shows the distribution of frictional stress with depth for the same Test. It is seen that the distribution is similar to that observed in laboratory model test.

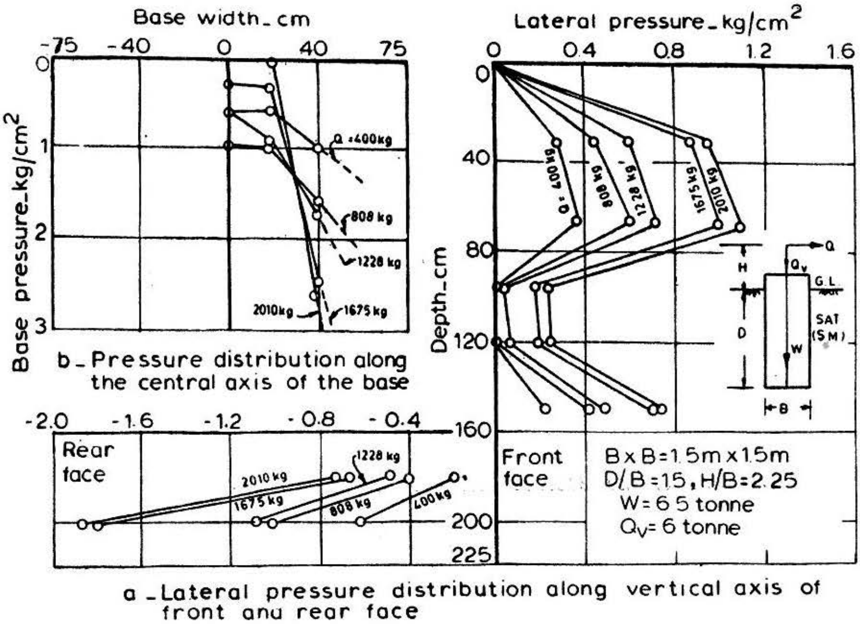


FIGURE 22 Pressure distribution on faces and base of field model

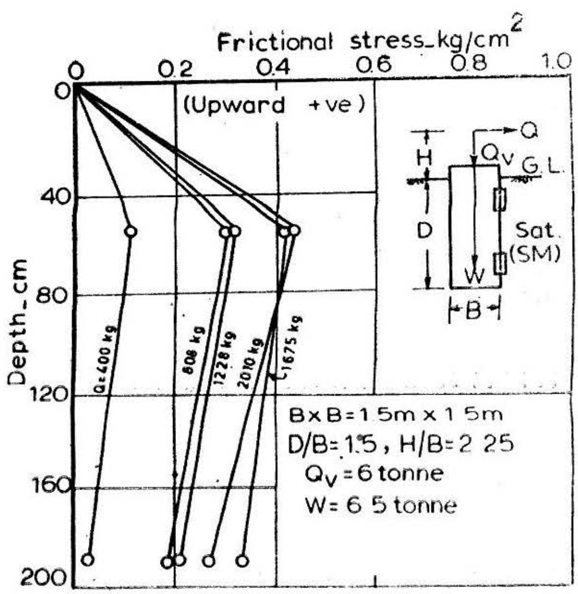


FIGURE 23 Friction on front and rear faces of field model

Conclusion

From the calibration curves of the earth pressure and friction cells, it is clearly seen that their characteristics are linear within the range of design. Their installation in the well models and observations under testing conditions, both in the laboratory and the field, show very good performance. The field model was tested even in outside saturated soil condition and the cells gave trouble free observations. The field model was sunk with the cells installed. It appears that both the pressure and friction cells could be used in prototype wells with some modifications regarding installations.

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