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A STUDY OF THE RESIDUAL LATERAL PRESSURES INDUCED IN A COHESIVE SOIL AFTER COMPACTION

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A STUDY OF THE RESIDUAL

LATERAL PRESSURES INDUCED IN

A COHESIVE SOIL AFTER COMPACTION

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A STUDY OF THE RESIDUAL

LATERAL PRESSURES INDUCED IN

A COHESIVE SOIL AFTER COMPACTION

Andrew Jackson Glenn, III

(40 Pages)

Directed by Professor George F. Sowers

The purpose of this study is to determine the magnitude of the residual lateral earth pressures remaining in a cohesive soil after compaction.

For the purpose of this investigation, a pressure cell was designed. SR-4 electrical resistivity strain gages were utilized in these cells to give indications of strain when the cell diaphragm was depressed. Each cell was calibrated by recording the corresponding strains for a range of uniform pressures applied on the diaphragm.

The cells were used to measure the earth pressure being exerted on a concrete wall. The following five tests were conducted:

1) Loose dumping the soil into place
2) Compacting the soil in 3-inch layers with a 10-pound hand tamper
3) Compacting the soil in 4-inch layers with a 210-pound gasoline (BARCO) rammer.
4) Compacting only the 18 inches nearest the wall. The soil was compacted in 4-inch layers using a 210-pound gasoline

(BARCO) rammer.

5) Compacting the soil in 6-inch layers with a sheepsfoot roller.

The conclusions resulting from these tests are:

1) The compaction of cohesive soils produces much higher residual lateral earth pressures than the loose dumping of the same soil.

2) The residual earth pressures within a compacted backfill are probably equal to or greater than the computed At-Rest earch pressures.

3) Residual lateral earth pressures are greater for the greater compactive efforts of larger and heavier compaction machines.

4) Residual lateral earth pressures are affected by time. They are reduced in the first day or two after completion of compaction.

CHAPTER I

INTRODUCTION

General Background - For centuries, some of the most important structures that engineers have had to design and construct have been those which serve to restrain the lateral movement of earth masses. These structures are usually referred to as retaining walls, and they must be designed to resist the lateral and vertical pressures resulting from the earth mass they are supporting. Before an engineer can design a retaining wall, he must first be able to determine the magnitude, direction, and distribution of the pressures which will be acting upon the wall. This problem has long been recognized. Written records from the eighteenth century on show the considerable amount of time and energy that has been expanded in the development of earth-pressure theories from both experimental work and observation of construction practive. A summary of the theories, observations, and experimental work on earth pressure has been made by Jacob Feld (11). Gregory P. Tschebotarioff (7) has also combined the classical theories of Coulomb Rankine with the modern theories which have resulted from more recent observations and testing.

Usually, structures which are to retain earth masses are constructed before the earth mass is placed or backfilled against them. In many cases it is necessary that these backfills be compacted by mechanical means to increase their strength, density, and ability to support further loadings without damaging settlement occurring. It has been suspected that the process of compacting a soil causes an increase in the lateral pressures within the soil mass. However, little is known concerning the magnitude and distribution of the lateral earth pressures against walls resulting from compaction. This is an important question left unanswered.

In some cases, excessive deflections of retaining structures have occurred during the construction of compacted fills against them. This fact has lead to the belief that lateral earth pressures do exist in magnitude worthy of consideration in the design of structures. It remains to be proven by actual measurement, whether or not the pressures exist and contribute materially to the forces acting on the retaining structure. If lateral pressures due to compaction do exist, they may be of a temporary nature only. However, if they are residual in nature they would be of considerable importance.

The accepted theories of today recognize three determinate values of lateral earth pressure caused by the soils weight alone: the Active, Passive, and At-Rest states of lateral earth pressure. The Active state of lateral earth pressure is defined as the state that exists when lateral expansion of the soil takesplace due to an outward deflection of the retaining structure sufficient to shear the soil mass. This movement is necessary in order to mobilize the internal friction and cohesive properties of the soil, an action which in turn reduces the lateral pressure on the retaining structure. Thus the full Active state is the lower limit of the lateral earth pressure and exists immediately preceding and during failure of the soil in its effort to hold itself intact.

Conversely, the Passive state exists when lateral compression of the soil takes place because of an inward deflection of the retaining structure. The passive state is the upper limit of lateral earth pressure. This maximum also exists just before the failure of the soil in shear, when all internal friction and cohesive properties have been mobilized.

The At-Rest state of lateral earth pressure has also been termed the neutral lateral earth pressure. It is defined as the lateral earth pressure which exists in a mass of soil which has neither contracted nor expanded after its formation.

Previous Testing - Other than the tests conducted by A. Robb at Georgia Tech (1), no studies of residual lateral earth pressures which remain in a soil due to previously imposed loadings have been found. Mr. Robb's tests were conducted using a thin-walled compaction cylinder on the sides of which electric strain gages were fitted and calibrated to measure lateral pressure. While this study provided a valuable starting point for future studies of residual lateral earth pressures, the results obtained were necessarily affected by the use of a small-scale device. The use of large-scale field tests would reduce the confining effect, which is present in small-scale testing.

In recent years, large-scale experimental tests have been conducted. It had become apparent that further conjecture concerning the subject of earth pressure was useless without new information obtained through controlled testing of soils on a large scale. Terzaghi (2), Spangler (5), and Tschebotarioff (3) have probably been the more prominent investigators using this approach. Their investigations included the effects upon lateral earth pressure due to combining both yielding and non-yielding walls with both sands and cohesive soils in dry, partially saturated, and flooded conditions. The effects of concentrated loads applied to the surface of the soil mass behind retaining walls were also studied. Although these studies shed light on earth pressure problems in general, they do not attempt to answer the problem of residual lateral earth pressures.

Purpose - The purpose of this investigation is to continue work begun by A. Robb in determining the magnitude of the lateral earth pressures remaining in a cohesive soil after compaction. It is hoped that use of large-scale field tests will reduce to a minimum any effects of confinement which may have been encountered in the small-scale tests conducted by Mr. Robb.

CHAPTER II

EQUIPMENT

Large-scale testing of lateral earth pressures usually has involved the construction of expensive structures and measuring devices and elaborate installations. The ideal pressure-measuring device would be cheap to manufacture and easy to install, yet give the required sensitivity and accuracy of measurement. It should be stable over long periods of measurement, even when placed beneath the ground water table. Such a device could be installed to measure the pressures exerted on actual structures and abandoned after the required information has been obtained. Its pressure should not affect the soil stresses which exist around it. In the past, several methods have been used to measure the magnitude of the lateral earth pressures acting on either a model or a full-sized structure.

One of the earliest devices employed the principle of the relation between the friction of soil on a steel band due to a given pressure normal to the band face and the force required to extract the band from the soil. Later, the measurement of the reaction forces necessary to hold the test wall in place was used as a means of determining the approximate magnitude and distribution of lateral earth pressures.

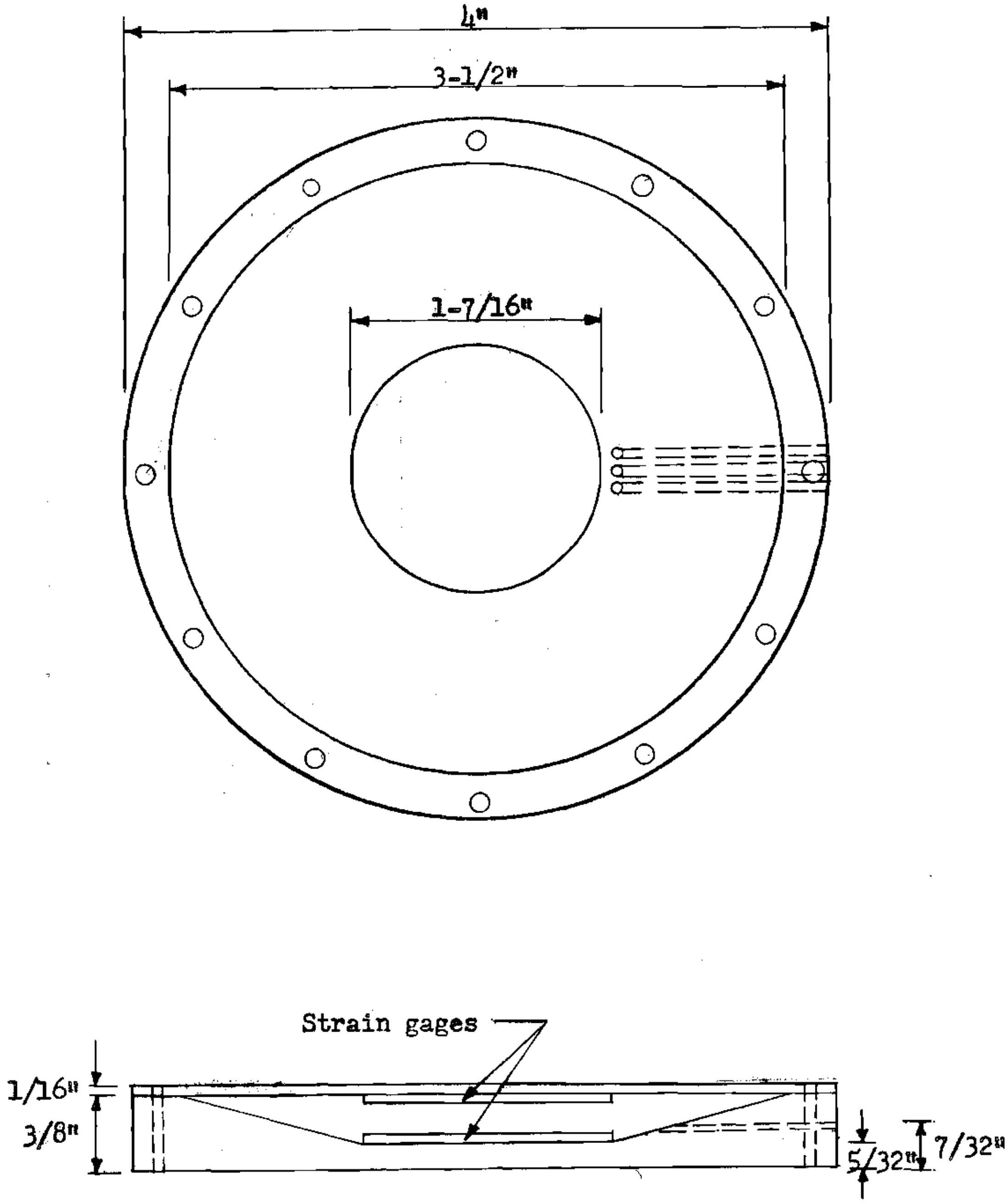
Pressure Cell - The development of pressure cells in recent years has allowed further studies of earth pressures encountered under field conditions. One of the more prominent designs has been the Goldbeck cell (4). This cell utilizes an electrical contact which is opened or broken by small movements of the cell diaphragm. The pressure exerted upon the cell diaphragm is measured by balancing it with air pressure from within the cell. Readings are taken at both the breaking and the reestablishment of electrical contact and are averaged in order to obtain the soil pressure.

The development of the SR-4 electrical resistivity strain gage has made possible the accurate measurement of strains previously impossible. They have been used by Tschebotarioff in his earth pressure experiments at Princeton (7), as well as by the engineers at the Waterways Experiment Station of the Corps of Engineers in Vicksburg, Mississippi (8).

In recent years, pressure cells for field use have been developed at the Waterways Experiment Station of the Corps of Engineers in Vicksburg, Mississippi. These cells were used in studies of both long and short duration in connection with earth and concrete dams, retaining walls, airport pavements and other types of structures. "All of these devices employ electrical gaging methods whereby movements of a diaphragm or bellows resulting from the pressure variations under study are converted to electrical signals for observations and/or recording at convenient locations remote from the point of pressure application. The pressure transducers utilize SR-4 strain gages with the exception of one type of low range hydrodynamic cell, which utilizes the Schaevitz linear differential transformer. By means of previously determined calibration constants the observed or recorded electrical signals from the pressure cells can be interpreted as pressure values at the points of measurement."* Although these cells have been fairly successful and reliable, they are also very expensive to construct. For the purposes of this investigation, it was decided to attempt the adaptation of the SR-4 strain gage to a defferent design of pressure cell. It was hoped that this design would enable accurate, sensitive measurement of pressures combined with easy cell installation, remote indication and recording, and low equipment costs.

The electrical resistivity strain gage operates on the principle that the resistance to a flow of an electric current is inversely proportional to the cross-sectional area of the conductor. Essentially, the gage consists of a short length of very fine wire (about .001 inch in diameter) which is attached to the piece being tested so that the wire is strained equally with the test piece. The electrical resistance of the wire used for these gages changes as the wire is strained. This change in resistance (a small fraction of an ohm), when detected by the proper instruments, is an accurate measurement of the strain in the wire and hence the strain in the underlying material being tested. Previous studies (6) of the effects of the thickness and size of pressure cells upon the recorded results indicate that the ideal would be a small diameter

* Pressure Cells for Field Use, Bulletin No. 40, Waterways Experiment Station, Corps of Engineers, U. S. Army, Vicksburg, Mississippi.



Scale: Full Size

Fig. 1. Earth Pressure Cell Showing Leading Dimensions

cell of infinite simal thickness. The ideal cell would also measure pressure without any movement of the weighing area or the diaphragm. To approximate these ideal conditions, a cell was designed which was 4 inches in diameter and 7/16 of an inch in thickness (see Fig. 1). Essentially, it consisted of a round, 3/8-inch-thick aluminum block base with a dish-shaped depression in one face and a 1/16-inch-thick diaphragm. A type A strain gage was attached to the underside of the diaphragm. This was to be the measuring or active gage. Another similar gage was attached to the base of the cell for use as the temperature compensating or dummy gage. The two gages were properly connected within the cell to allow the use of only three lead wires. These wires were introduced into the cell through small holes drilled through the side of the base. The gage and all connections within the cell were insulated from electrical grounding to the base and coated with beeswax in an effort to make them as waterproof as possible. The diaphragm was attached to the base with 12 machine screws, using a non-hardening type of gasket compound to seal the connection. The entry holes for the lead wires were then poured full with melted beeswax to seal out moisture.

A Baldwin Type L strain indicator was used to indicate the electrical resistance changes that occurred with diaphragm deflection. A six-position Baldwin switch box was used to allow switching from one cell to another in taking readings, without any errors occurring because of changing lead connections.

A circuit reversing switch was incorporated into the hook-up to allow normal and reverse readings of electrical resistance changes. This operation had been suggested by Perry & Lissner (9) as a means of eliminating zero drift with time. Since the strain indicator measures electrical resistance by means of the Wheatstone Bridge Principle, reversing the positions of the active and the dummy gages and averaging the resulting readings will produce a reading that is correct for drift.

Calibration Equipment - It was not the intention of this design to compute mathematically the pressure on the cell diaphragm from the measured strain. The main reason for not computing the pressure in that manner is the unknown amount of restraint to diaphragm movement which is present in the connection of the diaphragm to the block or body. Instead the cells were individually calibrated under conditions as near to those which would be encountered in actual field use.

A steel cylinder 12 inches high and 11 inches in diameter was used to place the cells under pressure. Because the cells were to be used in the field to measure pressure against a concrete wall, a concrete block was placed in the bottom of the cylinder for the cell to lie upon. There was a small hole in the side of the cylinder for the lead wires. The pressure on the cell was supplied by air pressure acting through a very thin flexible rubber membrane. In order to simulate actual field conditions more closely and to minimize soil arching effects, the cell was covered with approximately 2-1/2 inches of the same soil that was to be used in the field tests. The rubber membrane was placed on top of the soil, and a steel cover with heavy rubber gaskets was bolted down tight to hold the membrane in place and to provide an air tight seal. Compressed air entered through the top and forced the membrane down on the soil with a uniform pressure. The use of a flexible membrane for the application of the load had already been determined as preferable to a rigid plate by Tschebotarioff in his experiments with the Lateral Earth Pressure Meter (7). He found that friction between the soil and the rigid pressure plate prevented or retarded lateral expansion of the soil and consequently reduced lateral earth pressures. Since the thin rubber membrane is flexible, it will not produce this undesirable effect.

A mercury manometer was used to measure the air pressure inside the cylinder. This manometer was graduated to read pressure in psf. A pressure regulator and additional needle valve connected in series were used to control accurately the air pressure exerted on the membrane.

Poisson's Ratio - The small-scale lateral pressure measuring device developed by A. Robb (1) at the Georgia Institute of Technology was used to determine the Poisson's Ratio of the soil used in the field. This device consisted of a thin-walled steel cylinder which was slotted into horizontal bands on one side. Electric SR-4 strain gages were placed on these bands to measure their lateral strain when a pressure load was exerted by the soil inside. These lateral strains could in turn be converted into lateral pressures through the use of previously calibrated curves.

The various physical properties and characteristics of the soils used in the field tests were determined by the use of standard soil mechanics laboratory equipment and tests (10). The following tests were conducted:

Grain Size (sieve hydrometer)

Unconfined Compression

Triaxial Shear

Standard 3 layer Proctor Compaction.

CHAPTER III

PRESSURE CELL CALIBRATION

The pressure cell was placed on the concrete block which rested in the bottom of the calibration cylinder. The cylinder was then filled with the same soil which was to be used in the field tests. The thin rubber membrane was placed over the top of the cylinder, and the steel top bolted down. To load the pressure cell being calibrated, air pressure was applied to the top of the rubber membrane. The magnitude of the air pressure being applied was measured directly in psf using a mercury manometer, and the corresponding strain readings were obtained from the Baldwin Type L strain indicator. Calibration runs were accomplished using 100 psf and 200 psf increments on both the loading and unloading cycles.

The first attempts to calibrate the cells disclosed the following facts:

(1) The calibration curve was not linear.

(2) There was a hysteresis effect in the unloading cycle of the curves.

(3) Each cell had to be loaded and unloaded a number of times before its calibrations became uniform.

(4) Each cell produced a different calibration curve.

The changing in calibration of a new cell during its first few loading cycles was remedied by subjecting it to cyclic loading until it stabilized. This phenomenon was probably due to small changes in the seating of the diaphragm due to plastic flow of the gasket material. After this stabilization occurred, further calibrations were not affected by time. Two or more calibration runs were usually sufficient to establish a smooth curve.

The calibration curves for the cells which were used are included in the Appendix.

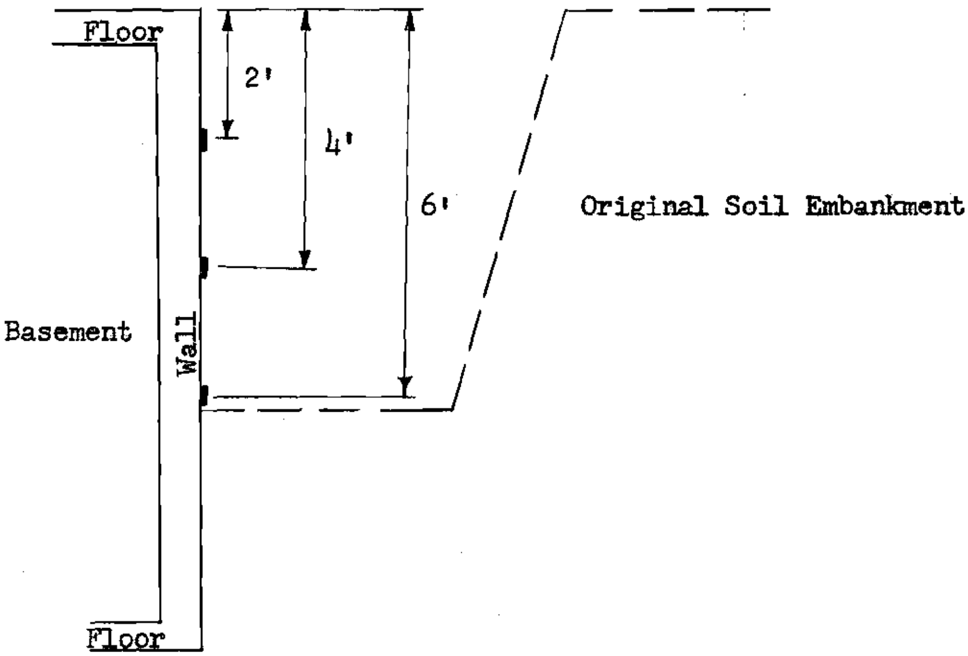


Fig. 2. Peachtree - Baker Building Test Pit Showing Location of Pressure Cells

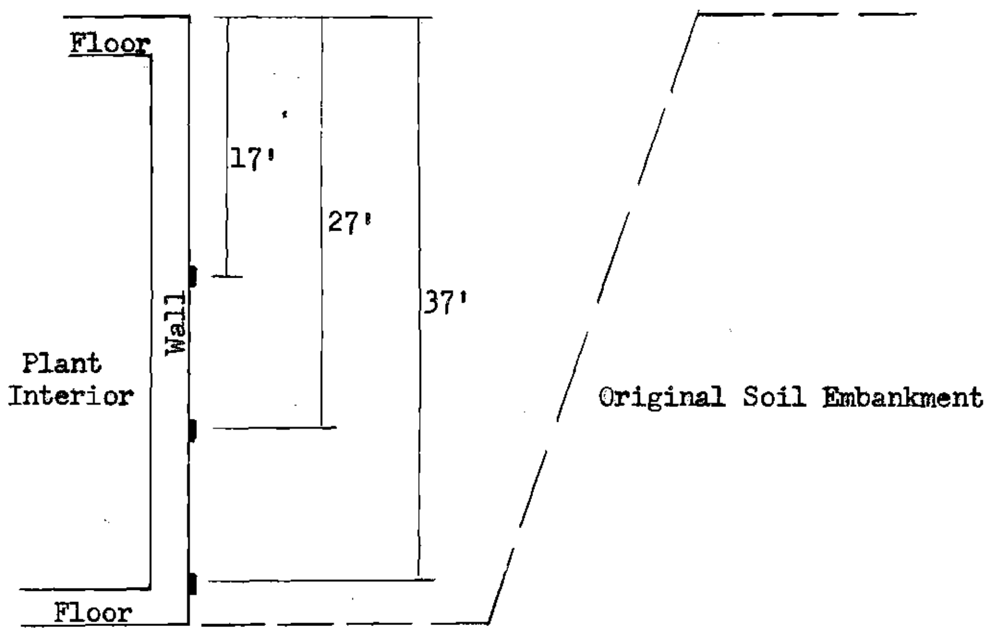


Fig. 3. Location of Pressure Cells at Allen Steam Plant, Charlotte, N.C.

CHAPTER IV

FIELD-TEST PROCEDURE

Four field tests were conducted at the site of the Peachtree-Baker Building in Atlanta, during its construction. The actual location was within the building, out of the weather. The measurement of pressures was made with the pressure cells placed on the upper 6 feet of an 8-inch-thick reinforced concrete retaining wall that extended between two floors of the building. This wall was 10 ft. tall and was supported laterally at either end by the floor slabs (see Fig. 2). The soil that was used in backfilling against the wall was a fine to coarse sandy micaceous silt with a fairly constant moisture content of approximately 18 per cent.

The four tests were conducted in the following manner:

Test I The backfill was made by loose-dumping the soil. Three cells had been mounted with plaster of paris to the wall at a depth of six feet below the final height of fill. Readings were taken over a period of one week; however, two of the cells showed signs of instability on the second day.

Test II The backfill was made in 3-inch lifts using a 10-pound hand tamper to compact the soil. Six cells were used in this test, two cells at each level of measurement. Using plaster of paris, the cells were mounted on the wall at depths of 2, 4 and 6 feet below the final backfill surface. Readings were taken for a period of 2 days.

One cell at the 2-foot level and one cell at the 6-foot level became unstable and their results were not valid.

Test III The backfill was made in 4-inch lifts, compacting the entire backfill area with the use of a gasoline (Barco) rammer weighing 210 pounds. Readings were taken for a period of 4 days.

Test IV The backfill was made in the same manner as described for Test III except that compaction was limited to a zone of 18 inches wide adjacent to the wall. The remainder of the backfill was merely dumped into place. Readings were taken for a period of one week.

At the completion of each test, moisture content and undisturbed samples were obtained from the fill directly in front of the pressure cells at each level of measurement. From these samples, the unit weight, moisture content, cohesion, and internal friction values of the fill material were determined.

Test V The fifth test was conducted at the Duke Power Company's Allen Plant Site in Charllotte, North Carolina. Cells were installed on a thick reinforced concrete retaining wall. The wall was 40 feet high and was laterally supported at both top and bottom. The cells were installed at distances of 17, 27 and 37 feet below the wall top (see Fig. 3). Compaction of the backfill was accomplished with the use of sheepsfoot rollers drawn by a bulldozer. The test was conducted over a period of two weeks, with the height of the fill being measured for each corresponding pressure measurement.

CHAPTER V

THEORY

The lateral earth pressure in a large soil mass above the water table, due to the weight of the soil above it, is equal to some function of the vertical pressure. Therefore, if $_{v} = {}_{h}$, where

σ_v = vertical pressure

γ = unit weight of soil

h = height of soil above location concerned

then $\sigma_h = Ko \ \gamma_h$, where Ko is the coefficient of earth pressure at rest.

Based on Hookes Law of stress being proportional to strain, the following general equations can be derived for the unit strain, , within a large elastic body.

where: σ_x, σ_y, σ_z are normal components of stress parallel to the x, y and z axes

ϵ_x, ϵ_y, ϵ_z are unit elongations in the x, y and z directions

E = modulus of elasticity or $\dfrac{\sigma}{\epsilon}$

μ = Poisson's Ratio, ratio of horizontal to vertical strain

$$\epsilon_x = \frac{\sigma_x}{E} \quad \text{for strain in one direction}$$

$$\epsilon_y = -\mu \frac{\sigma_x}{E}$$

$$\epsilon_y = \left[\frac{1}{E} \quad \sigma_y - \mu (\sigma_x + \sigma_z)\right]$$

This latter is a general equation for the lateral unit strain within a large elastic body. Since the At-Rest condition has been defined in Chapter I, as that in which no lateral contraction or expansion has taken place after its placement, the following must be so.

$$\epsilon_y = 0$$

$$\therefore \; 0 = \sigma_y - \mu \; \sigma_y - \mu \; \sigma_x$$

From this relationship, the expression for the coefficient of earth pressure of rest becomes

$$K_o = \frac{\sigma_y}{\sigma_x} = \frac{\mu}{1 - \mu}$$

The Poisson's Ratio of the soils used in these tests was found to be equal to .3. Therefore, $K_o = \frac{.3}{1.0 - 3} = .43$. This value of K_o was used to compute the earth pressure of rest for comparison with measured values of earth pressure from the field tests.

Expressions for the Active and Passive lateral earth pressures acting on a wall have been derived and can be found in any textbook on soil mechanics. The theory is based upon Coulomb's Sliding wedge analysis. The expressions are as follows:

$$\text{Active State} - \sigma_h = K_A \sigma_v = \sigma_v \tan^2 (45 - \phi/2)$$

$$- 2 c \tan (45 - \phi/2)$$

$$\text{Passive State} - \sigma_h = K_p \sigma_v = \sigma_v \tan^2 (45 + \phi/2)$$

$$+ 2 c \tan (45 + \phi/2)$$

where $\sigma_v = \gamma h$ as previously described

ϕ = the angle of internal friction for that particular soil

c = cohesion value for that particular soil.

If a soil is loosely placed behind an unyielding structure, the lateral earth pressure existing on the wall is equal to the earth pressure At-Rest. If, instead, the fill is made by mechanically compacting it, the horizontal pressures existing in the soil at the moment of compaction are greater than the At-Rest pressures. This condition is due to the added vertical loading. Since soil is composed of relatively incompressible particles, compaction takes place by the movement of particles across one another to form a more dense state. In order for this movement to take place, the interparticle frictional and cohesive forces which restrain the movement of the particles must be overcome. Conversely, it is theorized that in order for lateral expansion to take place after compaction, these same forces of friction and cohesion must be overcome. It is not known whether or not these intergranular properties of friction and cohesion remain the same for compaction and expansion.

Friction between the soil and the structure against which it is being compacted probably influences the amount of residual lateral pressure. Tschebotarioff (7) has noted the effect of friction between a rigid compaction plate and the soil in reducing the amount of lateral pressure measured in a small-scale lateral earth pressure meter. It is reasoned that like the inter-granular forces of friction and cohesion, similar forces will be overcome in compacting the soil down against the wall. When the compaction forces are removed, the upward movement is resisted by these same forces. Whereas these forces undoubtedly help maintain higher residual lateral forces in small-scale devices, such as those used by G. Tschebotarioff (7) and A. Robb (1), there is some question as to how large this effect would be when a soil is confined by a structure on only one side.

CHAPTER VI

DISCUSSION OF RESULTS

Tests 1, 2, 3, and 4 - The results of the field tests show that residual lateral earth pressures do exist after compaction and that they greatly exceed the pressures which were measured for the same soil when it was loosely dumped into place. The measured residual pressures were equal to or, more often, considerably greater than the computed At-Rest pressures. Fig. 7 is a graph which shows the average residual lateral pressure exerted on the wall at the different levels for each of the four tests conducted at the Peachtree and Baker Building site. The computed At-Rest pressure is also shown on the graph for comparison.

Figures 8 and 9 are graphs which show the relationship between lateral pressure and time. They also show the height of fill above the cell at the time the pressure was measured. A study of these graphs reveals a gradual decrease of residual pressure with time to a value which appears to be the lowest residual pressure for each particular set of conditions. This final residual pressure was greater than the computed At-Rest pressure in all cases.

Test V Figures 10 through 14 show the relationship between residual lateral earth pressure and the depth below the backfill surface for test V. The computed At-Rest earth pressures are also shown for comparison. Several things can be noted from these graphs.

(1) With the exception of the middle cell, the residual pressures seem to be equal to or greater than the computed earth pressure At-Rest. (2) The pressures recorded near the surface are approximately equal to the At-Rest pressure values, and the pressures recorded at the deepest point are greater than the At-Rest pressures. (3) All of the graphs show an increase in residual lateral earth pressure with an increase in depth.

There are two probable reasons for the lower than expected pressures which were recorded by the middle cell. The wall was laterally supported at the top and bottom, and since the middle cell was near the center height of the wall, any deflection of the wall would have been more pronounced here than where the bottom cell was located. Wall deflection would probably not affect the upper cell very much because only several feet of fill covered it at the time of the last reading shown on the graphs. The other possibility is that the compaction of the fill was not as thorough at the level at which the middle cell was installed.

Figures 15 and 16 show the relationship between residual lateral earth pressure, time and the height of fill. The general trend of these graphs is a gradual reduction in residual pressures with time when no additional fill or compaction is being accomplished. The graphs also show the increase in lateral earth pressures with an increase in the height of fill above the level of pressure measurement.

No formula or mathematical relationship between the lateral earth pressures recorded in these studies and the physical properties of the soils as determined by standard laboratory tests, could be obtained. Possibly the standard laboratory tests of todya do not determine the physical properties of a soil in such a manner that these properties have a simple relationship to measured residual earth pressures.

Conclusions and Recommendations

From this study the following conclusions have been reached:

1) The compaction of cohesive soils produces much higher residual lateral earth pressures than the loose dumping of the same soils.

2) The residual lateral earth pressures within a compacted backfill are probably equal to or greater than the computed At-Rest earth pressures.

3) Residual lateral earth pressures are greater for the greater compactive efforts of larger and heavier compaction machines.

4) Residual lateral earth pressures are affected by time. They are reduced in the first day or two after completion of compaction.

It is recommended that further testing be done with the use of improved cells.

The use of the Bakelite type of SR-4 strain gage would reduce creep and produce a more accurate cell for prolonged measurements. Better insulation from moisture could probably be attained through the use of Pefrosene-A Wax and a single, more rigid type of entrance for the three lead wires.

APPENDIX

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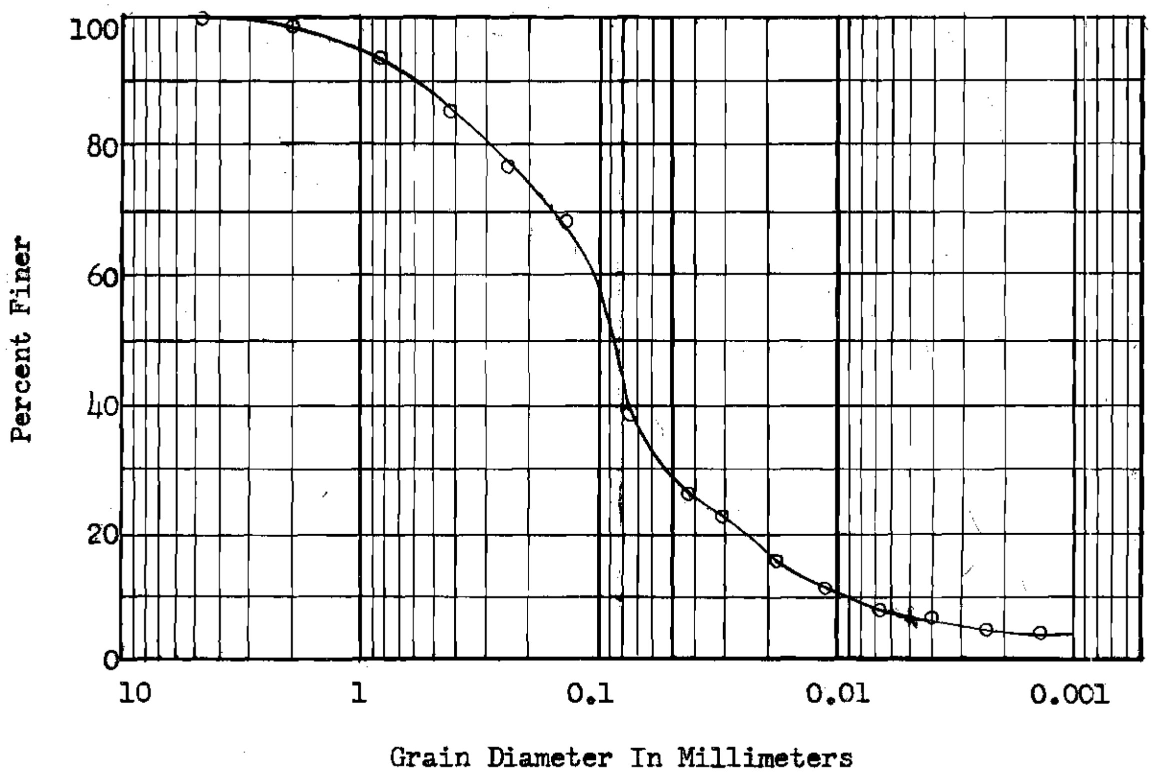

Fig. 4. Grain Size Distribution of Soil Used In Tests

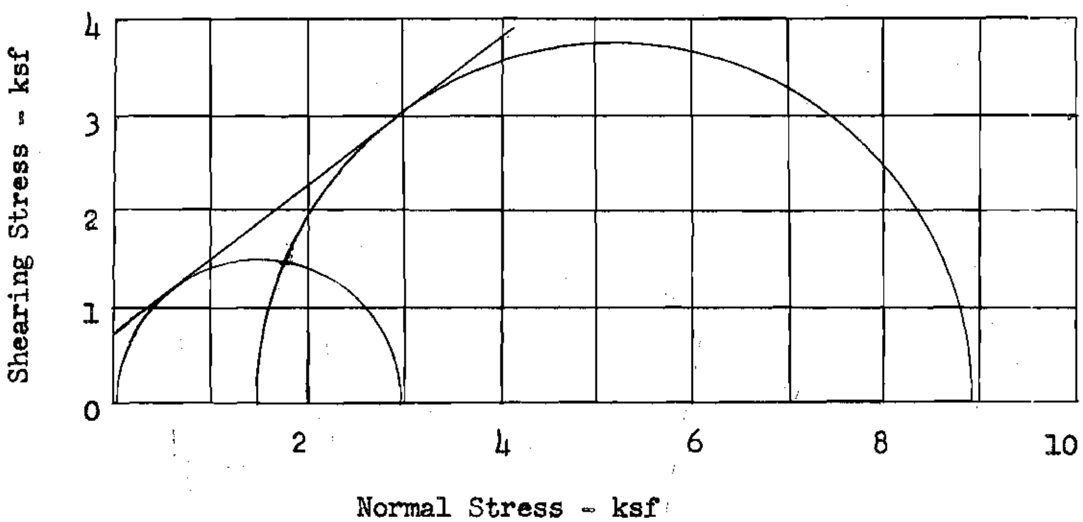

Fig.5. Triaxial Shear Test of Average Sample

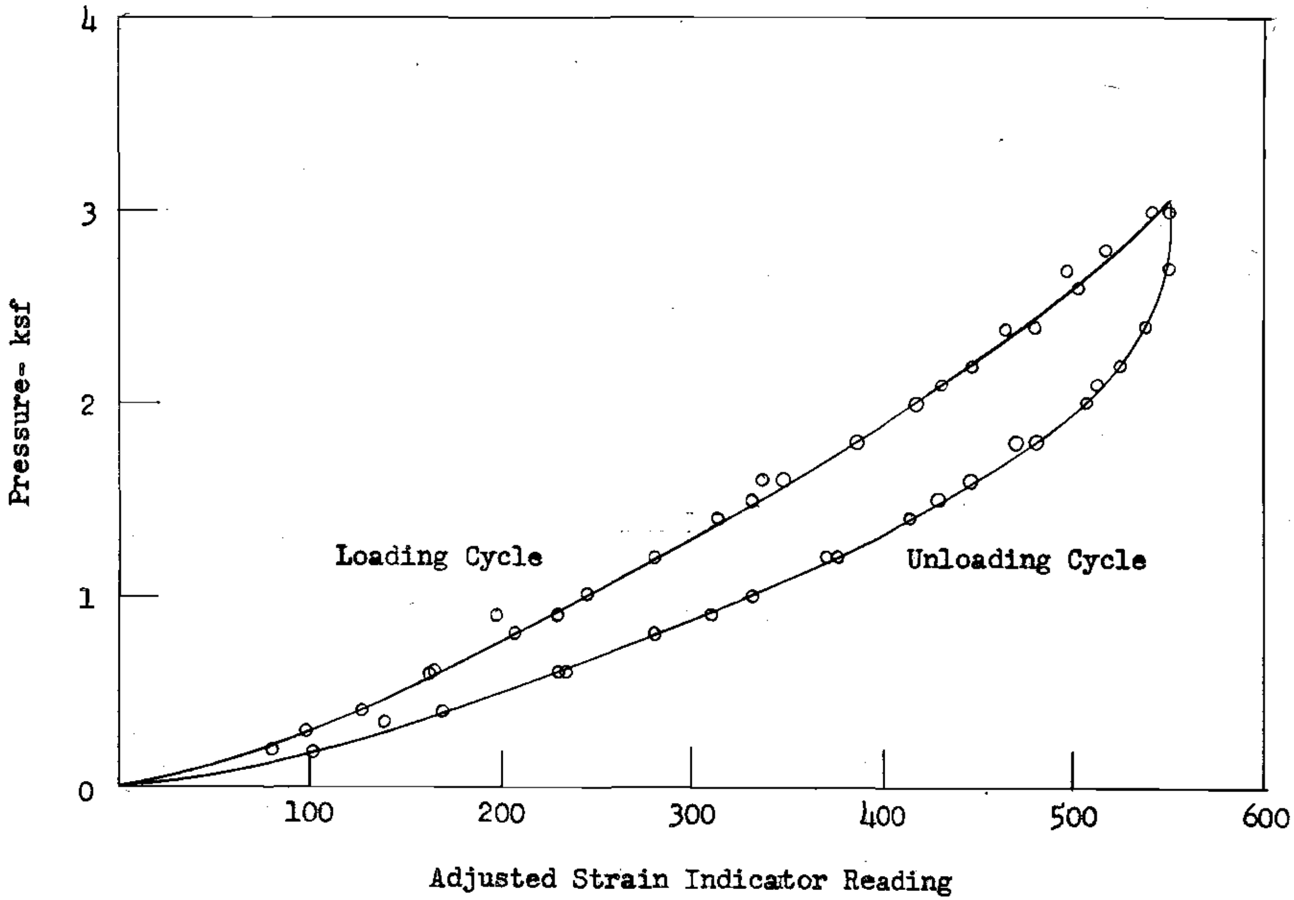

Fig. 6. Typical Pressure Cell Calibration Curve

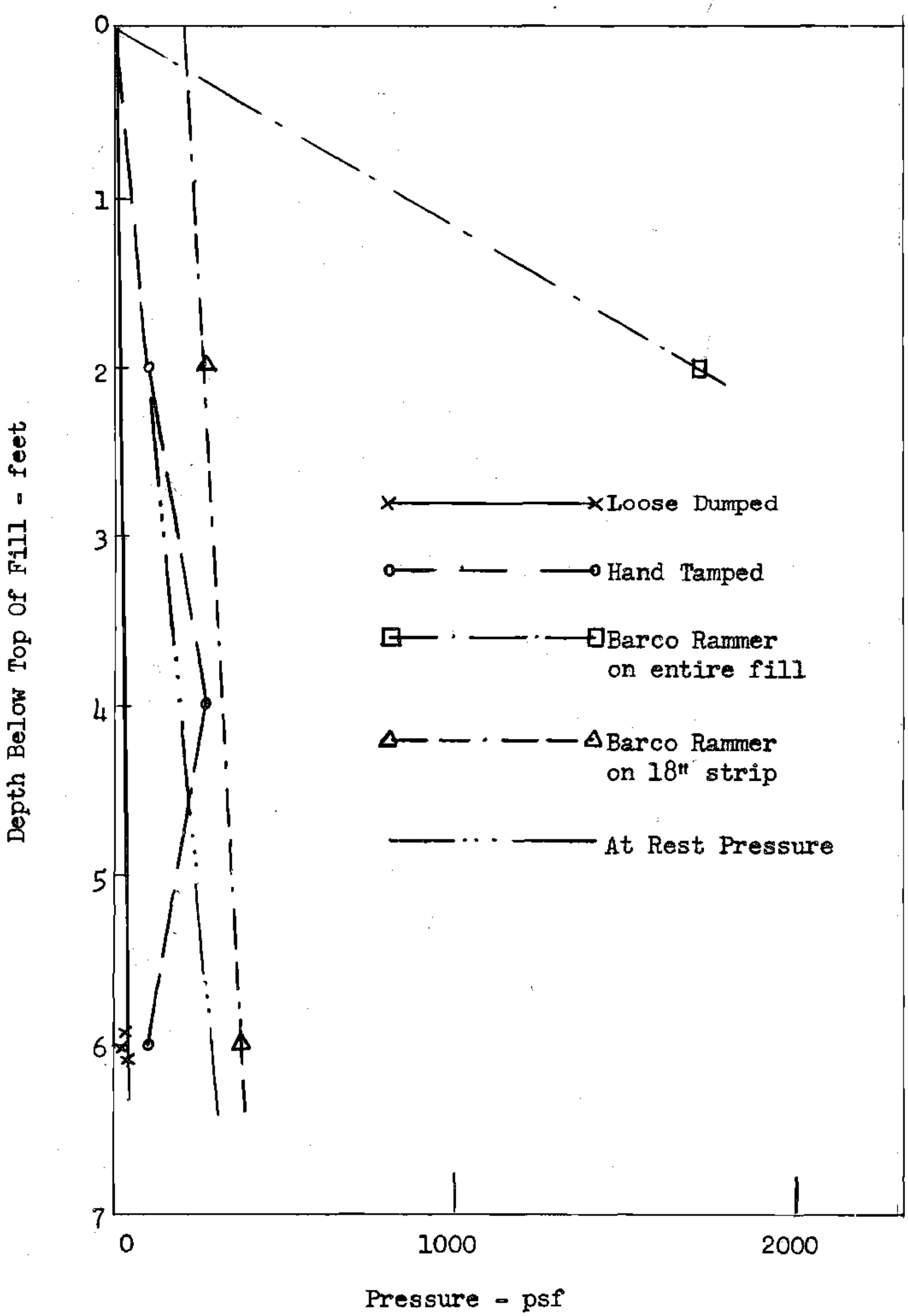

Fig. 7. Residual Lateral Pressure As Function Of Depth Below The Surface

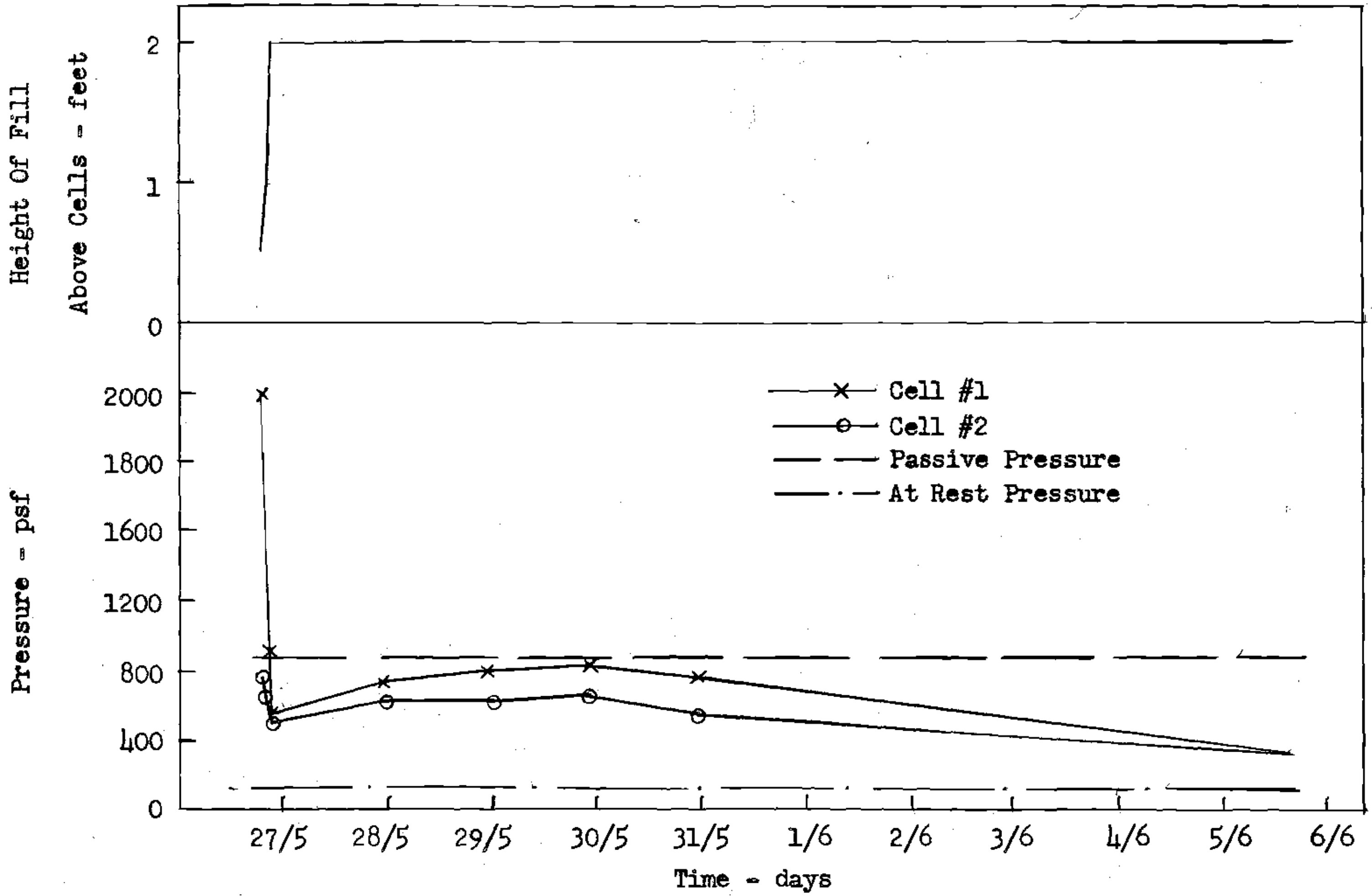

Fig. 8. Residual Lateral Pressure As Function Of Time - Test IV

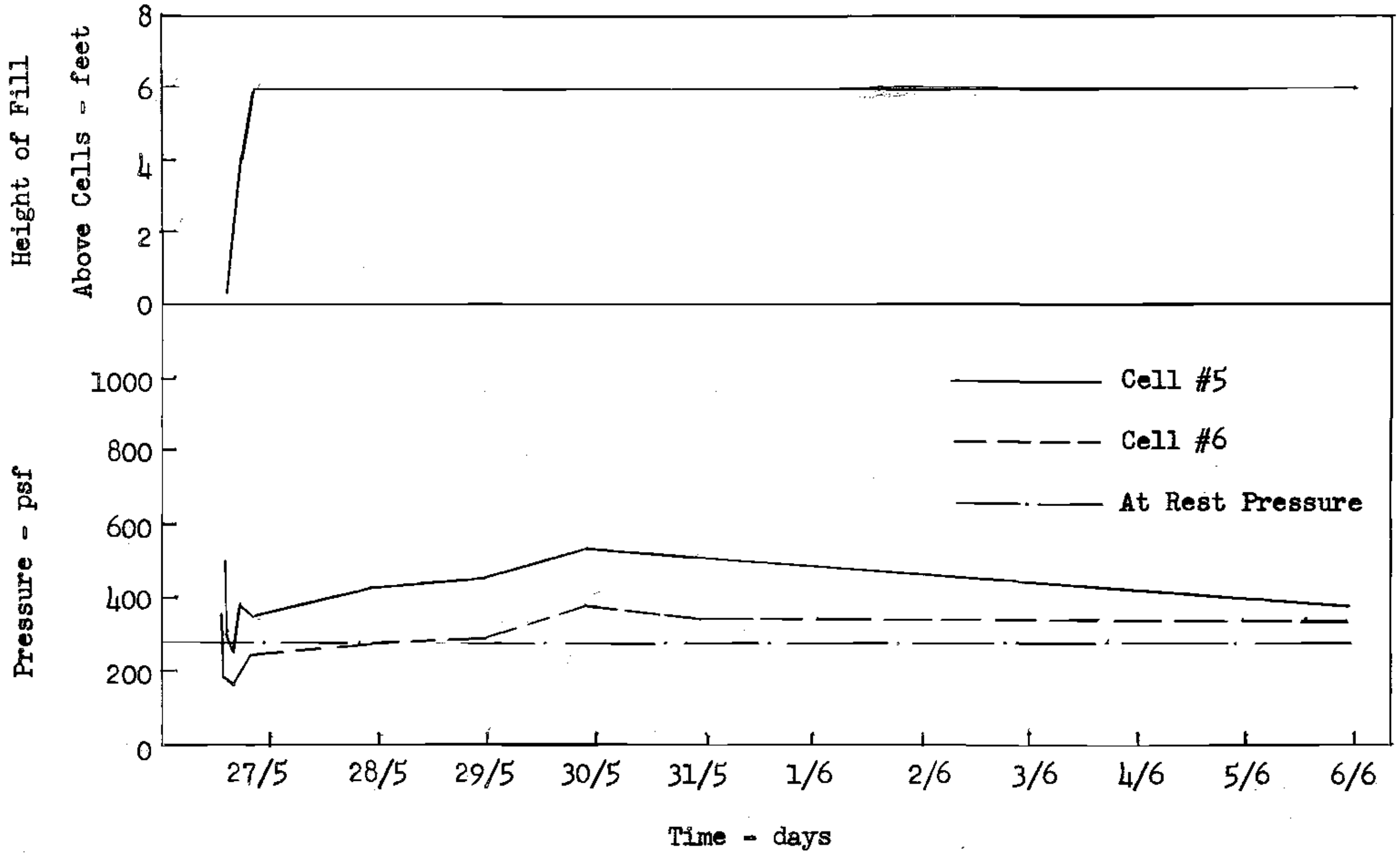

Fig. 9. Residual Lateral Pressure As Function Of Time - Test IV

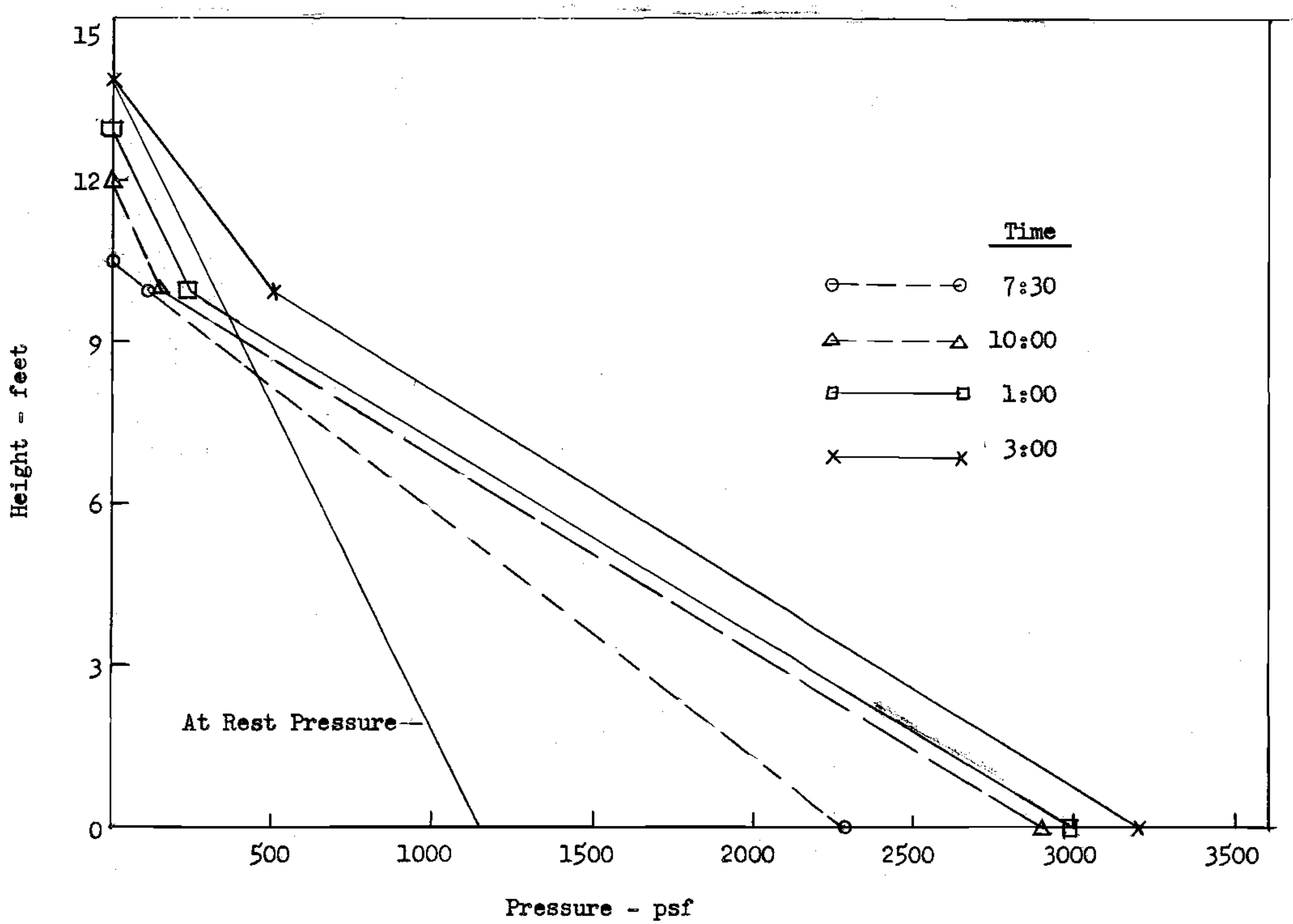

Fig. 10. Residual Lateral Pressure As Function Of Height - Test V, August 27, 1956

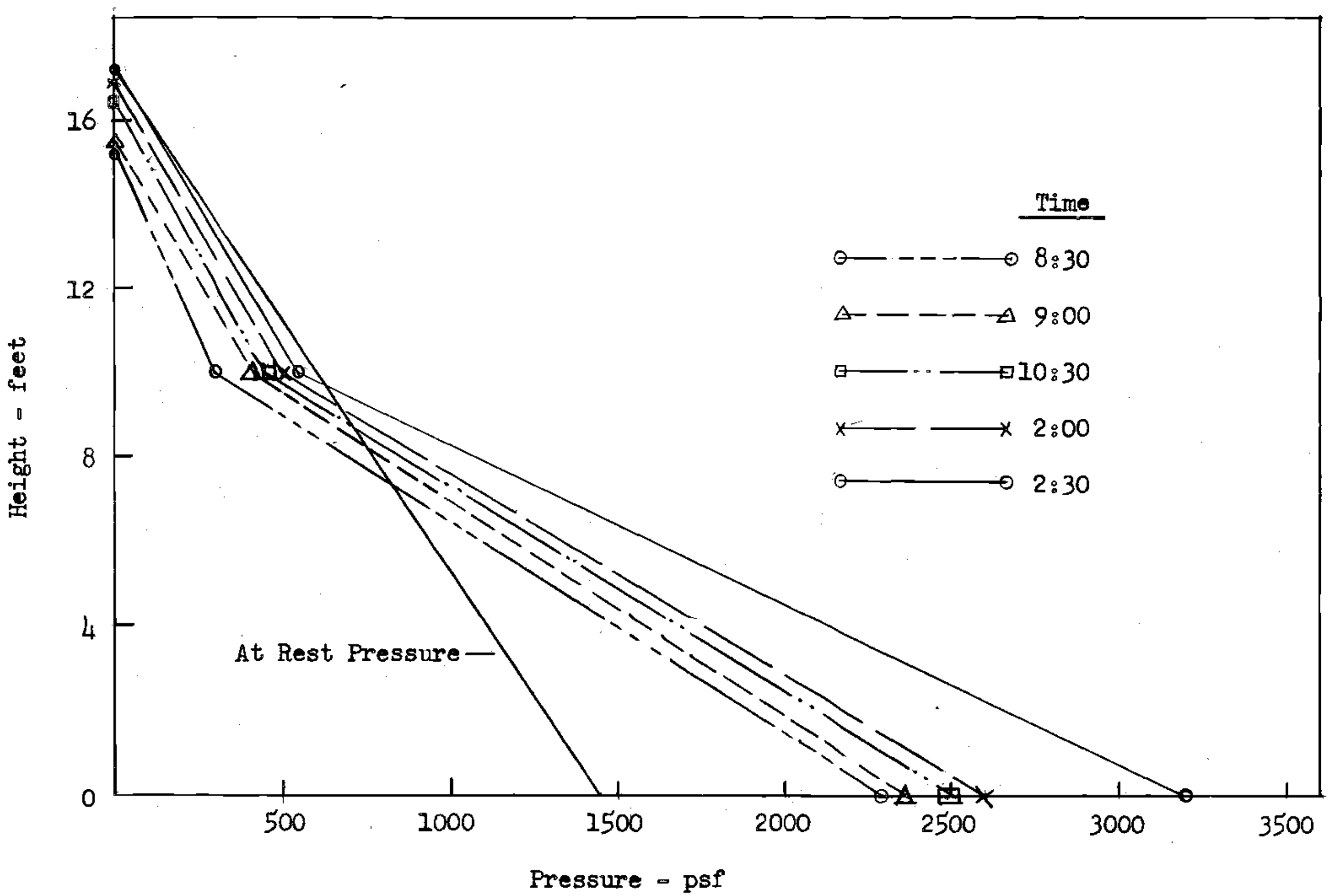

Fig. 11. Residual Lateral Pressure As Function Of Height - Test V, August 28, 1956

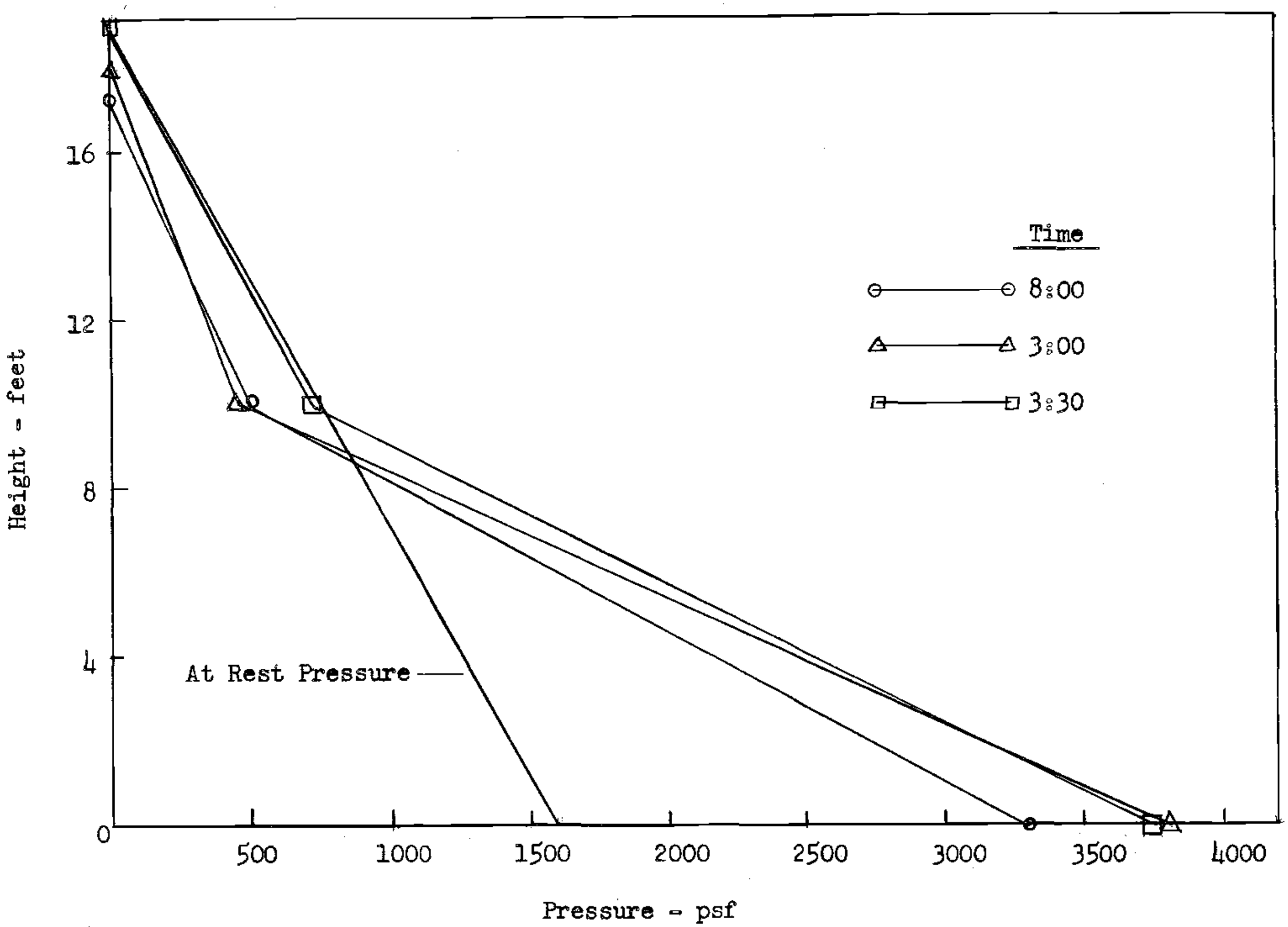

Fig. 12. Residual Lateral Pressure As Function Of Height - Test V, August 29, 1956

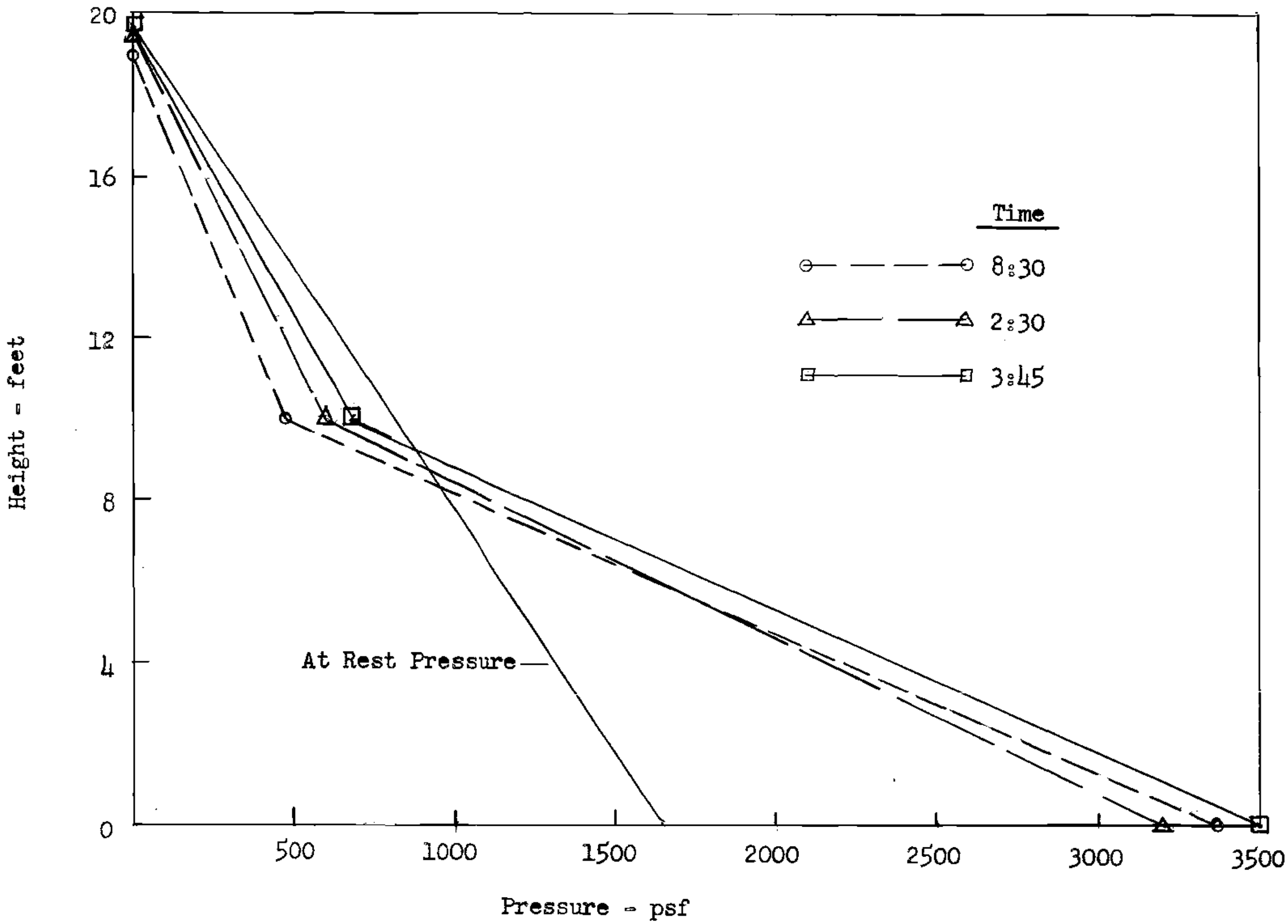

Fig. 13. Residual Lateral Pressure As Function Of Height - Test V, August 30, 1956

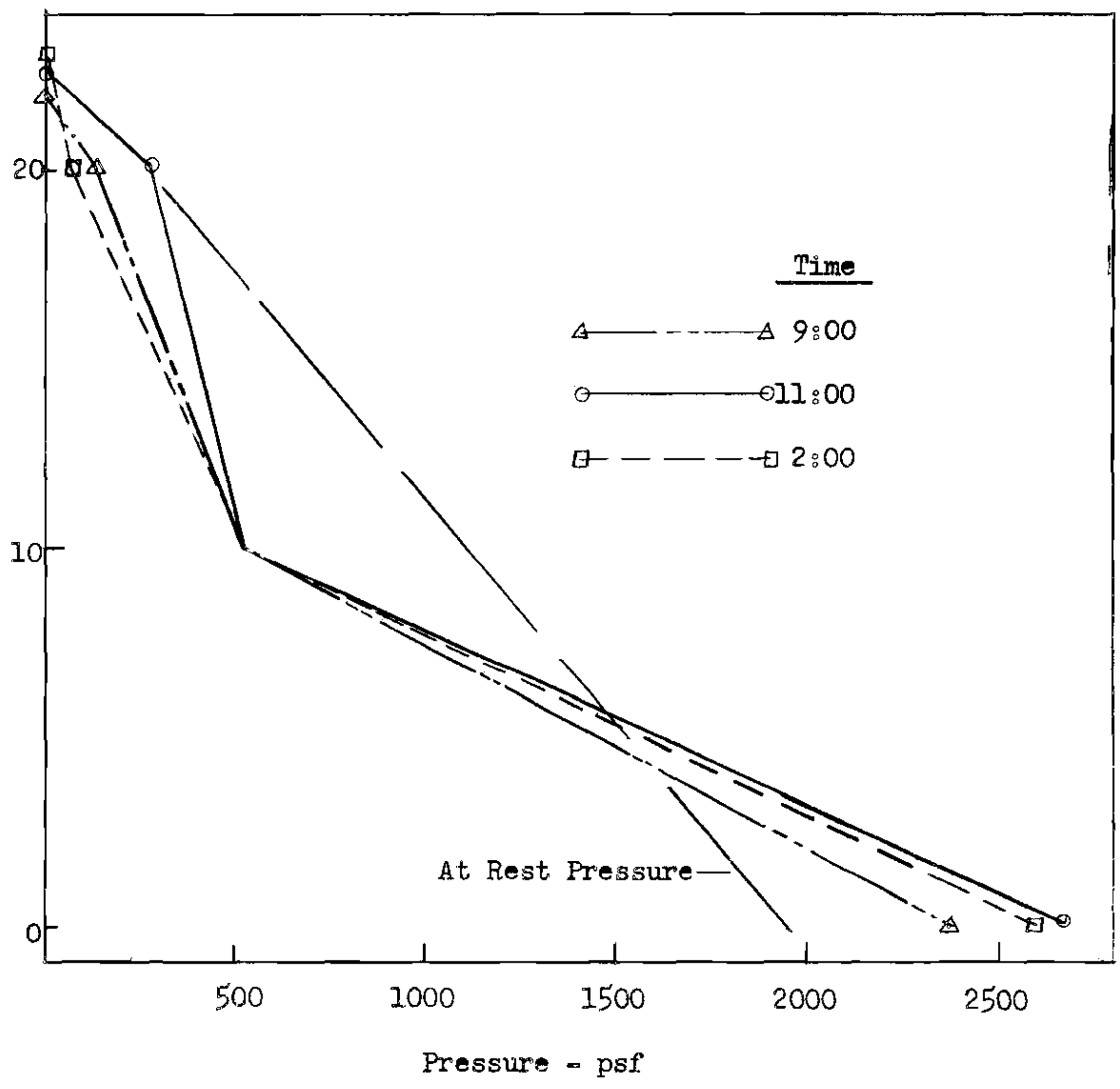

Fig. 14. Residual Lateral Pressure As Function Of Height

Test V, September 4, 1956

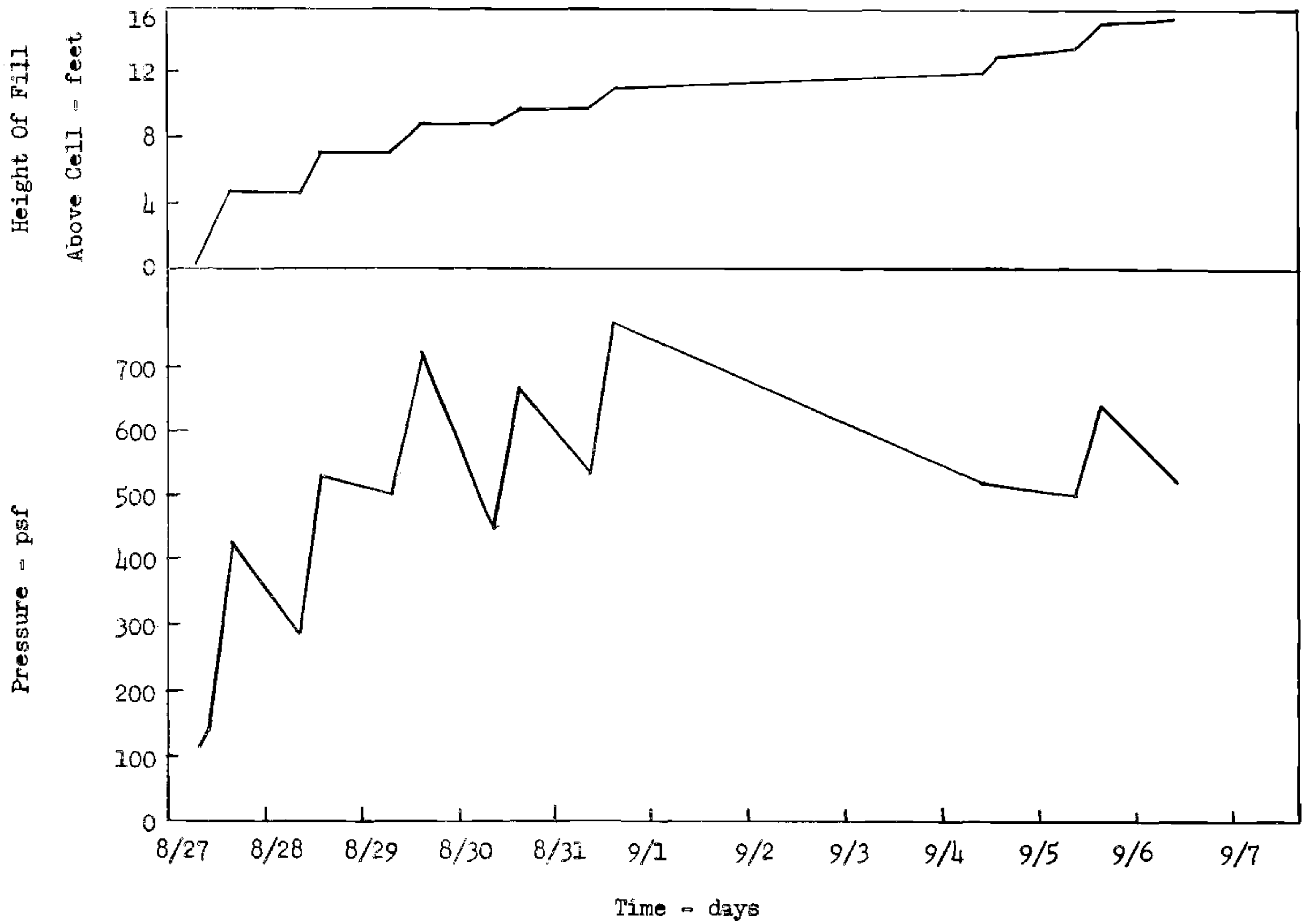

Fig. 15. Residual Lateral Pressure As Function Of Time - Test V, Cell #1

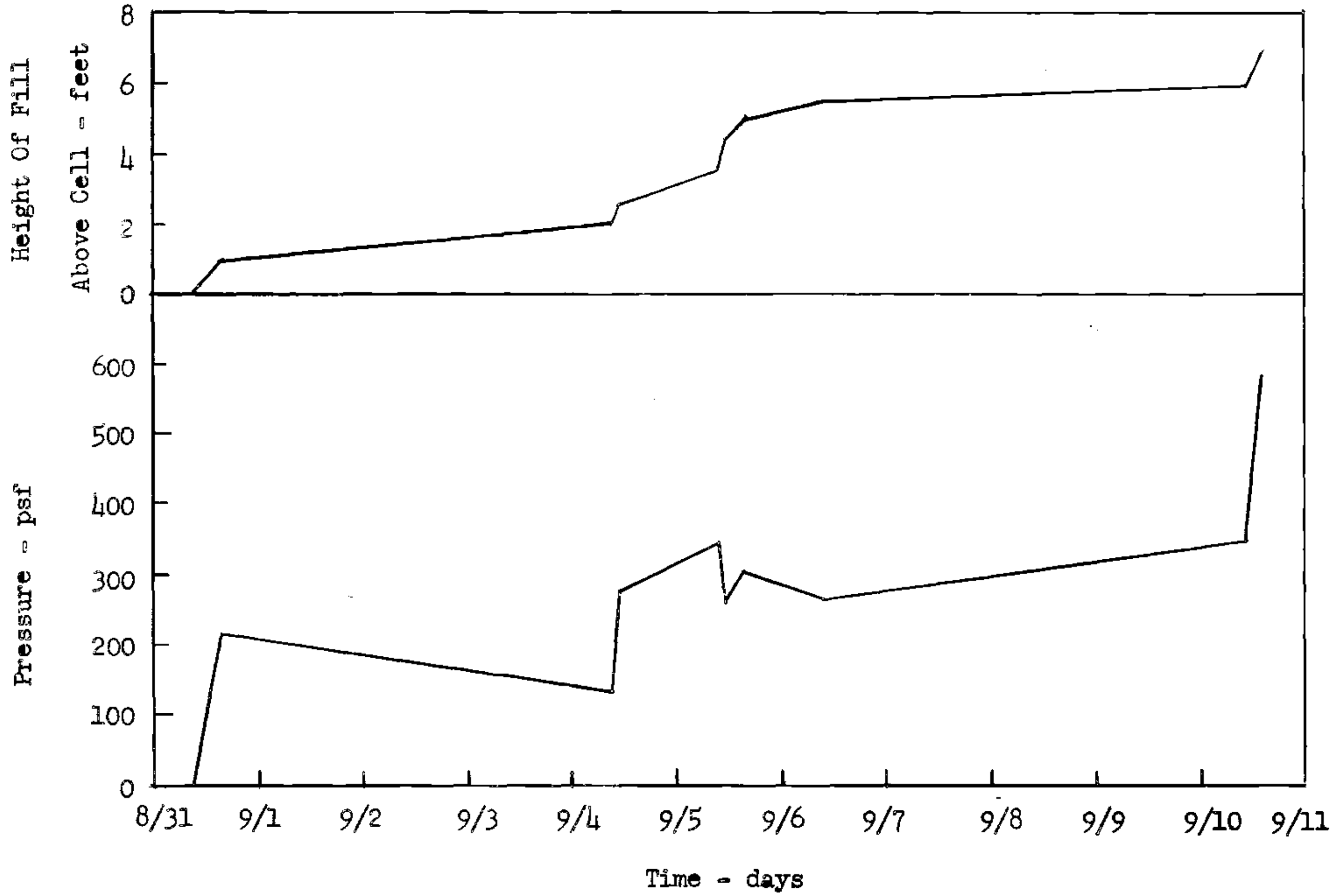

Fig. 16. Residual Lateral Pressure As Function Of Time - Test IV, Cell #5

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