CONSOLIDATION PROPERTIES OF SOILS
IN THE BEIRUT AREA

By

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SYMBOLS

With few exceptions the symbols used in this report conform generally to those suggested in 1941 by the American Society of Civil Engineers (Soil Mechanics Nomenclature, Manual of Engineering Practice No. 22).

It is noted that if no dimension is added to a symbol, the symbol indicates a pure number.

a_v (cm^2/g)	=	Coefficient of compressibility.
C_{c1}	=	Compression index for pressures below the preconsolidation load.
C_{c2}	=	Compression index for pressures above the preconsolidation load.
c_v (cm^2/min)	=	Coefficient of consolidation.
e	=	Void ratio.
e_o	=	Original void ratio.
Δe	=	Change in void ratio.
H (m)	=	(Thickness of soil layer (single drainage).) (Half-thickness of soil layer (double drainage).
H_o (m)	=	Original thickness of soil layer.
ΔH_1 (cm)	=	Consolidation due to pressures below the preconsolidation load.
ΔH_2 (cm)	=	Consolidation due to pressures above the preconsolidation load.
ΔH (cm)	=	Total consolidation.

k (cm/sec.)	=	Coefficient of permeability.
L_w	=	Liquid limit.
m_v (cm^2/g)	=	Coefficient of volume compressibility.
p (kg/cm^2)	=	Pressure.
p_c (kg/cm^2)	=	Preconsolidation pressure.
p_o (kg/cm^2)	=	Initial existing pressure.
P_w (%)	=	Plastic limit.
Δp (kg/cm^2)	=	Change in pressure.
t (min)	=	Time.
T_v	=	Time factor.
u (kg/cm^2)	=	Excess hydrostatic pressure.
U %	=	Degree of consolidation.
z (cm)	=	Depth.
γ_w (g/cm^3)	=	Unit weight of water.

CHAPTER I

INTRODUCTION

The study of soil settlement under various structures is of the utmost importance in many cases. Settlement may result in the total or partial failure of buildings, dams, retaining walls, towers, and other heavy structures. Even when failure does not occur, the effects of settlement such as unsightly cracks, uneven floors and other objectionable phenomena are too obvious to be ignored.

Whereas it is not possible and certainly not economical to design a structure to have no settlement at all, it is certainly possible, except in very rare cases, to control that settlement and to keep it within tolerable limits so as to eliminate any hazards for the safety and utility of the structure.

The problem of settlement, which in the case of cohesive soils is a direct consequence of the time-dependant consolidation under loading, acquires more serious proportions in areas where thick layers of such soils occur.

While the City of Beirut is not particularly unlucky in the type of soils it has so far as foundations are concerned, it is not known whether the prevailing types of soil deposits occuring in various parts of the City do present a settlement problem, especially in view of the increasingly heavier structures that are currently being constructed.

If information on the consolidation properties of the major soil types occuring in the Beirut Area were available to the design engineer, such information would serve the very useful function of reducing the amount of effort and cost necessary to predict the expected settlements of various types of proposed foundations, especially during the preliminary design phase.

This report is an effort towards obtaining this needed information and it is hoped that it will stimulate further work along these lines.

CHAPTER II

PURPOSE AND SCOPE

The purpose of this work is to study the consolidation properties of typical soils in the Beirut Area with a view of determining whether such soils present a problem to the foundation engineer so far as the amounts and the rates of settlement are concerned. It is noted here that studies of the settlement characteristics of soils in Beirut are lacking, and it is therefore hoped that this study would partially fill this gap.

To achieve this purpose undisturbed samples of soil were obtained from six areas within Beirut proper and were tested in the consolidation machine. In addition, several other tests were conducted on each type of soil for identification and classification purposes and for determining their strength properties. The six areas in question were:

A - Achrafiyeh

B - Bechara El-Khoury Street

C - Baalbeck Street

D - Nahr

E - Hamra Street

F - Maamari Street

From each of these areas five soil samples were obtained and tested, with the exception of the Nahr area from which, due to lack of testing facilities at the time, four samples only were secured and tested. The total number of samples tested was thus 29.

The results of the consolidation tests were analysed to obtain the soil properties to be used as criteria in the prediction of settlements.

These properties were then used to estimate the settlement of each soil type under various intensities of loading and the results were finally presented in the form of tables and graphs for quick reference.

CHAPTER III

SAMPLING AND TESTING

A - SAMPLING

Samples of the soil specimens required for testing were obtained from building foundation excavations conveniently located in the areas under study. Great care was exercised to obtain as undisturbed samples as possible for performing the consolidation and the unconfined compression tests, while for the classification and identification tests representative bag samples were secured. To obtain undisturbed samples for the consolidation test, the consolidation test ring itself was used. Care was taken to push the ring into the natural soil gently to avoid disturbance as much as possible.

For the unconfined compression tests, undisturbed samples were obtained by using thin-wall brass tubes, 1.5 inches in diameter and 4.5 inches in height, which were also pushed gently into the soil. The samples of soil were later extracted from these thin-wall tubes, carefully cut to a length of 3 inches and tested.

B - TESTING

The following tests were performed on the samples representing six major types of soil:

- Grain size analysis, sieve and hydrometer) one test per type
- Atterberg limits, liquid and plastic)
- Unconfined compression) a test on every soil sample
- Consolidation)

Furthermore the soils were classified according to the Unified Soil Classification System.

The consolidation tests were performed in 3.0 inch diameter and 0.8 inch high fixed-ring consolidometers using standard procedures. Free drainage discs were provided on both faces of the sample which was kept completely saturated during the entire testing period. The loading cycle was started with a load of 1/4 kg/cm^2 which was doubled every 24 hours until a load of 8 kg/cm^2 was reached. On two groups of soils, namely those from Nahr and Baalbeck Street, the loading was followed with an unloading cycle in which the load was reduced to a quarter of its value once every 24 hours until a load of 1/4 kg/cm^2 was again attained.

The results of all the tests described above are found in the Appendix to this study. (Page 67-98)

CHAPTER IV

ANALYSIS OF DATA

This chapter deals with the methods which were employed in analyzing the data made available from the tests conducted on the different types of soil. The information thus obtained was later used in the preparation of tables and graphs which summarize the essential findings of this study.

As has already been pointed out, the objective of this study was to investigate the consolidation characteristics of soils typical of the Beirut Area in order to ascertain whether such soils present a settlement problem in the study and design of building foundations. The consolidation test was therefore used, together with some other tests, to evaluate these soils and to predict the settlement of foundations placed on them.

The first step in analyzing the results of the consolidation tests was to obtain the various soil parameters, such as the coefficient of consolidation c_v, the coefficient of volume compressibility m_v, the coefficient of permeability k, and the compression index C_c.

These parameters were used to calculate the amounts of total expected settlement and the rate of such settlement of each type of soil under various conditions of pressure increments.

A - THEORY

The partial differential equation which is the basis of the theory of one-dimensional consolidation of soils is of the following well-known form:

$$c_v \cdot \frac{\partial^2 u}{\partial z^2} = \frac{\partial u}{\partial t}$$

in which z and t are the independent variables of space and time respectively, u the dependent variable of excess hydrostatic pressure, and c_v a composite soil property called the coefficient of consolidation. This coefficient may also be expressed in terms of the permeability coefficient k, the unit weight of water γ_w and the volume compressibility of the soil m_v, thus:

$$c_v = \frac{k}{m_v \cdot \gamma_w}$$

The solution of the above equation reduces it to a form which makes possible the expression of the average degree of consolidation U in terms of a dimensionless factor T_v such that:

$$U\,\% = f\,(T_v)$$

Where

$$T_v = \frac{c_v \cdot t}{H^2}$$

In this equation H is the longest drainage path in the soil layer, and t is the time during which the soil consolidates.

To obtain c_v experimentally, the deformation-time curve of a given increment of load during a consolidation test is analyzed by one of two well-known fitting methods, namely the square-root-of-time fitting method and the logarithm-of-time fitting method. Knowing c_v, and the boundary conditions of the consolidating soil, the degree of consolidation corresponding to a given time interval may readily be calculated.

This is as far as the rate of settlement is concerned. The total expected amount of settlement on the other hand is found from considerations of void ratio change Δ_e as given by the following expression:

$$\Delta H = \frac{\Delta e}{1 + e_o} . H.$$

If the relation of void ratio change is known in terms of pressure change the above equation may be written in the following form:

$$\Delta H = \frac{H_o}{1 + e_o} . C_c . \log_{10} \frac{p_o + \Delta p}{p_o}$$

Where:

C_c = the compression index which is defined as the absolute value of the slope of the void ratio - pressure curve on a semi-logarithmic plot - (e-log p curve).

H_o = the original thickness of layer.

e_o = the corresponding initial void ratio.

p_o = the original pressure.

Δp = the pressure increment.

B - PARAMETERS

As has already been mentioned, the data available from the consolidation tests were used to compute some soil parameters which would in turn be employed to estimate the rate and the amount of total expected settlement.

- The Coefficient of Consolidation c_v:

The logarithm-of-time fitting method was used to find this coefficient from the deformation-time plots. The value of c_v was found for the increment of pressure from 1 to 2 kg/cm^2 as this range of pressure was considered to represent more nearly the actual increments of pressure on such soils under a normal type of footing. Since c_v is known to vary with the increments of loading, however, it was obtained for all load increments in the case of one soil to give an idea of the change of c_v with load increments. (See Fig. 9, p. 97)

- The Coefficient of Compressibility a_v;
- The Coefficient of Volume Compressibility m_v;
- The Coefficient of Permeability k

These three coefficients were computed for the pressure increment from 1 to 2 kg/cm^2 for the same reasons which called for the choice of this range in computing c_v. Similarly, as in the case of c_v, the values of the three coefficients were computed for all increments for one soil and the results shown in the Appendix. (Table 6, p. 98)

The coefficient of compressibility a_v is the numerical value of the slope of the void ratio-pressure curve. It was thus found from the arithmetic plot of the void ratio versus pressure. The other coefficients were then computed from the following expressions:

$$m_v = \frac{a_v}{1 + e_o}$$

$$k = c_v \cdot \gamma_w \cdot m_v$$

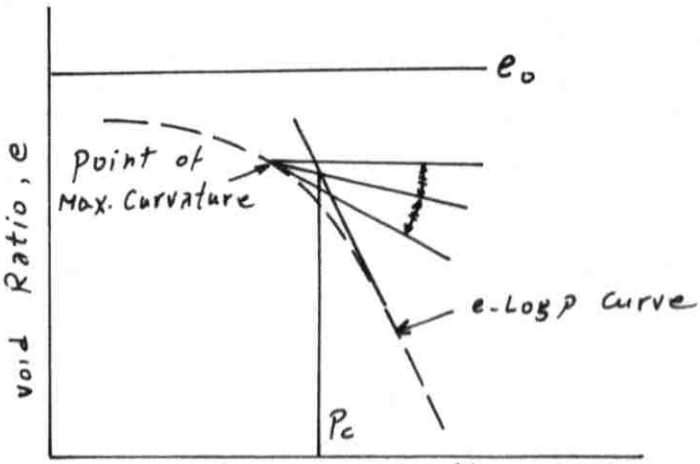
- <u>The Compression Index C_c</u>

The compression index of a soil is defined as the numerical value of the slope of the e-log p curve. For a soil which is normally loaded, a single compression index is sufficient to define the compressibility of the soil. However for a soil which has been precompressed, the compression index below the preconsolidation load is naturally smaller than that above this load.

The e-log p curve of the samples tested were examined and they were found to be typical of a preloaded clay of ordinary sensitivity[*1]. This preloading was probably due to the desiccation of the soil, the erosion of an overburden layer, the effects of sustained seepage forces, or to other factors.

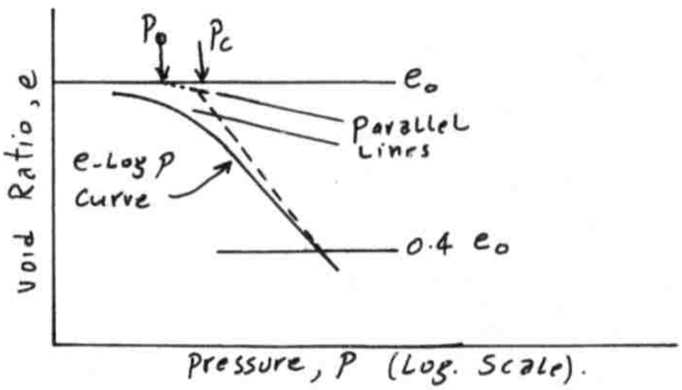
To determine the preconsolidation load for each soil the method proposed by A. Casagrande[*1 & 3] was used. In this method the e-log p curve is examined and the point of maximum curvature is found. The construction is then done as shown in the figure below, by bisecting the angle formed by the tangent to the curve at the point of maximum curvature and the horizontal line drawn through that point. The point of intersection of this bisector with the backward continuation of the straight portion of the curve is assumed to correspond to the preconsolidation load p_c.

* Superscript numbers refer to the references.



Graphical Contruction for determining P_c *1
(After A. Casagrande).

Having found p_c, the compression indices below and above p_c were then determined*3 as illustrated in the figure below:



Graphical construction for determing C_{c_1} + C_{c_2}. *3

On the e-log p curve a horizontal line was drawn through the point representing the initial void ratio e_o of the soil. Next, from the point representing the existing pressure on the soil in the field, p_o, and the corresponding void ratio e_o a line was drawn parallel to the first portion of the e-log p curve or to the rebound or unloading curve when such unloading was done. The slope of this line was then taken to be the compression index of the soil for pressures below the preconsolidation load.

To obtain the second compression index i.e. the index for pressures above p_c, the point of the intersection of the line defining the first compression index with the vertical line through p_c was noted. This point was then joined by a straight line to that point on the e-log p curve corresponding to $0.4\ e_o$. The slope of this second line was then taken to be equal to the compression index of the soil beyond the preconsolidation load [3].

C - TOTAL EXPECTED SETTLEMENT

Once the compression indices were found, the total expected settlement of a given soil layer could be computed. A soil layer one meter in thickness was considered, and its total expected settlement under different initial loading conditions and varying pressure increments was computed as follows:

The initial existing pressure p_o on the soil was computed from a knowledge of the depth at which the sample was obtained and the unit weight of the soil. The preconsolidation load was found by the graphical method explained earlier in this chapter (p. 11). The difference betwee p_o and p_c represents the difference between the maximum intergranular pressure on the soil in its past history and the existing intergranular pressure at the depth from which the sample was obtained. In other words (p_c-p_o) corresponds to the part of the overburden (or other cause of preconsolidation) which was removed leaving the soil at a lower existing pressure than the preconsolidation pressure.

Now if any other layer is considered, the existing pressure p_o would naturally be different from that on the layer from which the samples were obtained. The preconsolidation load p_c would likewise be different; but the difference between p_c and p_o represents the effect of the removal of the same part of the over-burden as that for the layer from which the samples were obtained, and therefore $(p_c - p_o)$ would be the same in both cases.

It can therefore be concluded that the value $(p_c - p_o)$ is constant at all depths, and that the preconsolidation load at any depth can be obtained by adding this constant value to the existing intergranular pressure p_o at that depth.

To obtain the amount of soil settlement of a layer one meter in thickness under different loading conditions, various pressure increments Δp were assumed to act at the middle of the layer which was itself taken at different depths. Thus the assumed Δp's are due to some loading intensities under the footings which would produce those Δp's at the middle of the one-meter-layer considered.

In computing the total intergranular pressure $(p_o + \Delta p)$, two cases were noted:

a) $p_o + \Delta p \leq p_c$

in which case the total expected settlement was based on the value of the first compression index which applies for pressures below p_c, and

b) $p_o + \Delta p > p_c$

in which case the total expected settlement was based on the values of both indices of compression, and thus two values of settlement were found and totalled, one due to the increase of pressure from p_o to p_c and the other due to the increase of pressure from p_c to $(p_o + \Delta p)$.

D - EXPECTED SETTLEMENT IN 25 YEARS

Having computed the total expected settlement of the different types of soil, it became necessary to assess how much of this total settlement would occur during the useful life of a structure.

A period of 25 years was chosen as a reasonable period of time for the life of normal structures, and the amount of settlement during that period, expressed as percent of total expected settlement, was computed. Results were presented in graphical form where percent consolidation in 25 years is plotted versus thickness of soil layers.

The case of single drainage only was considered. To obtain the percent consolidation in the case of double drainage, the graph for the single drainage case is entered with a soil thickness equal to half that of the doubly-drained layer.

CHAPTER V

RESULTS OF STUDY

This chapter includes in tabular and graphical form the results of this study.

As has been noted earlier, it is hoped that these results would be of use to those interested in the design of foundations in Beirut. The material in this chapter is intended to assist in comparing the soil encountered with the types studied in this report, and if applicable, in obtaining information on the consolidation properties of the soil in question.

A - CORRELATION AND AVERAGING OF RESULTS

A close inspection of the test results from each area shows that there is considerable similarity among the results of the individual soils. This similarity is exhibited on the e-log p curves and consequently on the e-p curves. The same can be said about the results of the unconfined compression tests.

It is commonly agreed, however, that there are various factors which influence the similarity of test results in Soil Mechanics. Notable among these factors are those attributable to personal errors and deviations during sampling and testing. Moreover, two soils can never be exactly the same even though they may be obtained from nearby locations in the same pit.

These discrepencies were notable in the case of this report, on soils from Achrafiyeh Area where two soils were found to deviate slightly from the other three on the e-log p curves.(Fig.1-A, p.25)

This brings us to the question of averaging. Averaging of test results tends to minimize the effects of errors encountered during testing and the effects due to the differences among the soils. The idea behind doing a number of tests on the same type of soil is to enable us to have fairly representative results which can be applied to the group of soil in question.

Hence it is believed that if the results of the tests on a certain soil fall within the curves of the individual soils of one of the groups studied here, the average results of that group of soils can be used to represent the properties of the soil in question.

B - PRESENTATION OF RESULTS

For each of the six soil groups studied, the following average results are presented.

1 - Soil Identification and Properties

Giving the properties of the soil obtained by the various tests including the consolidation test. Each soil is further identified visually and given a classification according to the Unified Soil Classification System. (See p. 19-24)

2 - Total Expected Settlement

This is presented in graphical form giving the amount of the total expected settlement per meter thickness of soil at various depths and for several intensities of loading at the middle of the layer. (Figs.3A,4A;3B,4B;3C,4C;3D,4D;3E,4E;3F,4F)

3 - Settlement in 25 Years

A graph is presented giving the percentage consolidation in 25 years as a function of the thickness of the consolidating layer. The case of single drainage only is presented, since to obtain the percent consolidation of a doubly-drained layer it is only necessary to enter the graph with a thickness equal to half the thickness of the doubly draining soil. (See Figs. 5A, 5B, 5C, 5D, 5E, 5F)

C - USE OF RESULTS

In order to use these results to estimate the settlement of a foundation soil in the Beirut Area, the following steps should be taken:

1 - Soil Profile

A soil profile of the site should be obtained showing the types and thicknesses of the different soil layers.

2 - Testing

The following tests should then be performed on samples of soil obtained from the layer in question:

a) Identification of the soil by the "unified soil classification system".

b) Atterberg limits tests: liquid and plastic.

c) Sieve analysis (including hydrometer).

d) One unconfined compression test (on undisturbed and remoulded sample).

e) One consolidation test on an undisturbed sample.

3 - Determination of Δp, p_o and p_c

With the soil profile known, the preliminary location of the footings could be chosen. Moreover, knowing the loads on the footings, the pressure increments Δp at the middle of the layers considered could be determined by some method of pressure distribution.

p_o would be computed from a knowledge of the unit weight of the soil and the depth of the layer.

The value of p_c would be obtained from the e-log p curve of the consolidation test.

4 - Comparison of Results

The results of the tests and computations for the soil in question would now be compared with the corresponding values for the groups of soil studied in this report. In particular the e-log p curve obtained would be compared with the group of e-log p curves it resembles most; the values of p_c are also compared as well as all other test results.

5 - If it is found that the results of the tests on the soil fit closely within the results of one of the soil groups studied, then the appropriate charts for that group would give a preliminary estimate of the amount and rate of expected settlement. This estimate would indicate whether a settlement problem exists and whether further and more detailed settlement studies should be performed.

ACHRAFIYEH AREA

AVERAGE SOIL PROPERTIES

A - Sampling:

Average depth of samples : 5 meters

B - Identification:

Very stiff whitish silty-clay, (CL)

58% passing No. 200 sieve

C - Properties:

Natural unit weight : 1.77 g/cc

Specific gravity : 2.70

Atterberg limits%

L_w : 35

P_w : 16

Unconfined compressive strength:

Undisturbed : 3.12 kg/cm^2

Remoulded : 2.80 kg/cm^2

Sensitivity : 1.12

D - Results of the consolidation tests:

$C_{c1} = 0.046$ $P_c = 1.40\ kg/cm^2$

$C_{c2} = 0.240$ $P_o = 0.90\ kg/cm^2$

For a pressure increment of 1-2 kg/cm^2:

$c_v = 0.024\ cm^2/min.$

$a_v = 4.0 \times 10^{-5}\ cm^2/g$

$m_v = 2.12 \times 10^{-5}\ cm^2/g$

$k = 0.93 \times 10^{-8}\ cm/sec.$

BECHARA EL-KHOURY STREET AREA

AVERAGE SOIL PROPERTIES

A - Sampling:

Average depth of samples : 5.5 meters

B - Identification:

Stiff brown silty-sandy-clay (ML)

75% passing No. 200 sieve.

C - Properties:

Natural unit weight : 1.73 g/cc

Specific gravity : 2.68

Atterberg limits %

L_w : 41

P_w : 28

Unconfined compressive strength:

Undisturbed : 1.93 kg/cm^2

Remoulded : 1.55 kg/cm^2

Sensitivity : 1.25

D - Results of the consolidation tests:

C_{c1} = 0.075 P_c = 1.30 kg/cm^2

C_{c2} = 0.260 P_o = 0.95 kg/cm^2

For a pressure increment of 1-2 kg/cm^2

$c_v = 0.0706\ cm^2/min.$

$a_v = 5.0 \times 10^{-5}\ cm2/g$

$m_v = 2.38 \times 10^{-5}\ cm^2/g$

$k = 2.80 \times 10^{-8}\ cm/sec.$

BAALBECK STREET AREA

AVERAGE SOIL PROPERTIES

A - Sampling:

Average depth at which samples were taken : 4.9 meters

B - Identification:

Very stiff brown to whitish sandy-silty-clay, (CL-ML)

73% passing No. 200 sieve

C - Properties:

Natural unit weight : 2.04 g/cc

Specific gravity : 2.64

Atterberg limits %

L_w : 25

P_w : 20

Unconfined compressive strength:

Undisturbed : 2.45 kg/cm^2

Remoulded : 2.04 kg/cm^2

Sensitivity : 1.20

D - Results of the consolidation tests:

C_{c1} = 0.086 P_c = 1.65 kg/cm^2

Cc_2 = 0.141 P_o = 1.00 kg/cm^2

For a pressure increment of 1-2 kg/cm^2

c_v = 0.091 $cm^2/min.$

$a_v = \frac{2.6}{10^5}\ cm^2/g$

$m_v = 1.60 \times 10^{-5}\ cm^2/g$

$k = 2.42 \times 10^{-8}$ cm/sec.

NAHR AREA

AVERAGE SOIL PROPERTIES

A - Sampling:

Average depth at which samples were taken: 1.70 meters

B - Identification:

Stiff brownish silty-clay (CL)

81% passing No. 200 sieve.

C - Properties

Natural unit weight : 2.03 g/cc

Specific gravity : 2.72

Atterberg limits %

L_w : 42

P_w : 25

Unconfined compressive strength:

Undisturbed : 2.02 kg/cm^2

Remoulded : 1.70 kg/cm^2

Sensitivity : 1.19

D - Results of the consolidation tests:

$C_{c1} = 0.082$ $P_c = 1.15$ kg/cm^2

$C_{c2} = 0.302$ $P_o = 0.35$ kg/cm^2

For a pressure increment of 1-2 kg/cm^2

$c_v = 0.0084$ cm^2/min.

$a_v = 5.82 \times 10^{-5}$ cm^2/g

$m_v = 3.34 \times 10^{-5}$ cm^2/g

$k = 0.41 \times 10^{-8}$ cm/sec.

HAMRA STREET AREA

AVERAGE SOIL PROPERTIES

A - **Sampling:**

Average depth at which samples were taken : 5 meters

B - **Identification:**

Very stiff dark to medium brown silty-clay (ML)

79% passing No. 200 sieve.

C - **Properties:**

Natural unit weight	: 1.60 g/cc
Specific gravity	: 2.66
Atterberg limits %	
L_w	: 30
P_w	: 24
Unconfined compressive strength:	
Undisturbed	: 2.90 kg/cm^2
Remoulded	: 2.33 kg/cm^2
Sensitivity	: 1.24

D - **Results of the consolidation tests:**

$C_{c1} = 0.073$ $P_c = 1.00\ kg/cm^2$

$C_{c2} = 0.200$ $P_o = 0.80\ kg/cm^2$

For a pressure increment of 1-2 kg/cm^2

$c_v = 0.1140\ cm^2/min.$

$a_v = 4.06 \times 10^{-5}\ cm^2/g$

$m_v = 1.86 \times 10^{-5}\ cm^2/g$

$k = 3.7 \times 10^{-8}\ cm/sec.$

MAAMARI STREET AREA

AVERAGE SOIL PROPERTIES

A - Sampling:

Average depth at which samples were taken : 4 meters

B - Identification:

Very stiff, light to medium brown silty-sandy-clay (CL)

77% passing No. 200 sieve.

C - Properties

Natural unit weight : 1.85 g/cc

Specific gravity : 2.67

Atterberg limits %

L_w : 30

P_w : 20

Unconfined compressive strength:

Undisturbed : 3.04 kg/cm^2

Remoulded : 2.26 kg/cm^2

Sensitivity : 1.35

D - Results of the consolidation tests:

$C_{c1} = 0.075$ $P_c = 0.90$ kg/cm^2

$C_{c2} = 0.190$ $P_o = 0.75$ kg/cm^2

For a pressure increment of 1-2 kg/cm^2

$c_v = 0.0490$ cm^2/min.

$a_v = 4.3 \times 10^{-5}$ cm^2/g

$m_v = 2.37 \times 10^{-5}$ cm^2/g

$k = 1.77 \times 10^{-8}$ cm/sec.

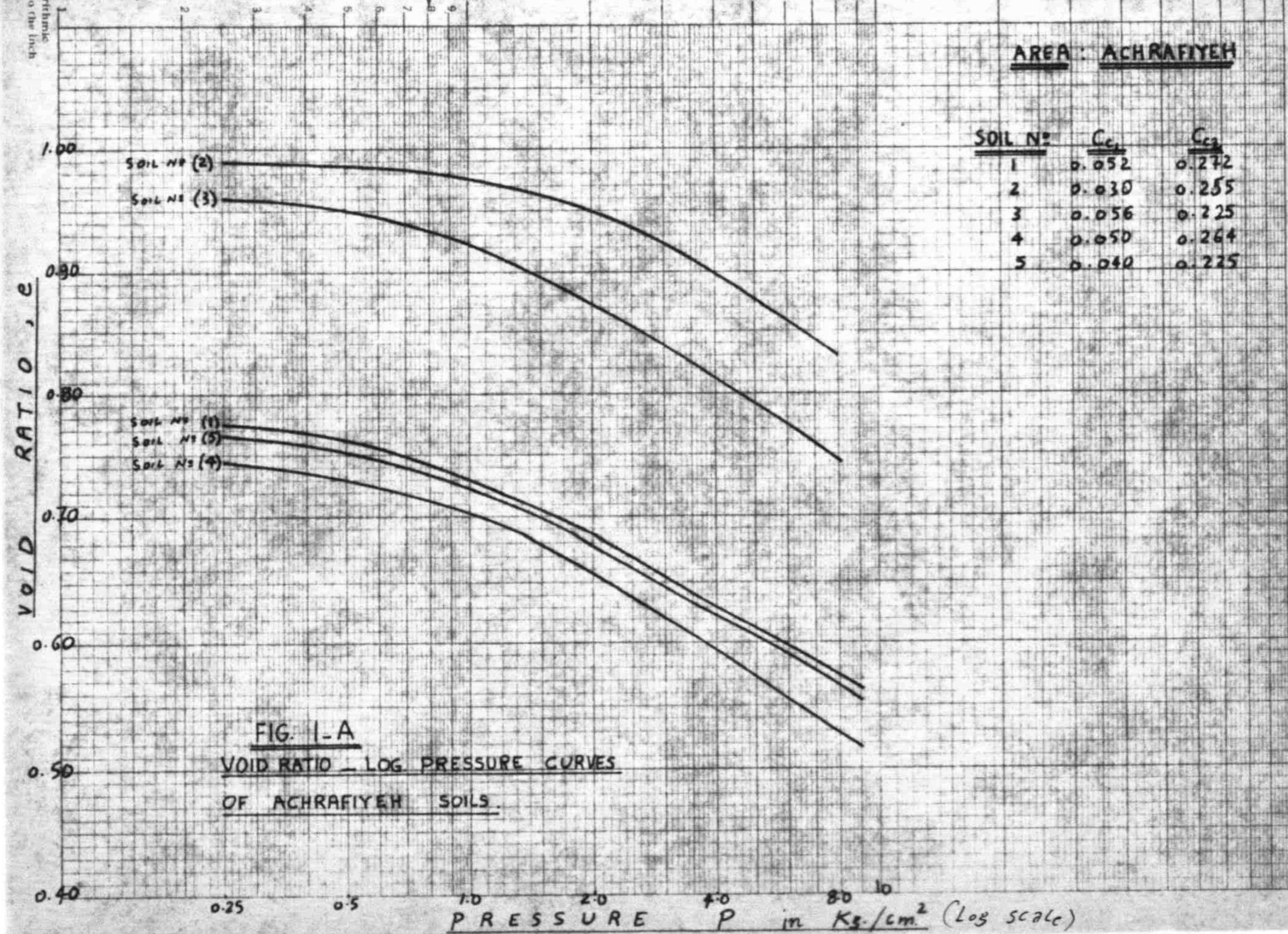


FIG. 1-A
VOID RATIO _ LOG PRESSURE CURVES
OF ACHRAFIYEH SOILS.

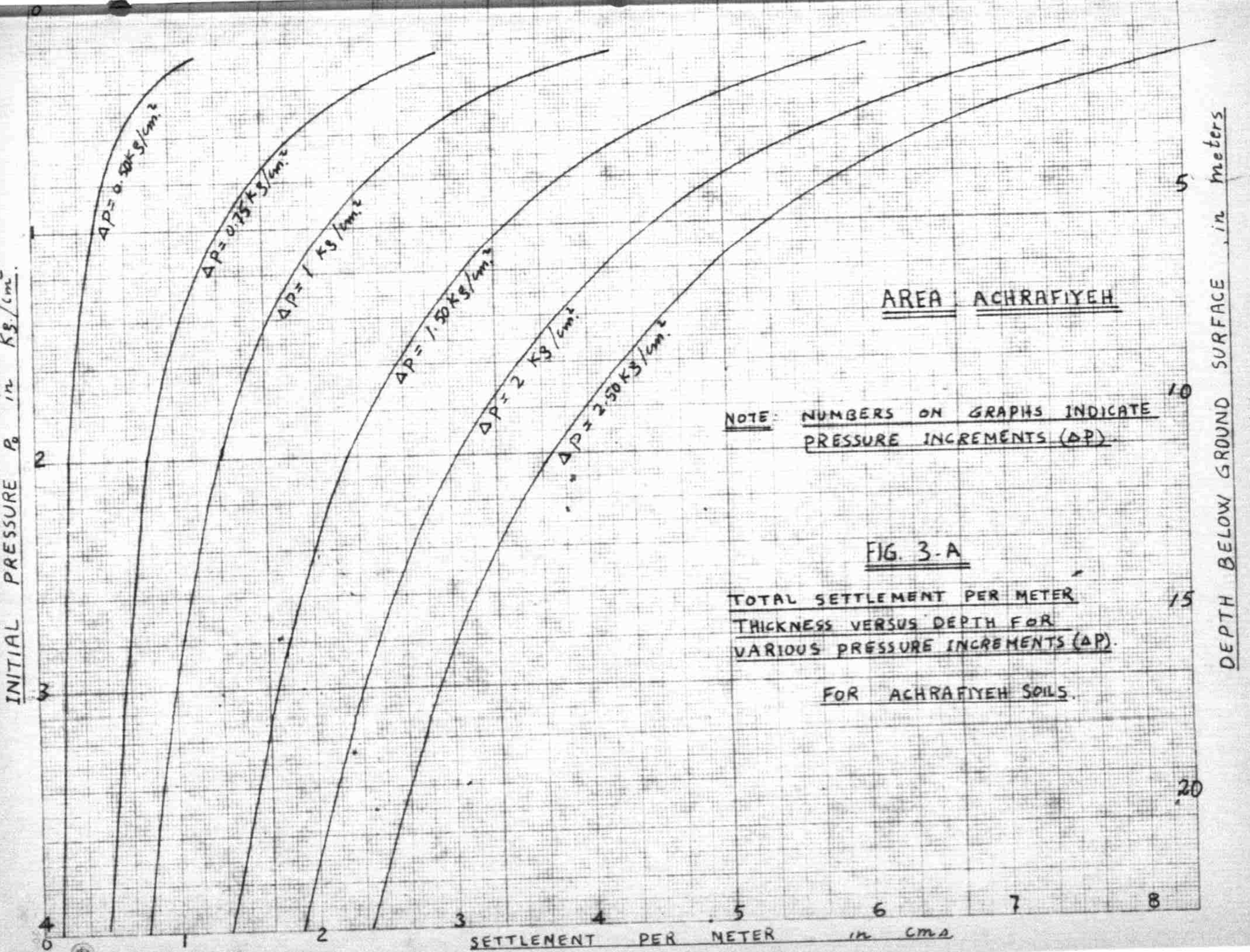
AREA : ACHRAFIYEH

SOIL No.	a_v, cm²/g.	m_v, cm²/g.	k, cm/sec.
1	4.7×10^{-5}	2.50×10^{-5}	0.48×10^{-8}
2	2.5×10^{-5}	1.20×10^{-5}	0.50×10^{-8}
3	4.5×10^{-5}	2.31×10^{-5}	0.97×10^{-8}
4	4.5×10^{-5}	2.51×10^{-5}	1.34×10^{-8}
5	3.7×10^{-5}	2.12×10^{-5}	1.33×10^{-8}

NOTE: ALL VALUES ARE FOR A PRESSURE INCREMENT OF 1-2 Kg./cm².

FIG. 2-A.

VOID RATIO — PRESSURE CURVES OF ACHRAFIYEH SOILS.



AREA ACHRAFIYEH

NOTE: NUMBERS ON GRAPHS INDICATE PRESSURE INCREMENTS (ΔP).

FIG. 3-A

TOTAL SETTLEMENT PER METER THICKNESS VERSUS DEPTH FOR VARIOUS PRESSURE INCREMENTS (ΔP).

FOR ACHRAFIYEH SOILS.

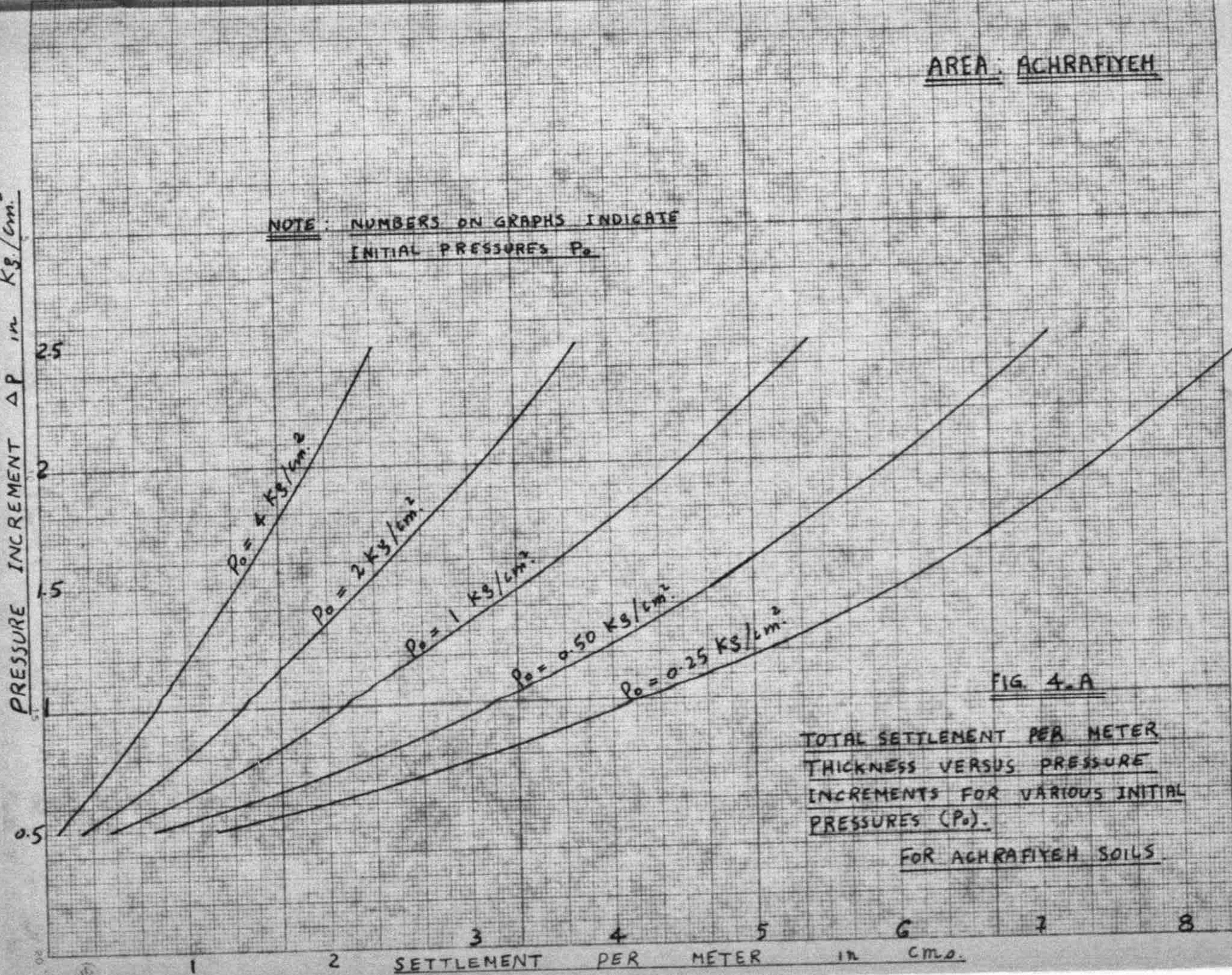


FIG. 4.A

TOTAL SETTLEMENT PER METER THICKNESS VERSUS PRESSURE INCREMENTS FOR VARIOUS INITIAL PRESSURES (P_o).

FOR ACHRAFIYEH SOILS.

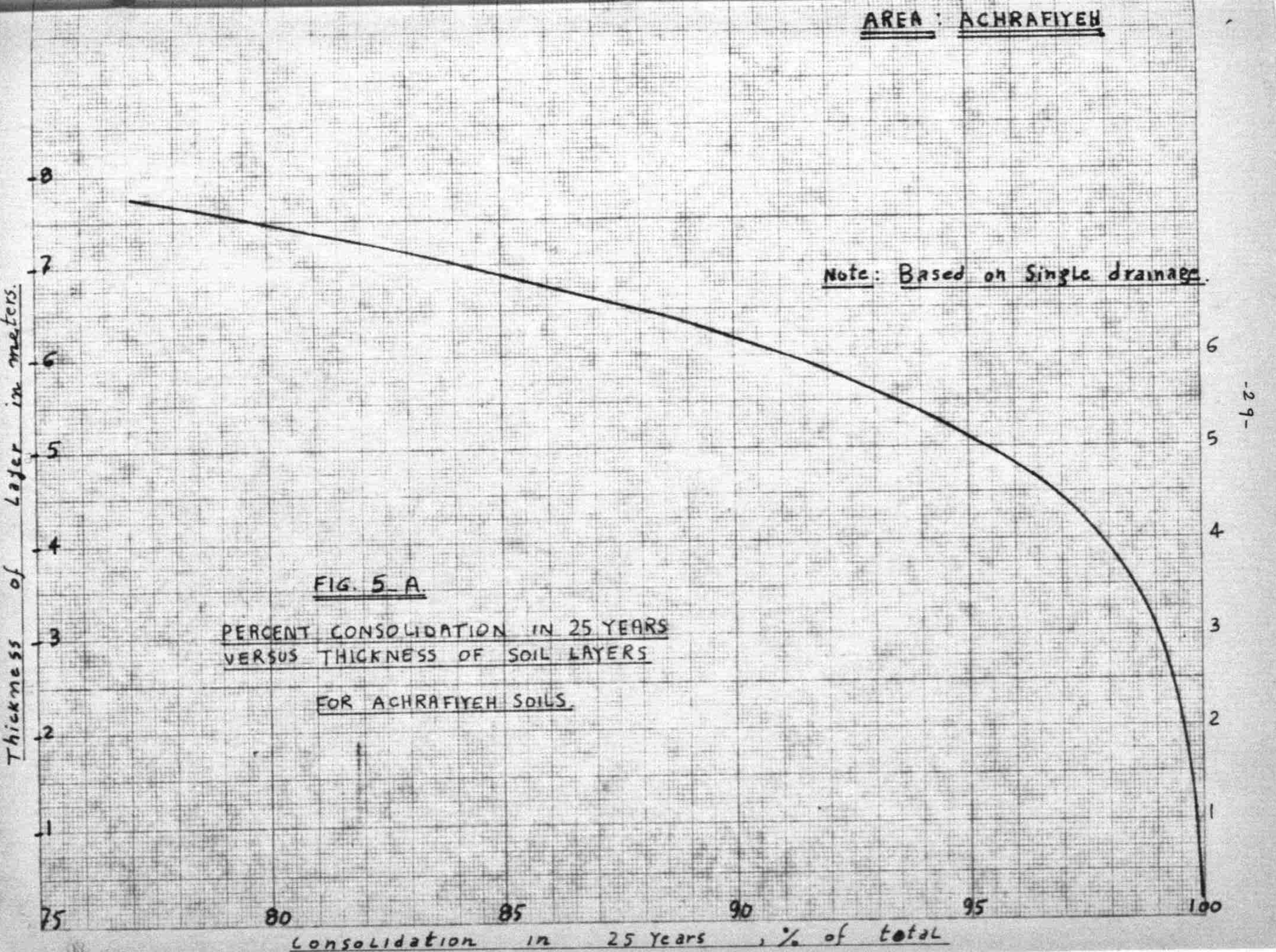
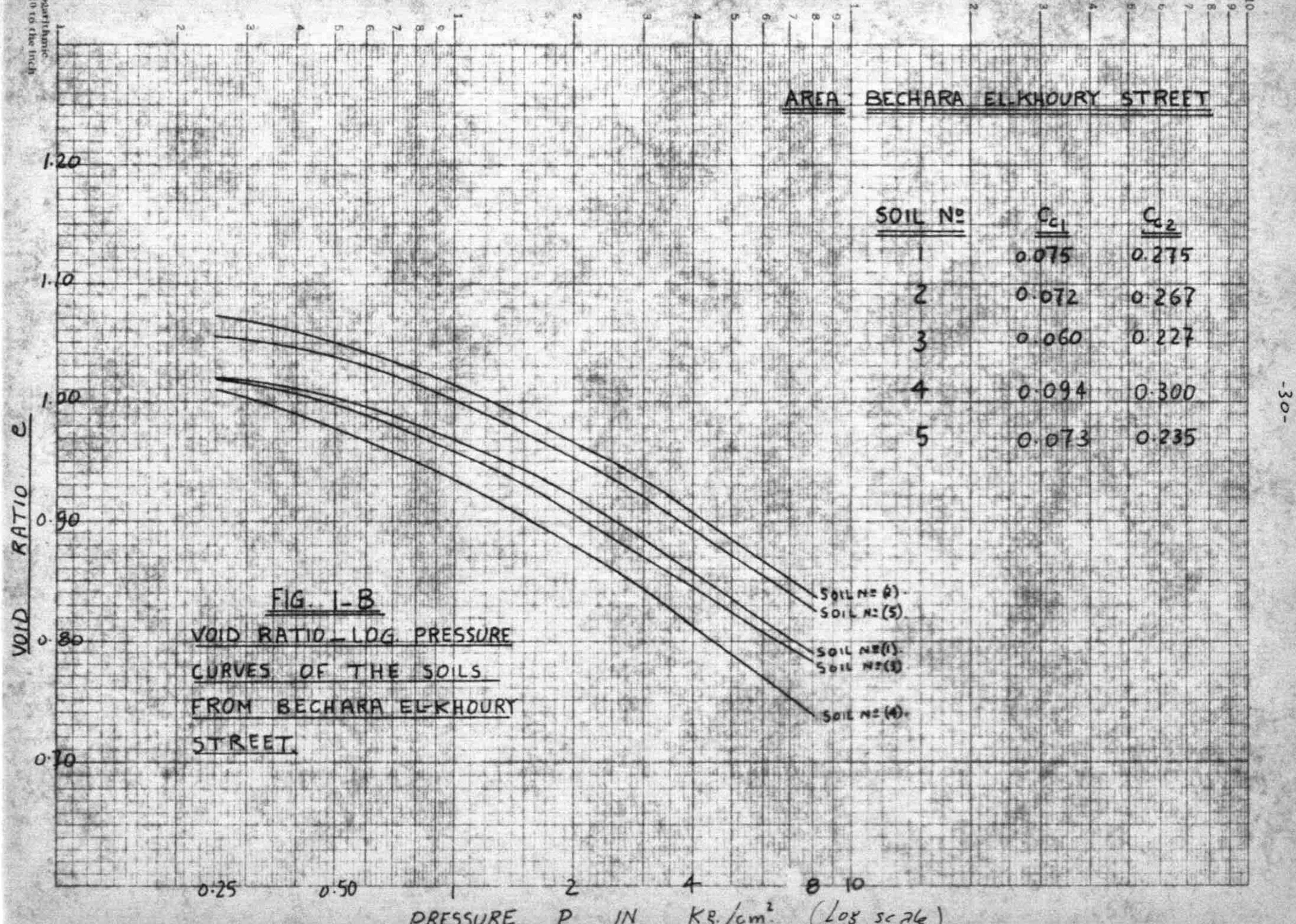


FIG. 5 A.

PERCENT CONSOLIDATION IN 25 YEARS VERSUS THICKNESS OF SOIL LAYERS FOR ACHRAFIYEH SOILS.



AREA : BECHARA EL-KHOURY STREET

SOIL No	C_{c_1}	C_{c_2}
1	0.075	0.275
2	0.072	0.267
3	0.060	0.227
4	0.094	0.300
5	0.073	0.235

FIG. 1-B
VOID RATIO – LOG PRESSURE CURVES OF THE SOILS FROM BECHARA EL-KHOURY STREET.

AREA: BECHARA EL-KHOURY STREET

SOIL No.	a_v ; cm^2/g	m_v ; cm^2/g	k_z ; cm/sec
1	4.7×10^{-5}	2.23×10^{-5}	4.81×10^{-8}
2	6.2×10^{-5}	2.91×10^{-5}	3.62×10^{-8}
3	4.2×10^{-5}	2.07×10^{-5}	1.50×10^{-8}
4	5.0×10^{-5}	2.41×10^{-5}	1.13×10^{-8}
5	4.8×10^{-5}	2.30×10^{-5}	2.90×10^{-8}

NOTE: ALL VALUES TABULATED ABOVE ARE FOR A PRESSURE INCREMENT OF 1-2 Kg./cm².

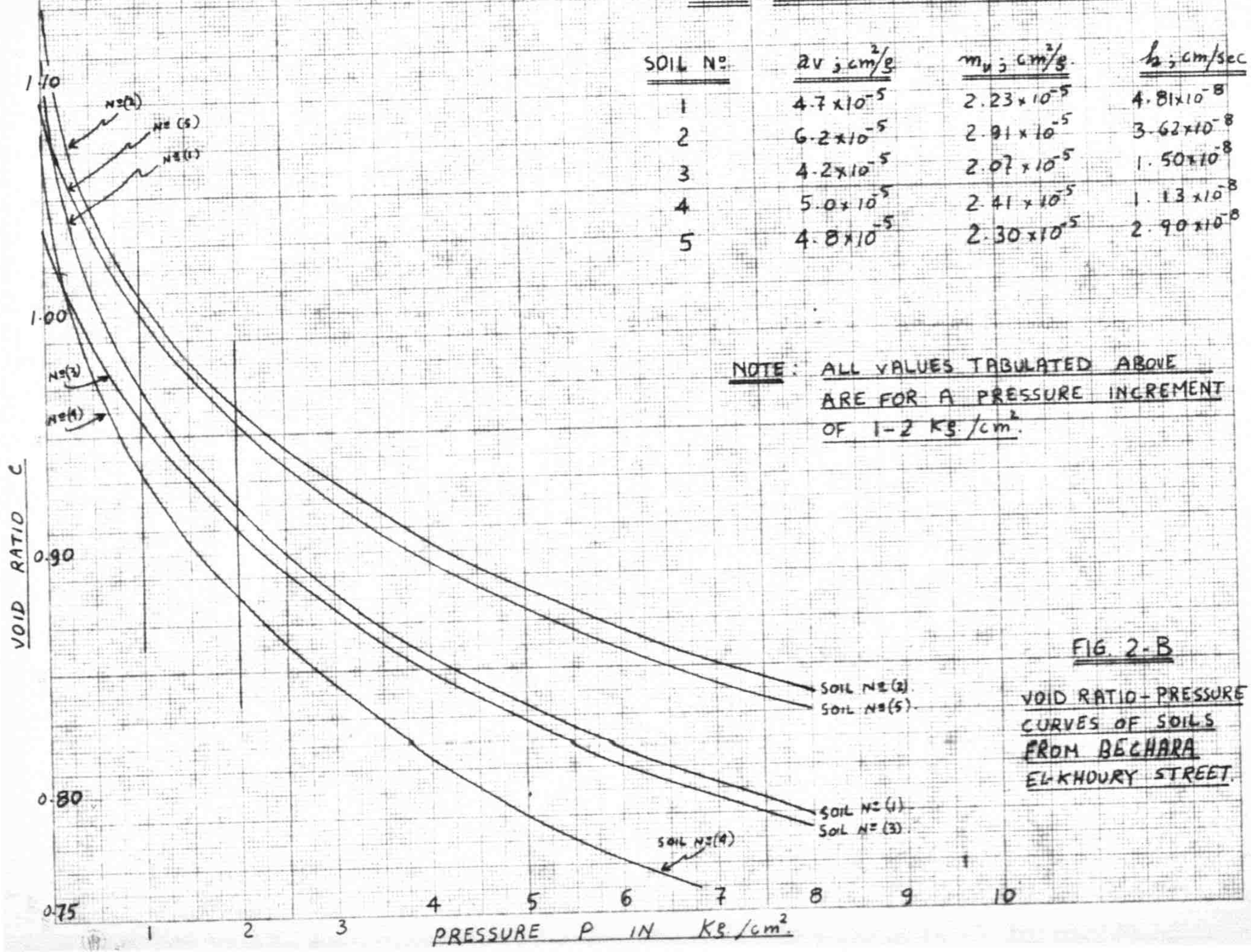


FIG. 2-B

VOID RATIO-PRESSURE CURVES OF SOILS FROM BECHARA EL-KHOURY STREET.

AREA: BECHARA EL-KHOURY STREET

SOIL No.	a_v ; cm^2/g	m_v ; cm^2/g	k ; cm/sec.
1	4.7×10^{-5}	2.23×10^{-5}	4.81×10^{-8}
2	6.2×10^{-5}	2.91×10^{-5}	3.62×10^{-8}
3	4.2×10^{-5}	2.07×10^{-5}	1.50×10^{-8}
4	5.0×10^{-5}	2.41×10^{-5}	1.13×10^{-8}
5	4.8×10^{-5}	2.30×10^{-5}	2.90×10^{-8}

NOTE: ALL VALUES TABULATED ABOVE ARE FOR A PRESSURE INCREMENT OF 1-2 Kg/cm^2.

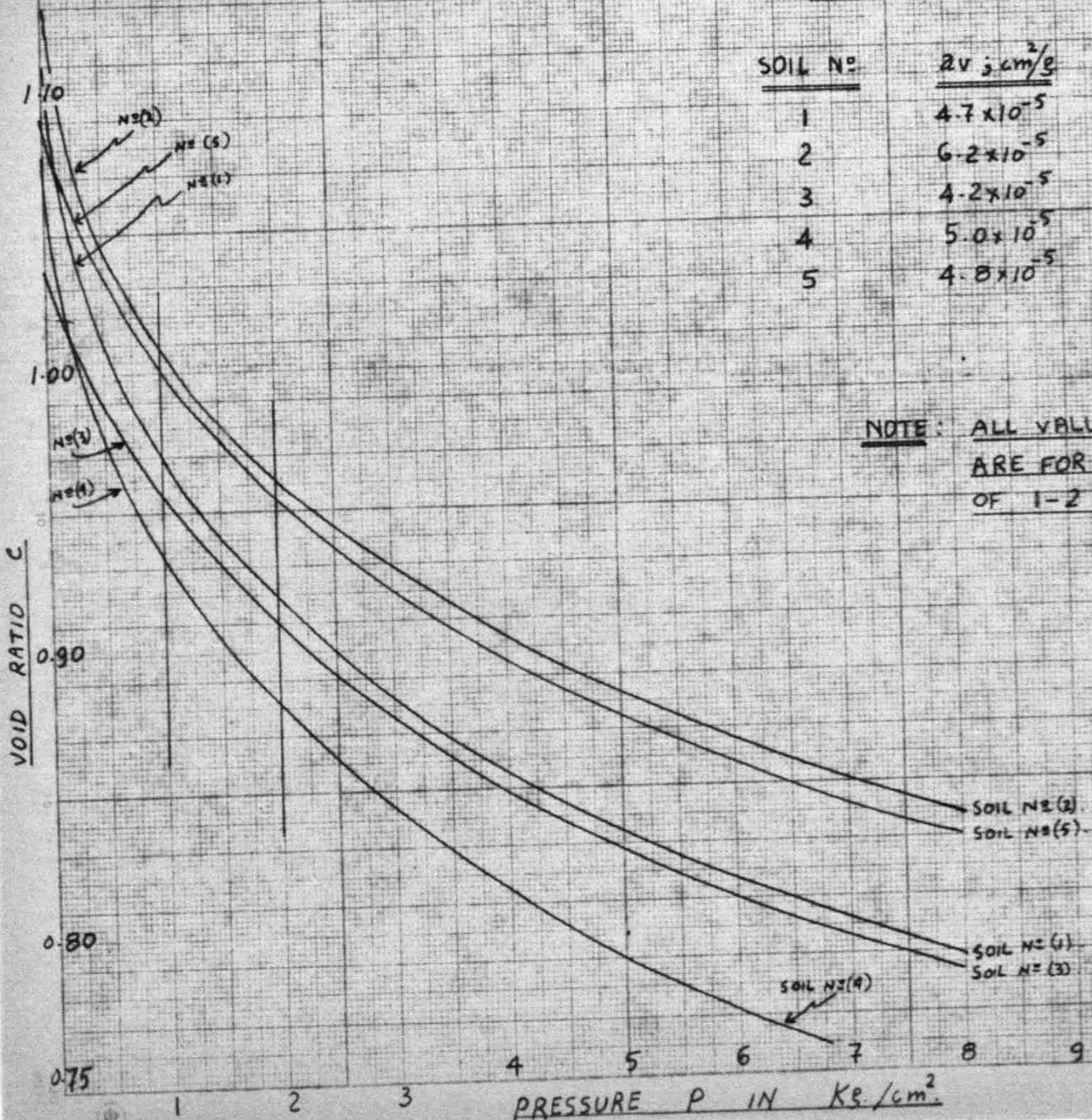


FIG. 2-B

VOID RATIO-PRESSURE CURVES OF SOILS FROM BECHARA EL-KHOURY STREET.

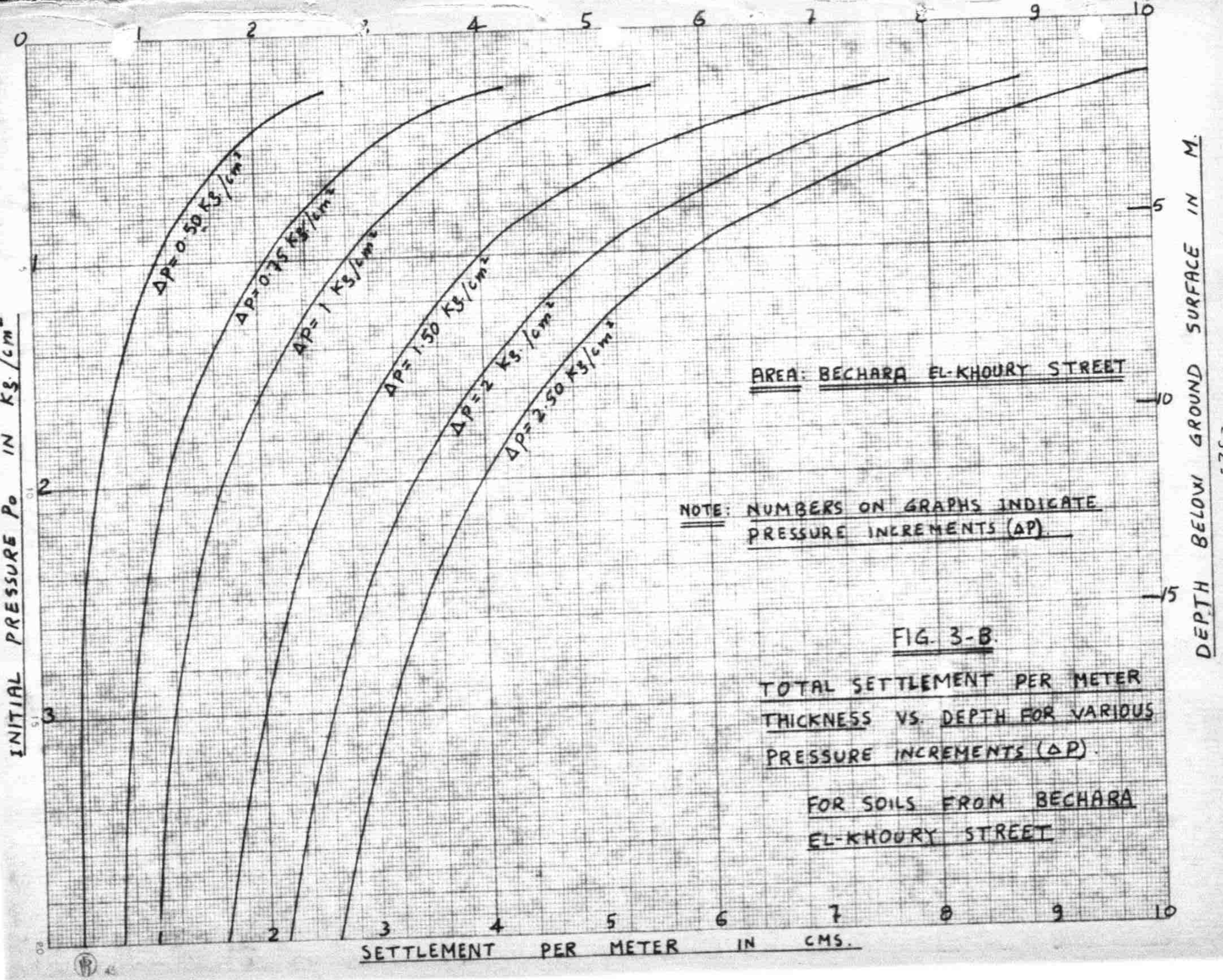


FIG. 3-B.

TOTAL SETTLEMENT PER METER THICKNESS VS. DEPTH FOR VARIOUS PRESSURE INCREMENTS (ΔP).

FOR SOILS FROM BECHARA EL-KHOURY STREET

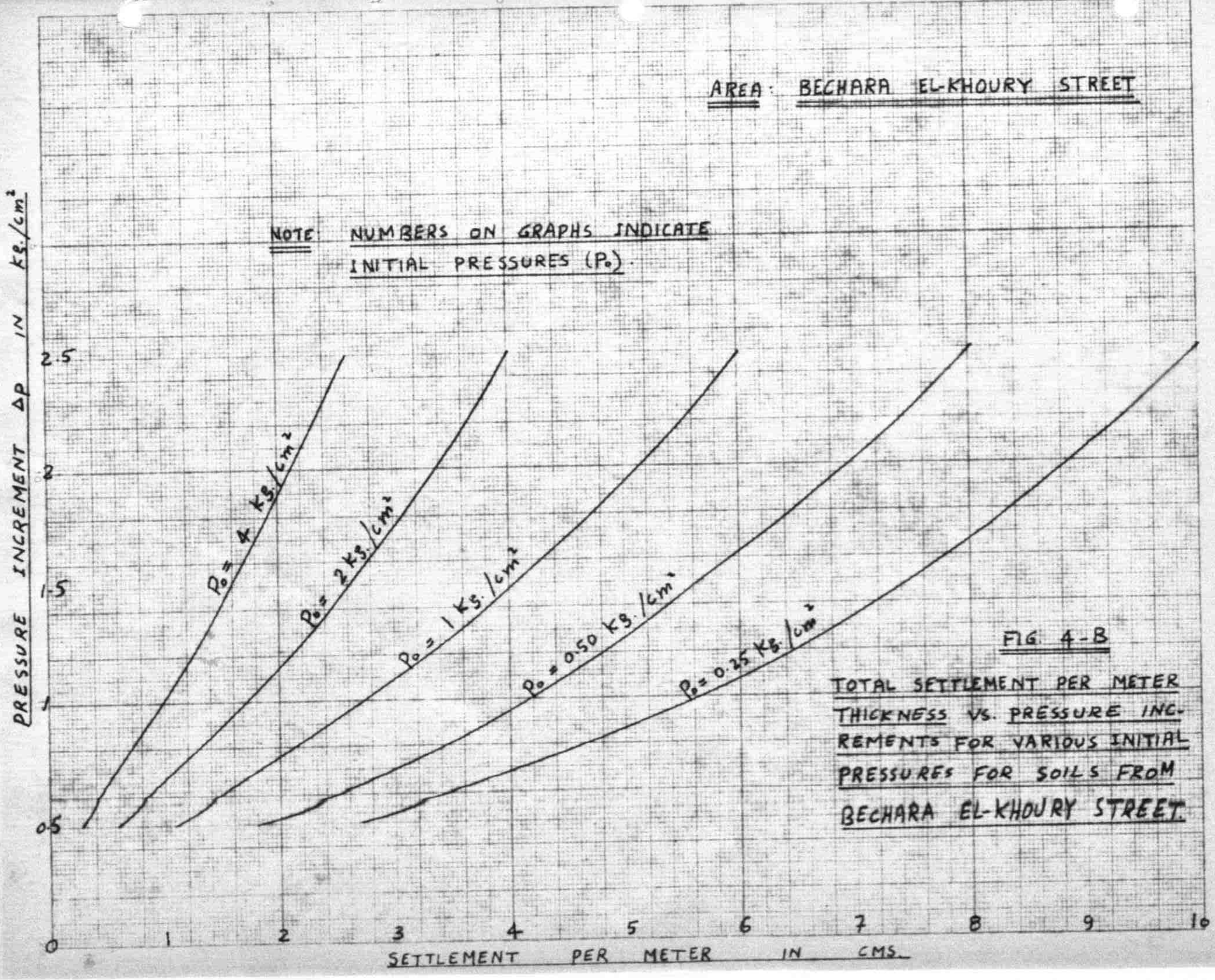


FIG 4-B

TOTAL SETTLEMENT PER METER THICKNESS VS. PRESSURE INCREMENTS FOR VARIOUS INITIAL PRESSURES FOR SOILS FROM BECHARA EL-KHOURY STREET

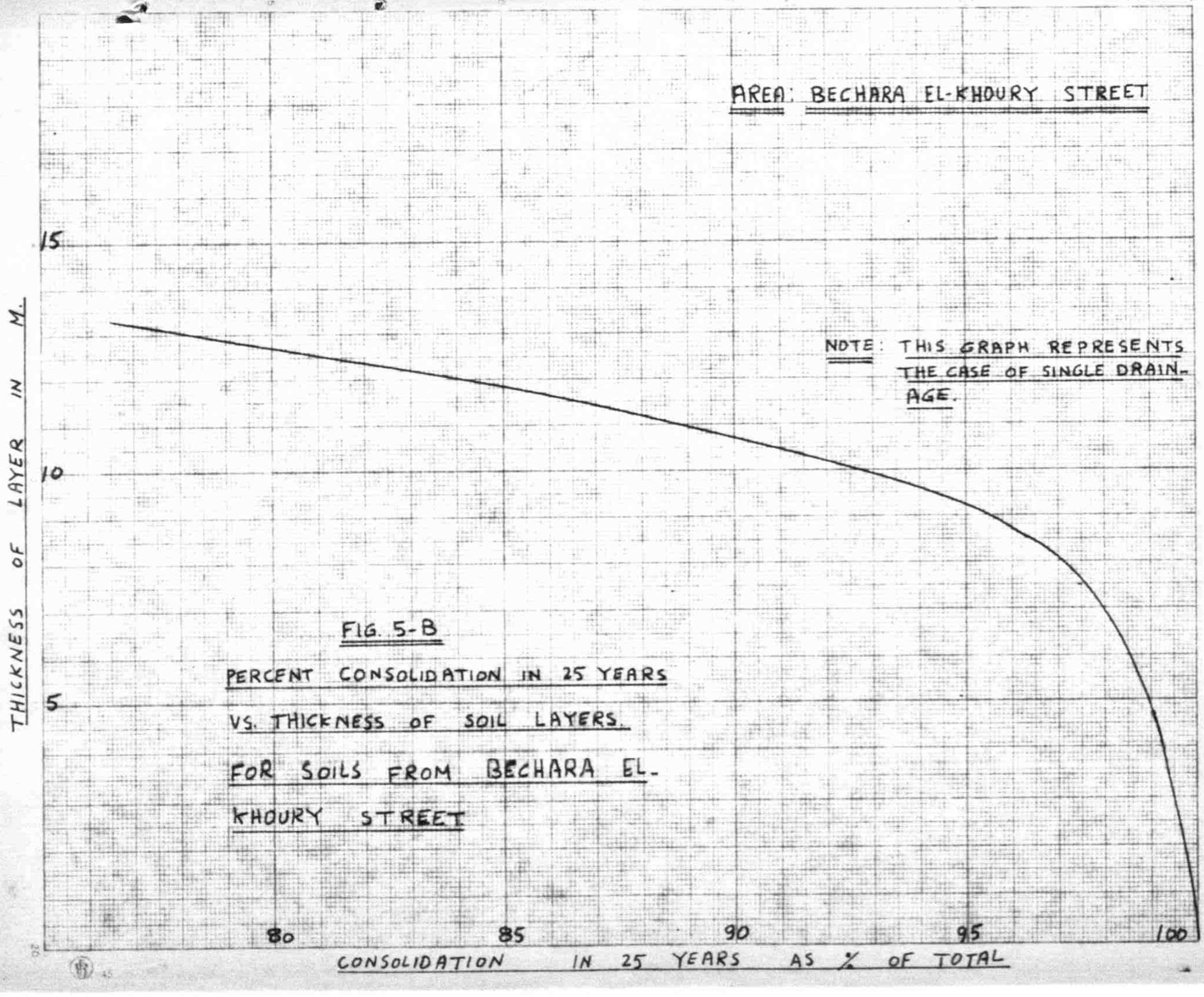


FIG. 5-B

PERCENT CONSOLIDATION IN 25 YEARS VS. THICKNESS OF SOIL LAYERS. FOR SOILS FROM BECHARA EL-KHOURY STREET

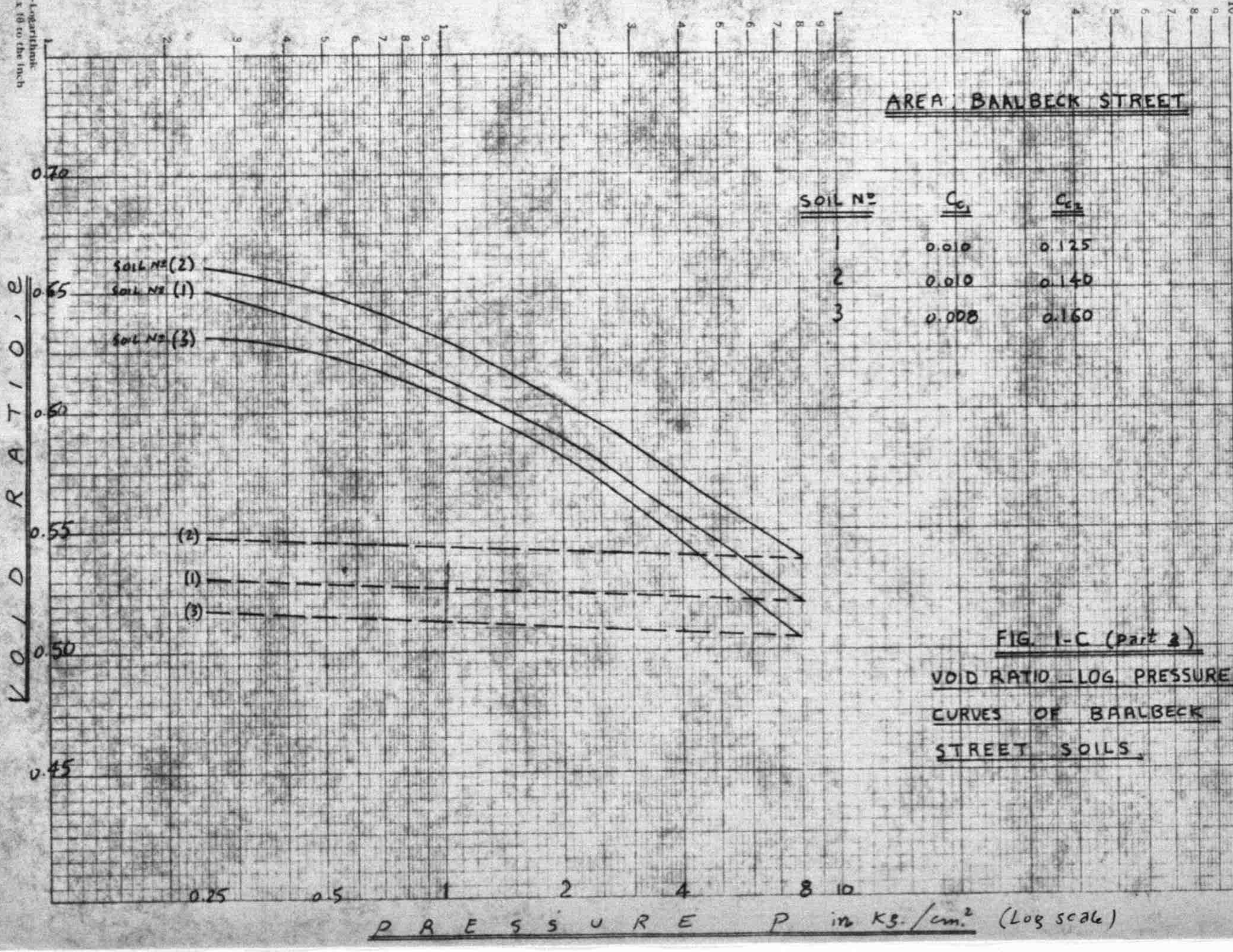


FIG. 1-C (part 2)
VOID RATIO – LOG. PRESSURE CURVES OF BAALBECK STREET SOILS.

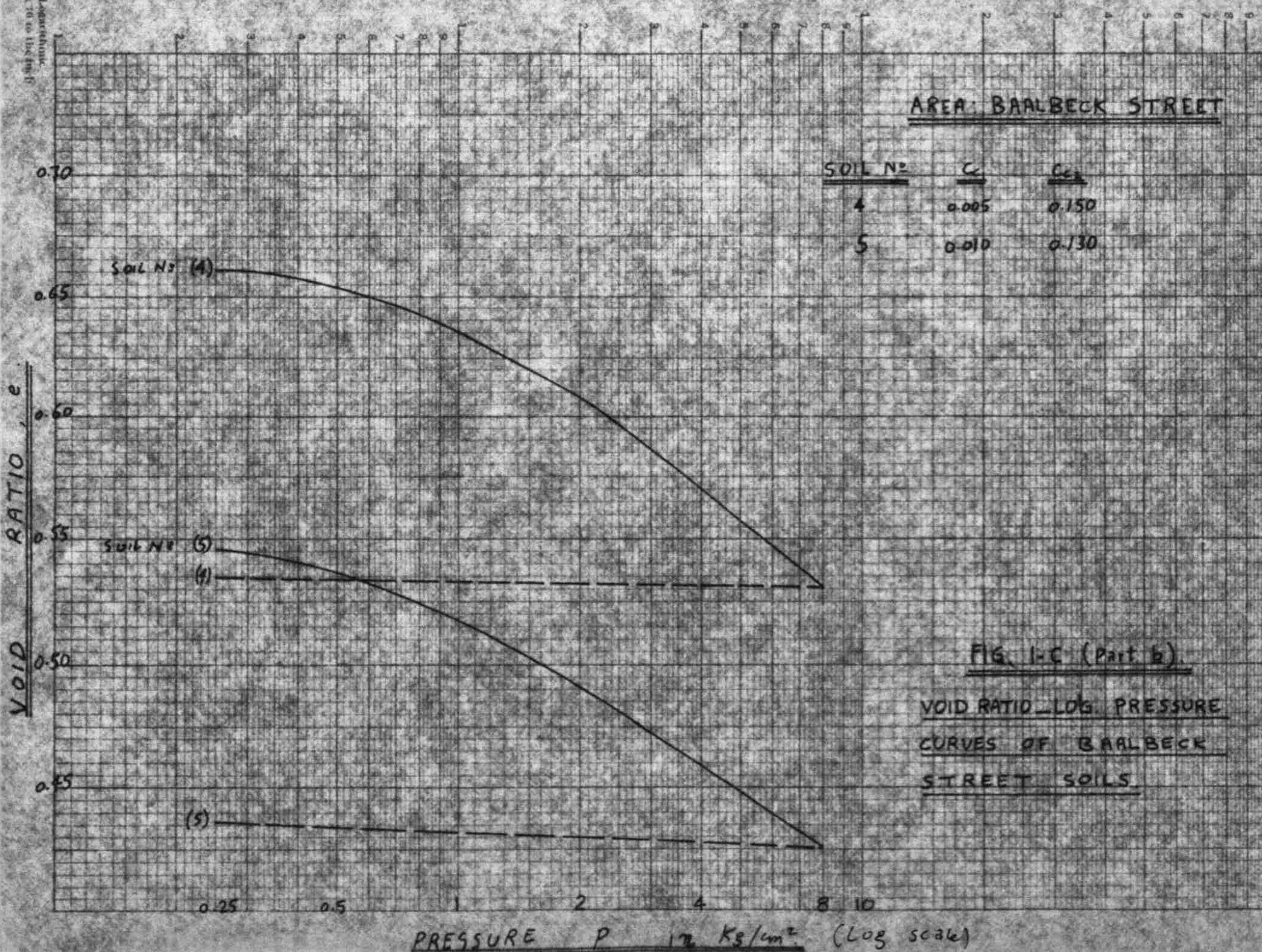


FIG. 1-C (Part b).

VOID RATIO - LOG. PRESSURE CURVES OF BAALBECK STREET SOILS.

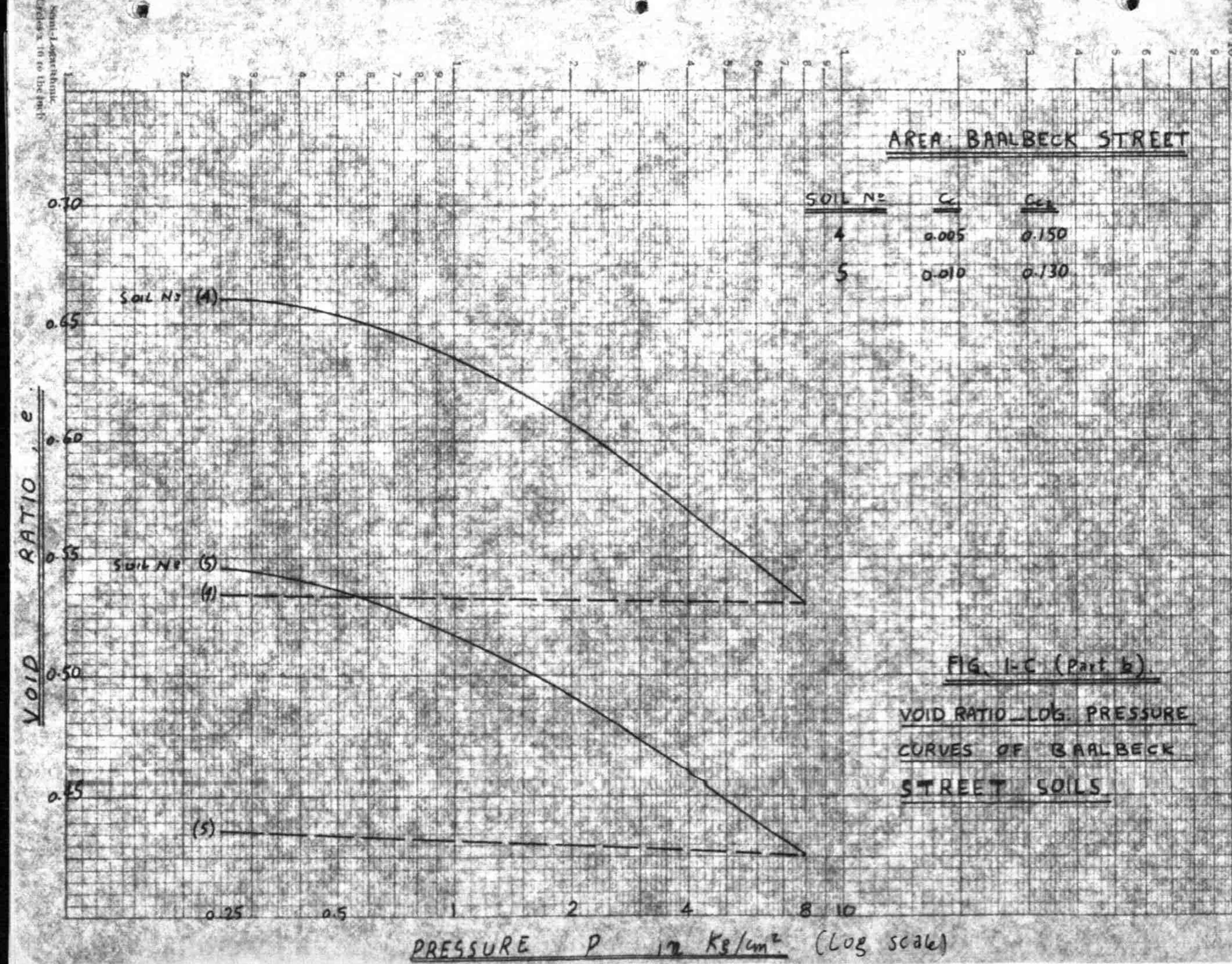


FIG. 1-C (Part b)

VOID RATIO – LOG. PRESSURE CURVES OF BAALBECK STREET SOILS

AREA: BAALBECK STREET

SOIL N°	a_v — cm^2/g.	m_v — cm^2/g.	k — cm/sec.
1	2.8×10^{-5}	1.68×10^{-5}	2.03×10^{-8}
2	2.8×10^{-5}	1.66×10^{-5}	1.92×10^{-8}
3	2.5×10^{-5}	1.52×10^{-5}	2.11×10^{-8}
4	2.5×10^{-5}	1.49×10^{-5}	3.06×10^{-8}
5	2.6×10^{-5}	1.67×10^{-5}	2.98×10^{-8}

NOTE: ALL VALUES TABULATED ABOVE ARE FOR A PRESSURE INCREMENT OF 1-2 Kg./cm^2.

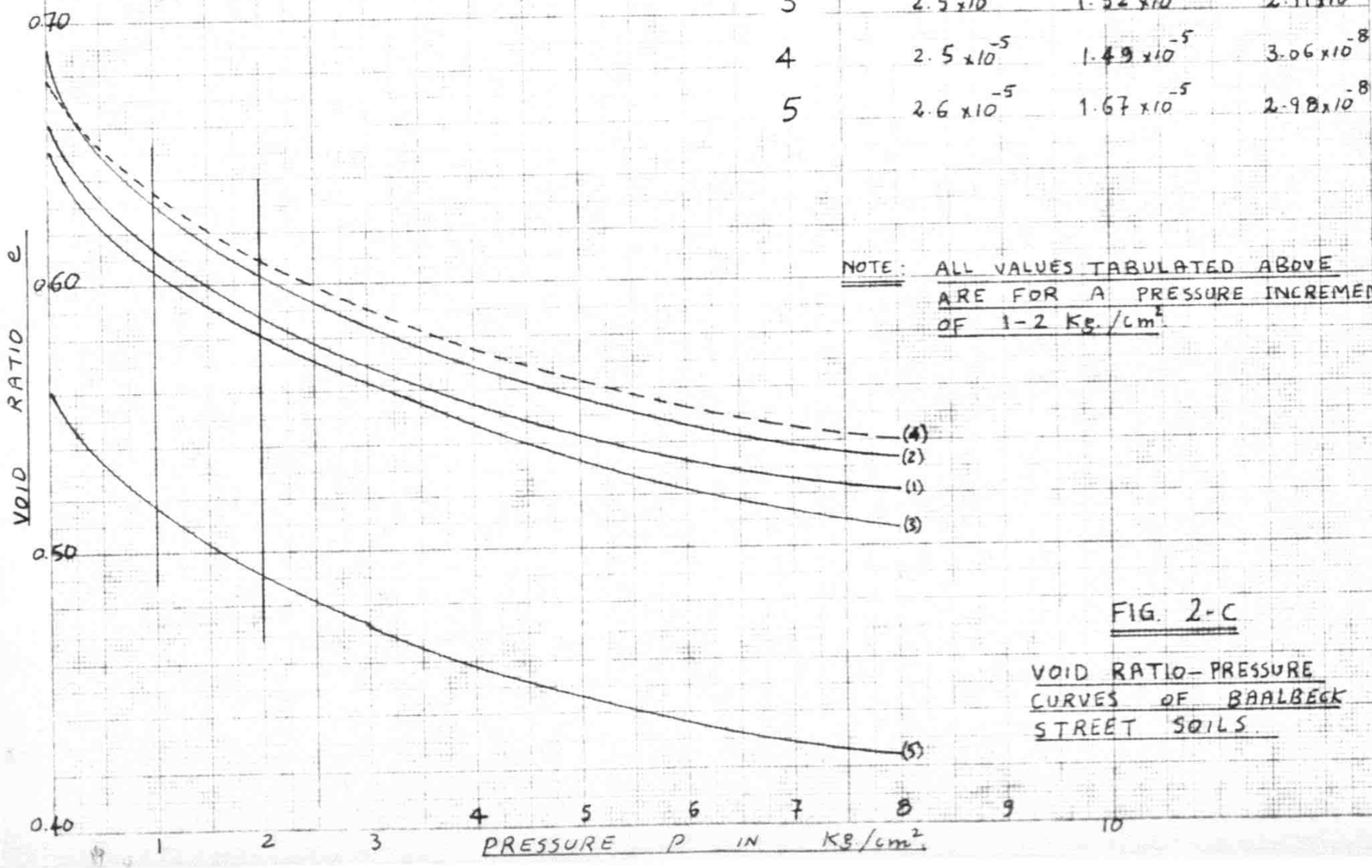


FIG. 2-C

VOID RATIO-PRESSURE CURVES OF BAALBECK STREET SOILS.

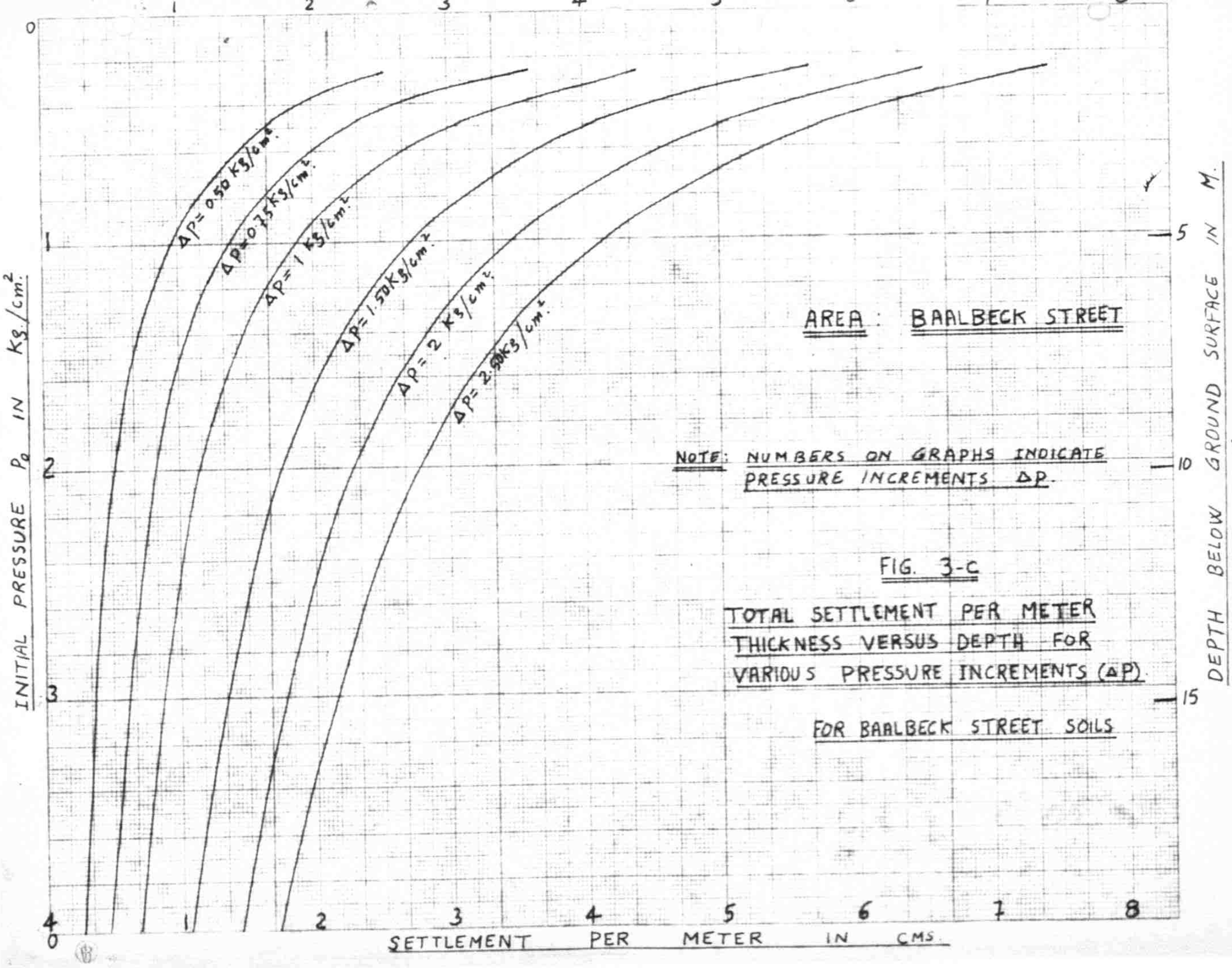


FIG. 3-C

TOTAL SETTLEMENT PER METER THICKNESS VERSUS DEPTH FOR VARIOUS PRESSURE INCREMENTS (ΔP)

FOR BAALBECK STREET SOILS

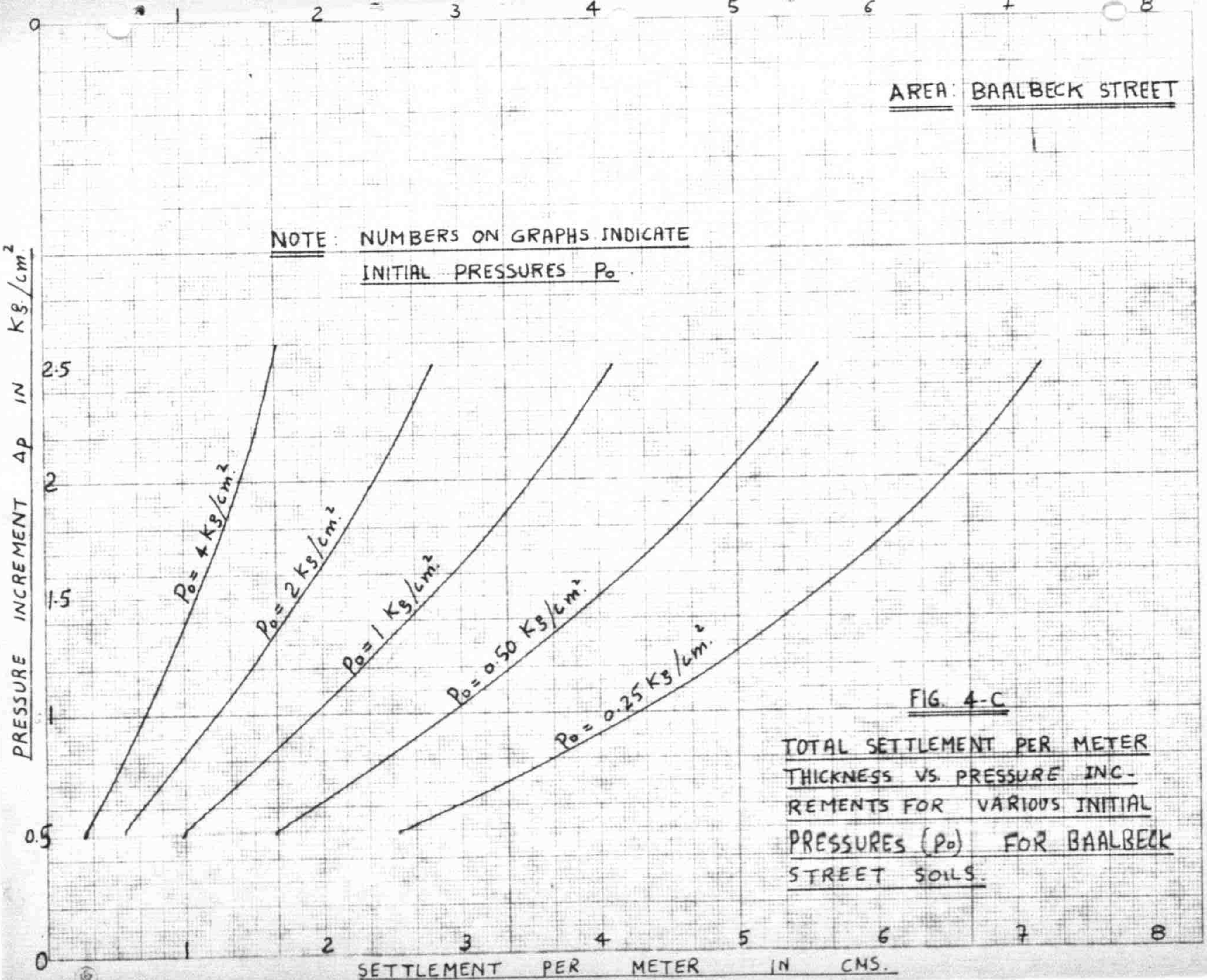


FIG. 4-C

TOTAL SETTLEMENT PER METER THICKNESS VS. PRESSURE INCREMENTS FOR VARIOUS INITIAL PRESSURES (P_o) FOR BAALBECK STREET SOILS.

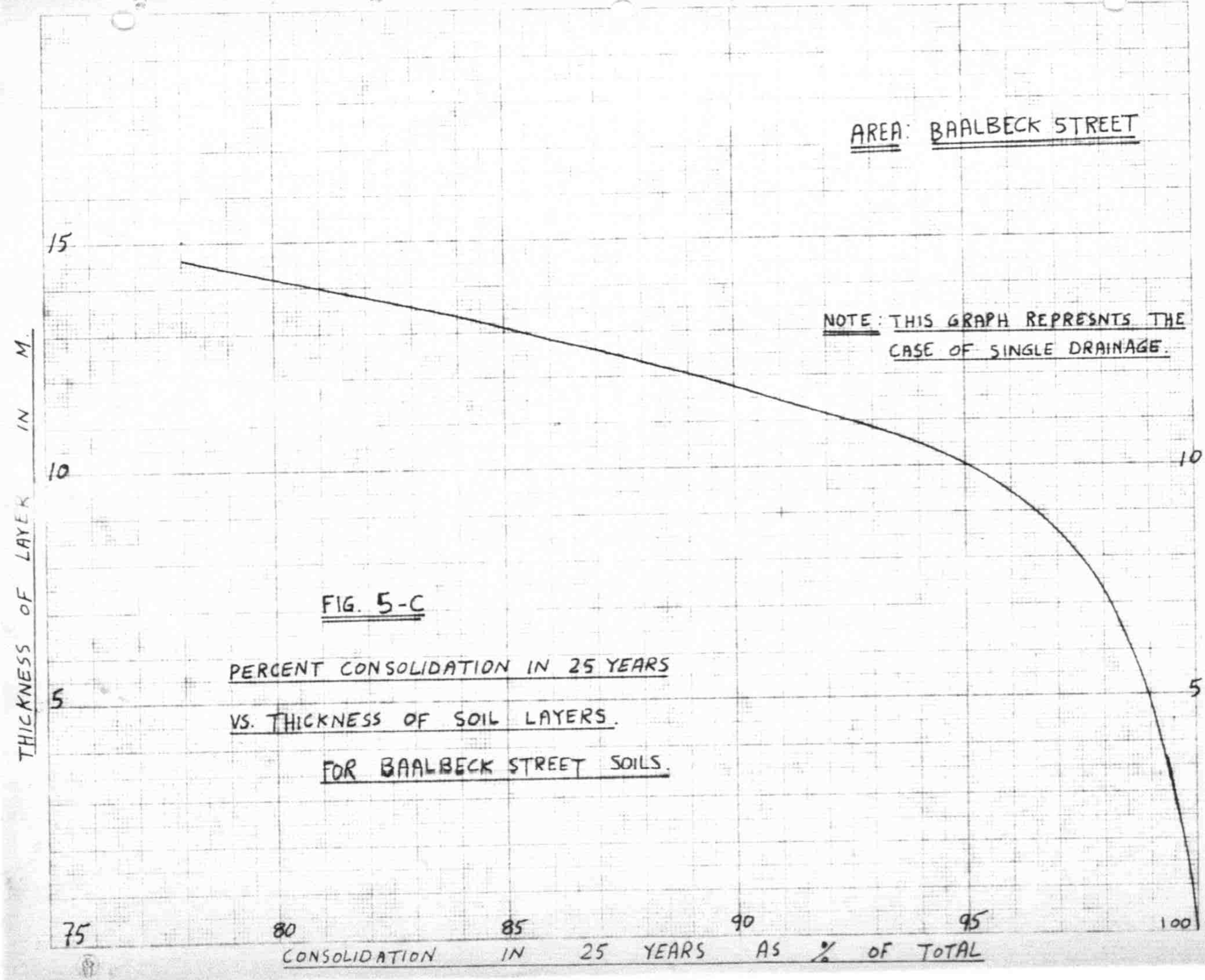
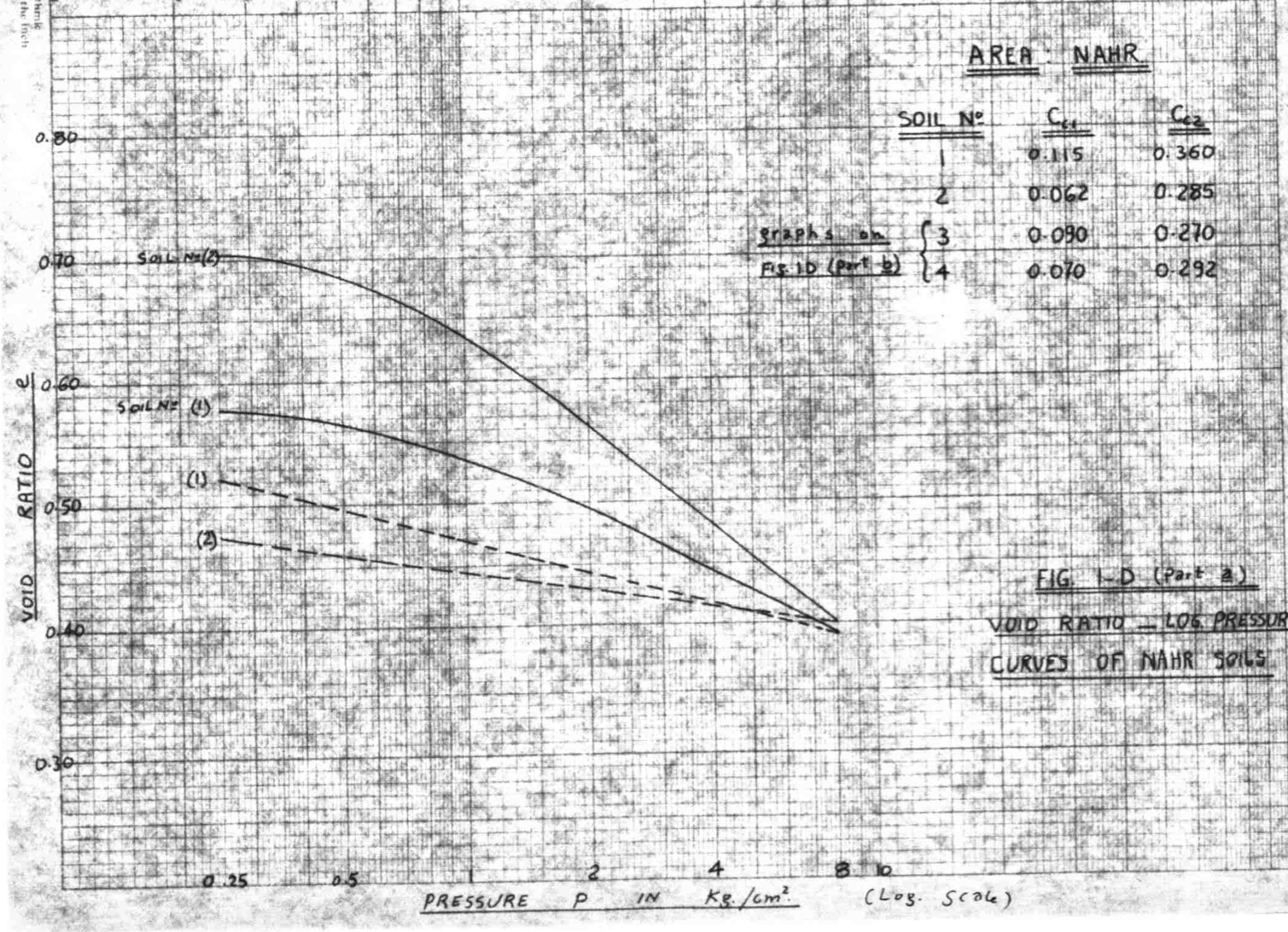


FIG. 5-C

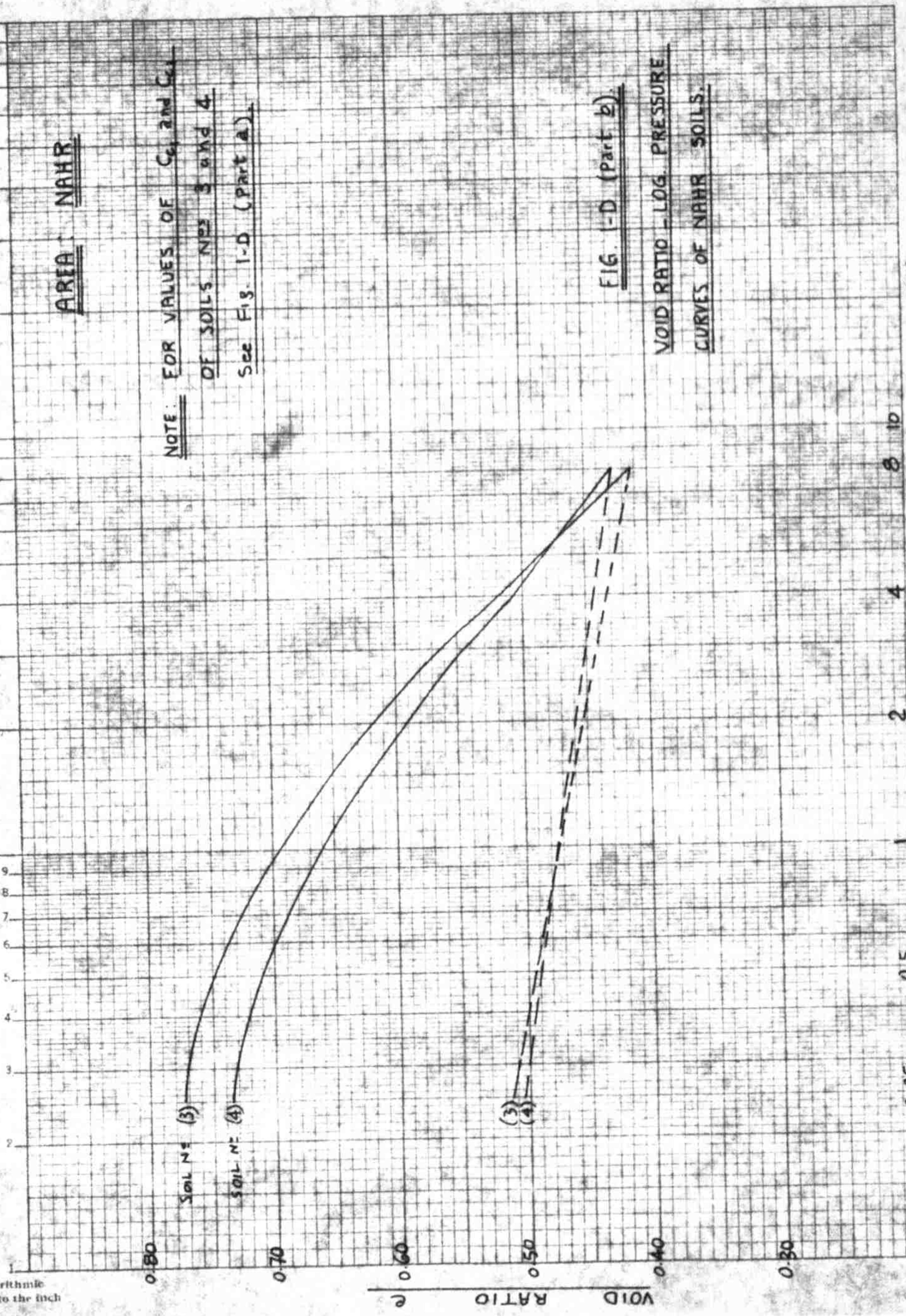
PERCENT CONSOLIDATION IN 25 YEARS VS. THICKNESS OF SOIL LAYERS. FOR BAALBECK STREET SOILS.



SOIL No	C_{c1}	C_{c2}
1	0.115	0.360
2	0.062	0.285
graphs on Fig. 1D (part b) { 3	0.090	0.270
4	0.070	0.292

FIG. 1-D (Part a)

VOID RATIO — LOG PRESSURE CURVES OF NAHR SOILS



Semi-Logarithmic
3 Cycles x 10 to the inch

AREA: NAHR

SOIL Nº	a_v; cm^2/g	m_v; cm^2/g	k; cm/sec
1	4.6×10^{-5}	2.64×10^{-5}	0.82×10^{-8}
2	6.1×10^{-5}	3.57×10^{-5}	0.24×10^{-8}
3	6.2×10^{-5}	3.52×10^{-5}	0.20×10^{-8}
4	6.4×10^{-5}	3.73×10^{-5}	0.39×10^{-8}

NOTE: ALL THE VALUES TABULATED ABOVE ARE FOR A PRESSURE INCREMENT OF 1-2 Kg./cm^2.

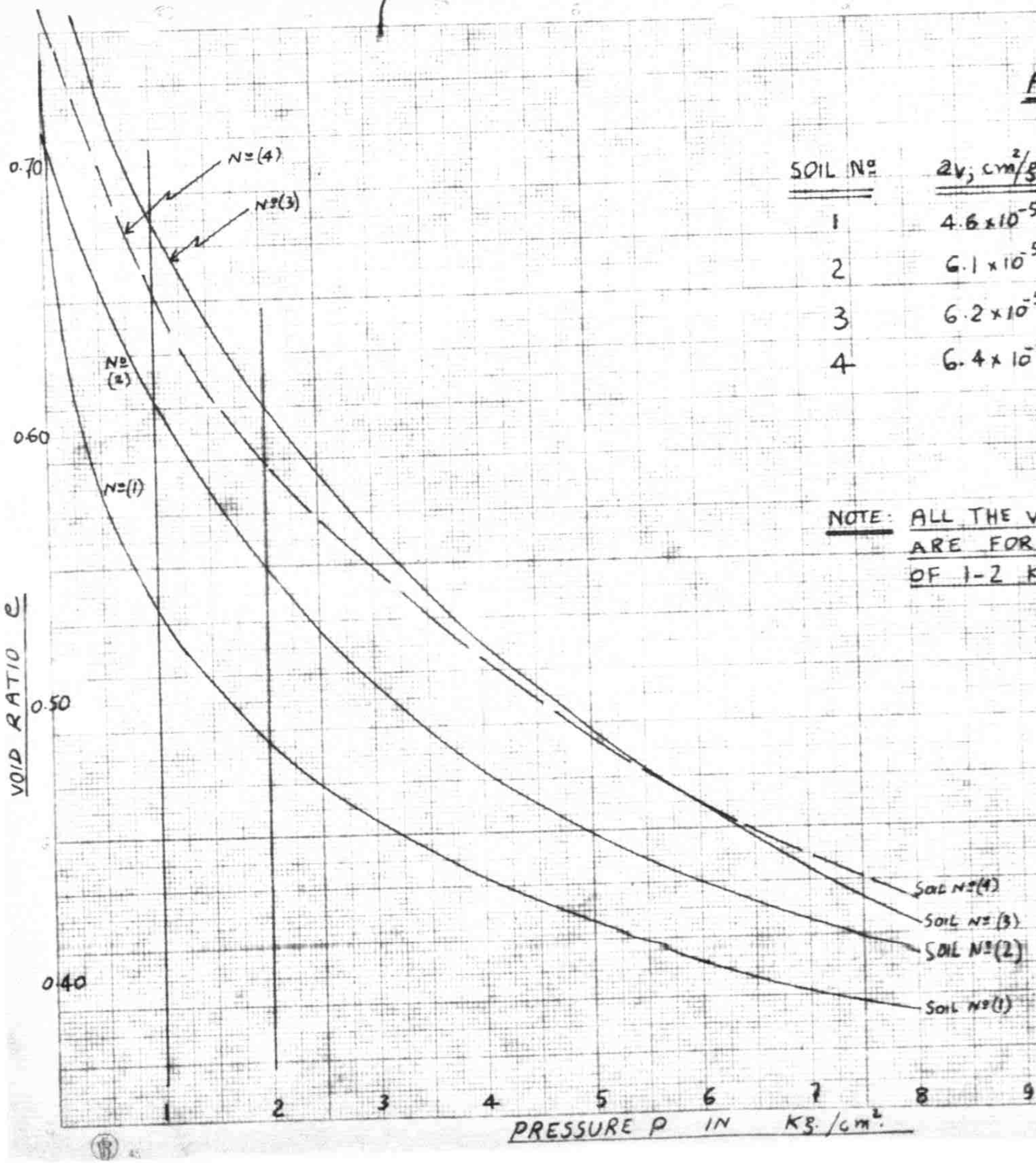


FIG. 2-D

VOID RATIO - PRESSURE CURVES OF NAHR SOILS.

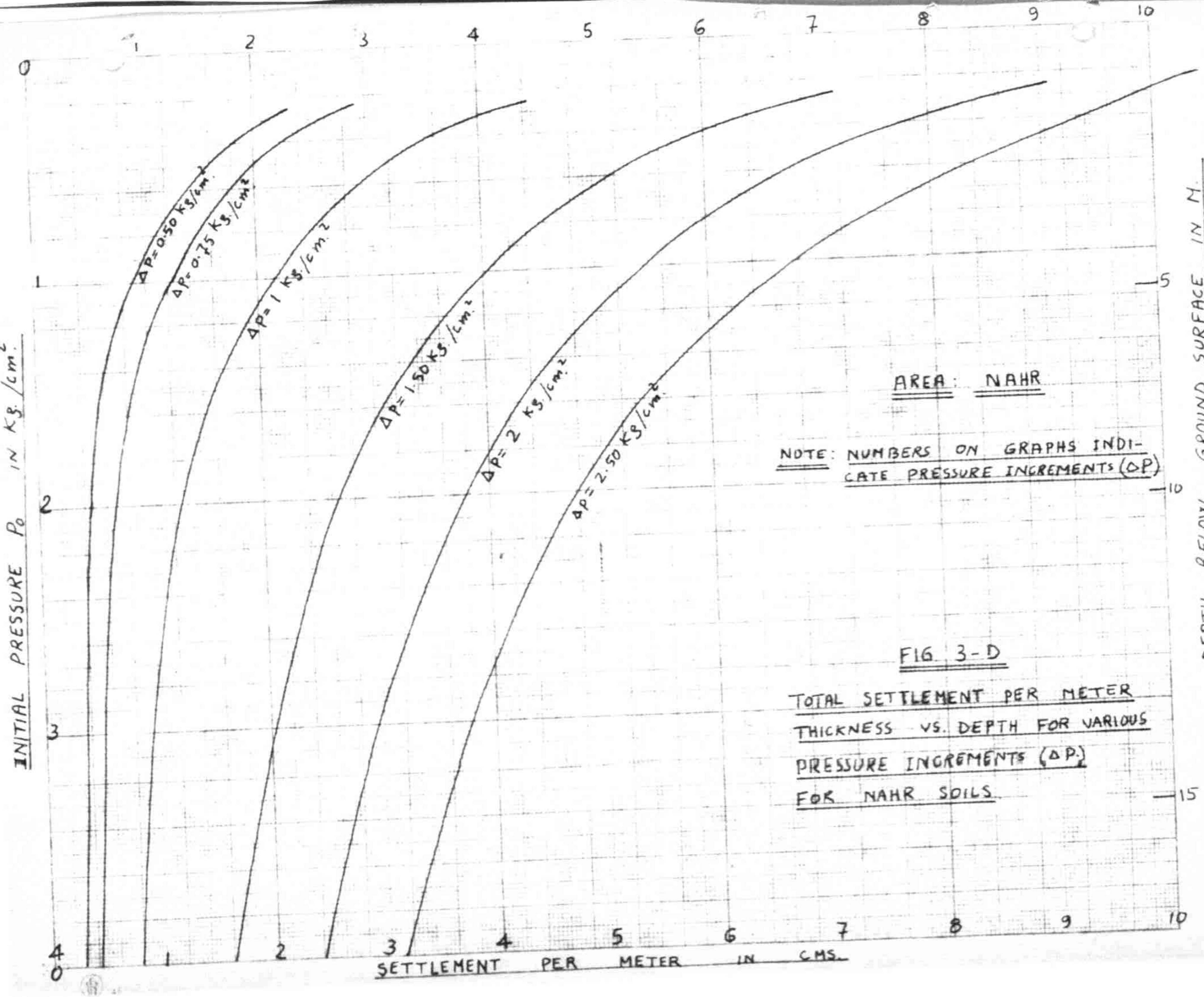


FIG. 3-D

TOTAL SETTLEMENT PER METER THICKNESS VS. DEPTH FOR VARIOUS PRESSURE INCREMENTS (ΔP.) FOR NAHR SOILS.

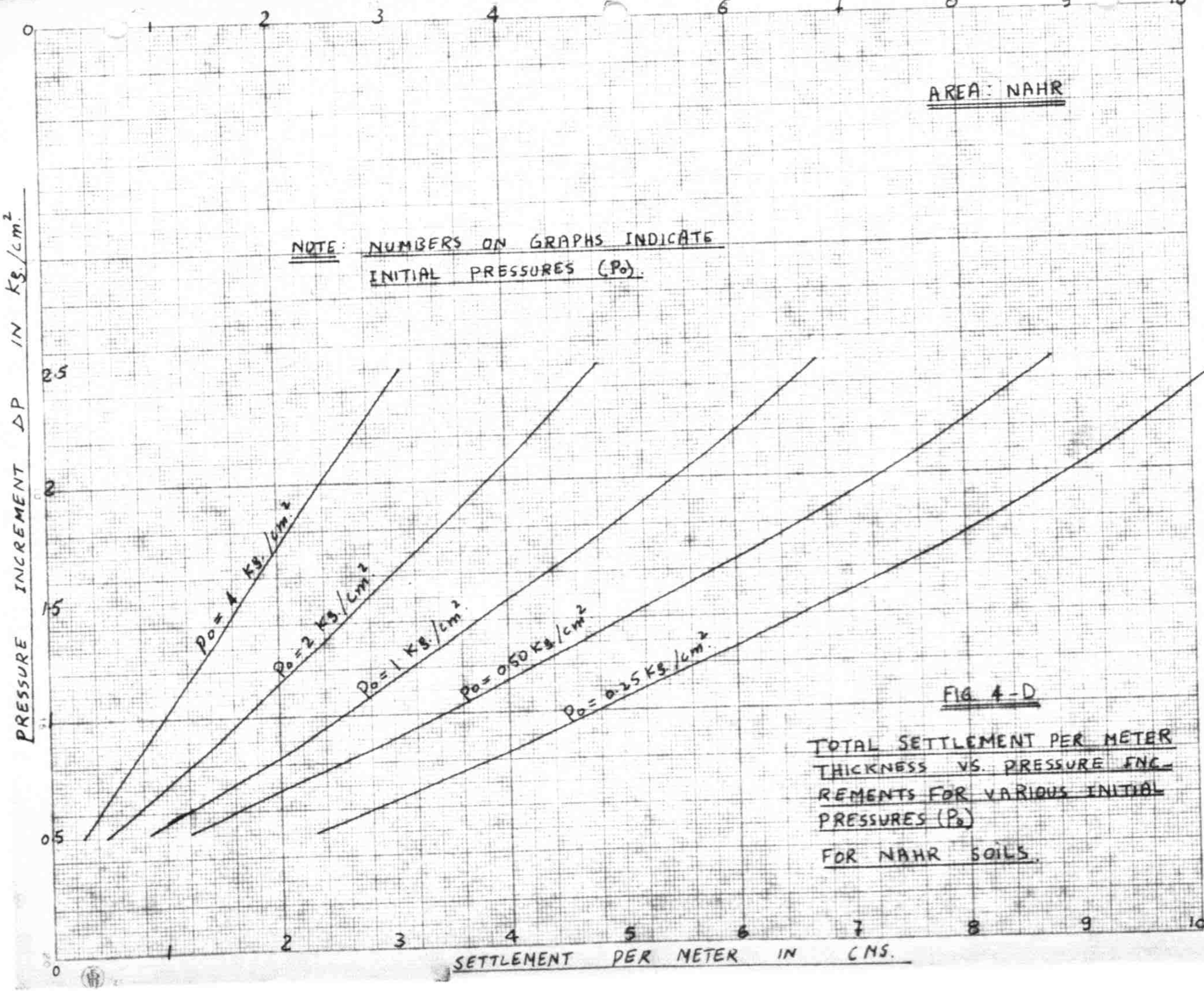


FIG 4-D

TOTAL SETTLEMENT PER METER THICKNESS VS. PRESSURE INCREMENTS FOR VARIOUS INITIAL PRESSURES (P_o)

FOR NAHR SOILS.

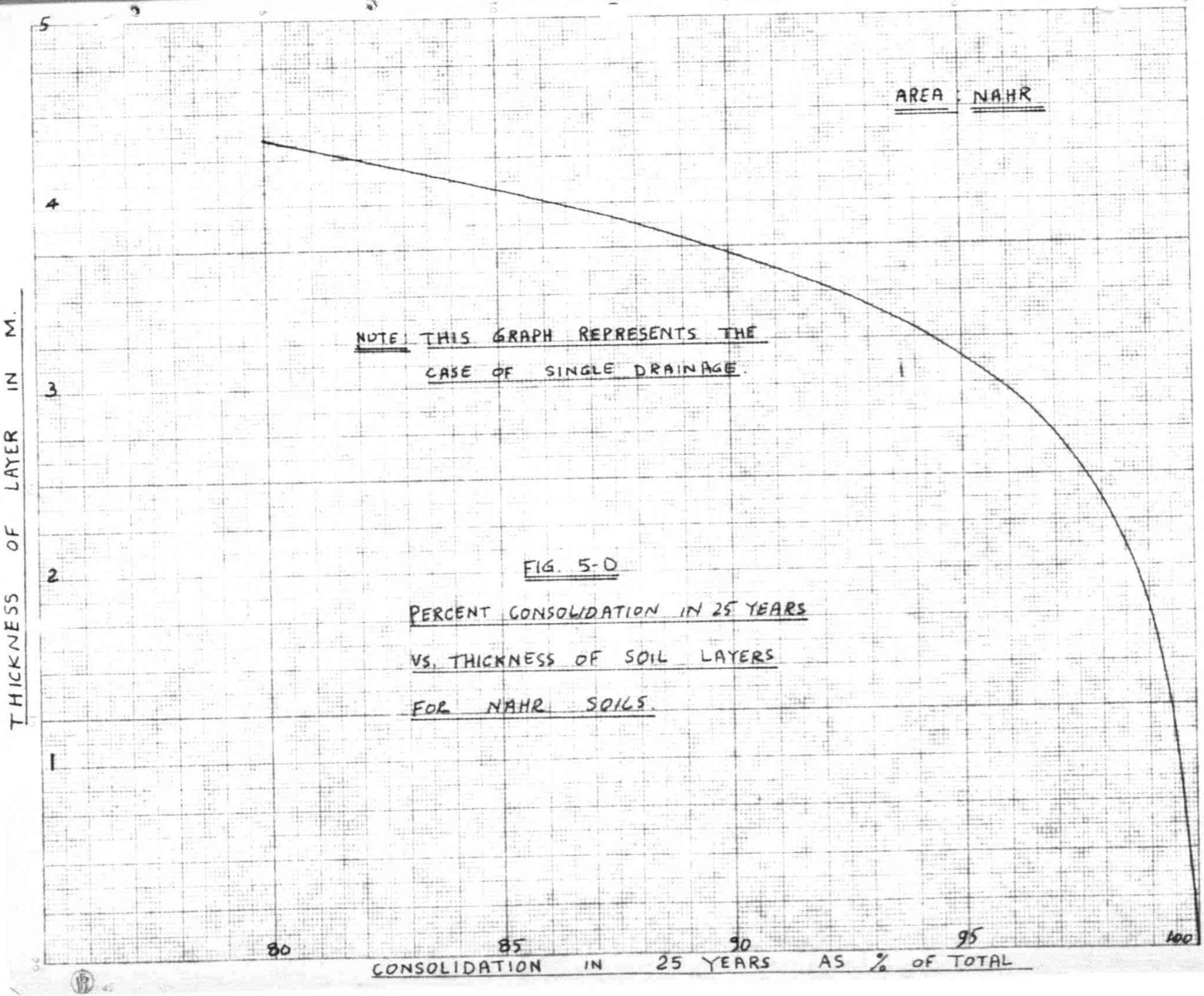
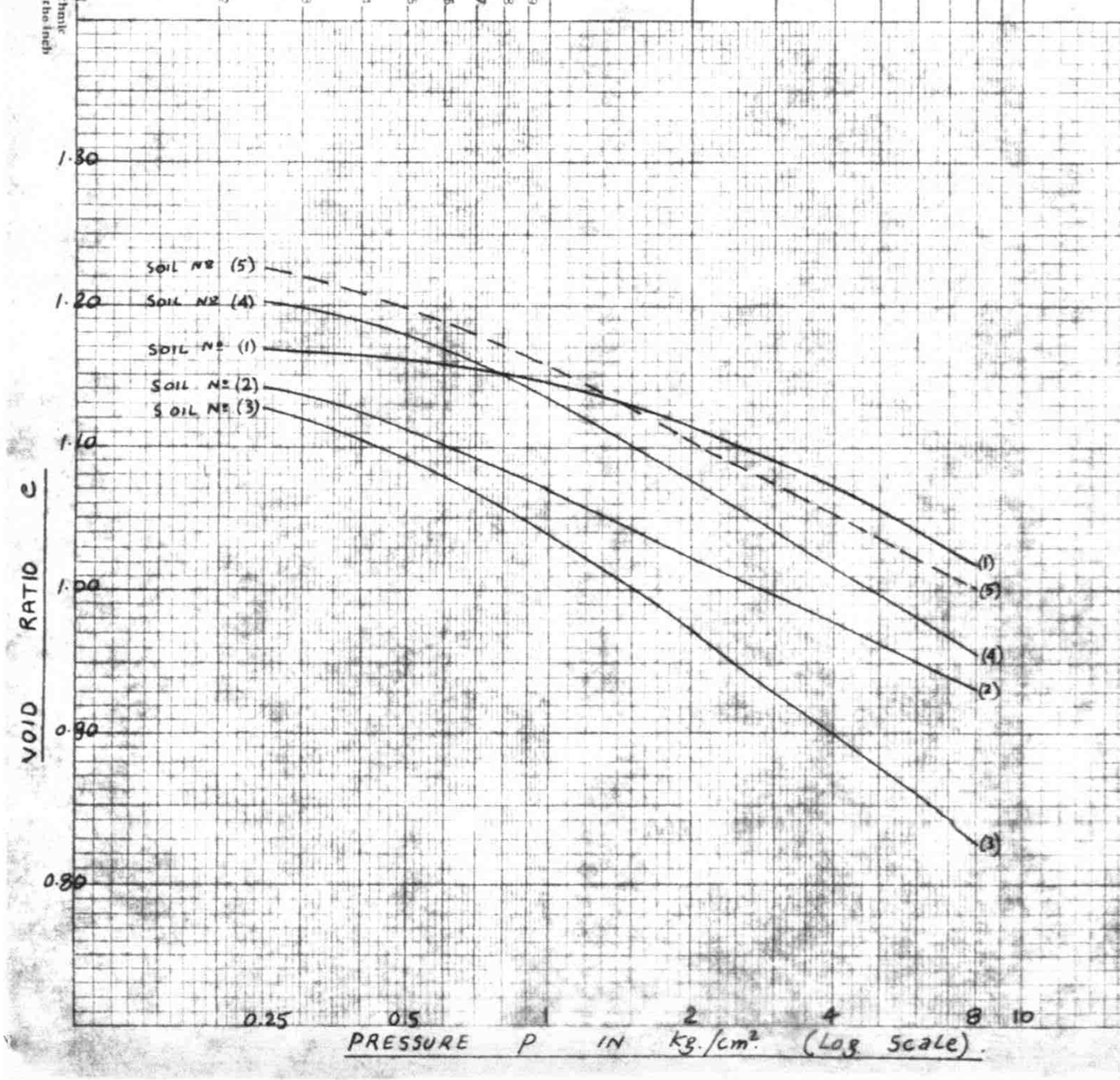


FIG. 5-D

PERCENT CONSOLIDATION IN 25 YEARS VS. THICKNESS OF SOIL LAYERS FOR NAHR SOILS.

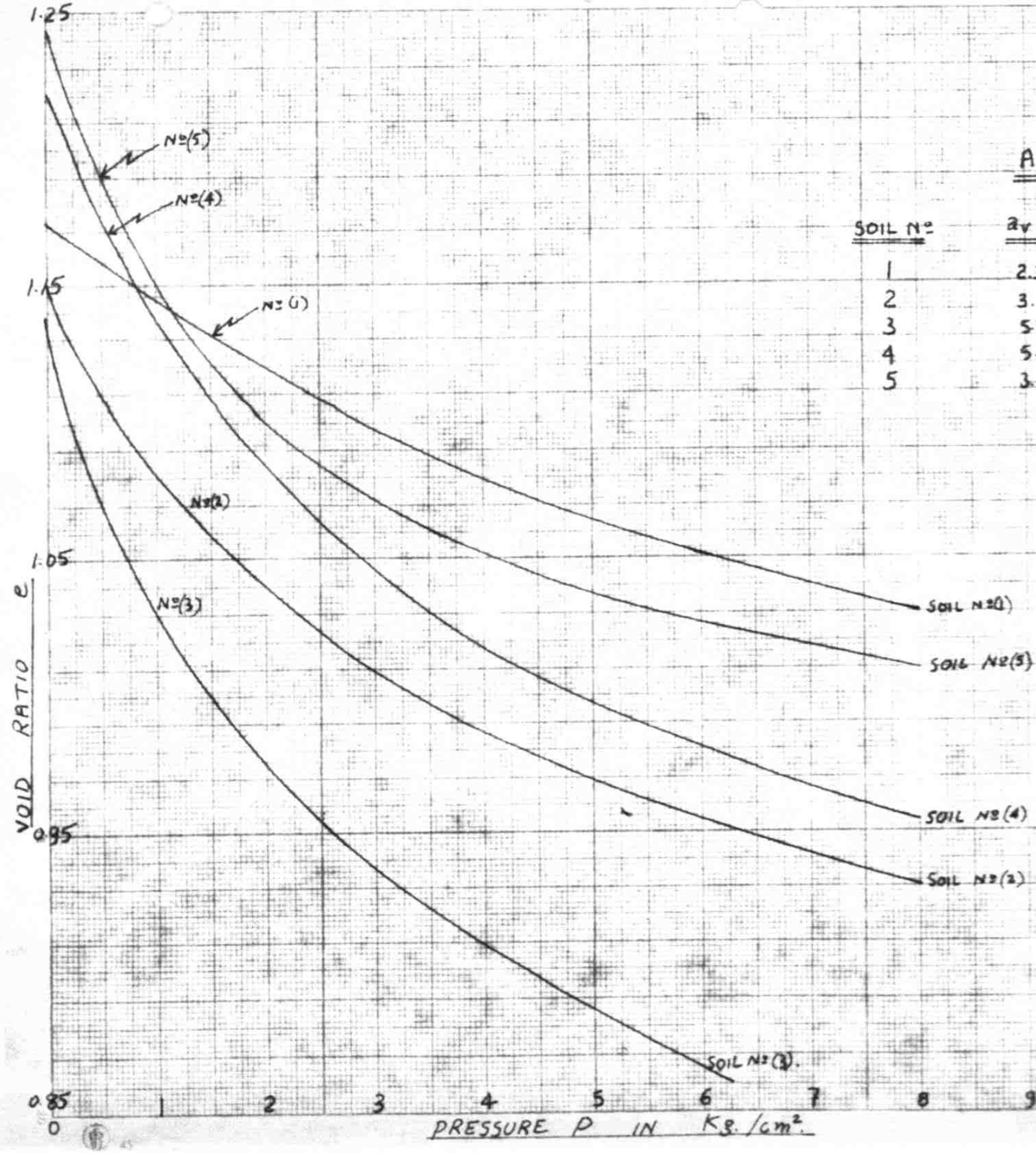


AREA: HAMRA STREET

SOIL No	C_{c_1}	C_{c_2}
1	0.025	0.185
2	0.080	0.182
3	0.110	0.255
4	0.065	0.190
5	0.083	0.190

FIG. 1-E

VOID RATIO - LOG. PRESSURE CURVES OF HAMRA STREET SOILS



AREA: HAMRA STREET

SOIL N°	a_v; cm²/g.	m_v; cm²/g.	k; cm/sec.
1	2.3×10^{-5}	1.06×10^{-5}	1.22×10^{-8}
2	3.6×10^{-5}	1.68×10^{-5}	3.33×10^{-8}
3	5.7×10^{-5}	2.66×10^{-5}	6.15×10^{-8}
4	5.1×10^{-5}	2.30×10^{-5}	4.00×10^{-8}
5	3.6×10^{-5}	1.61×10^{-5}	3.76×10^{-8}

NOTE: ALL THE VALUES TABULATED ABOVE ARE FOR A PRESSURE INCREMENT OF 1-2 Kg./cm².

FIG. 2-E

VOID RATIO - PRESSURE CURVES OF HAMRA STREET SOILS.

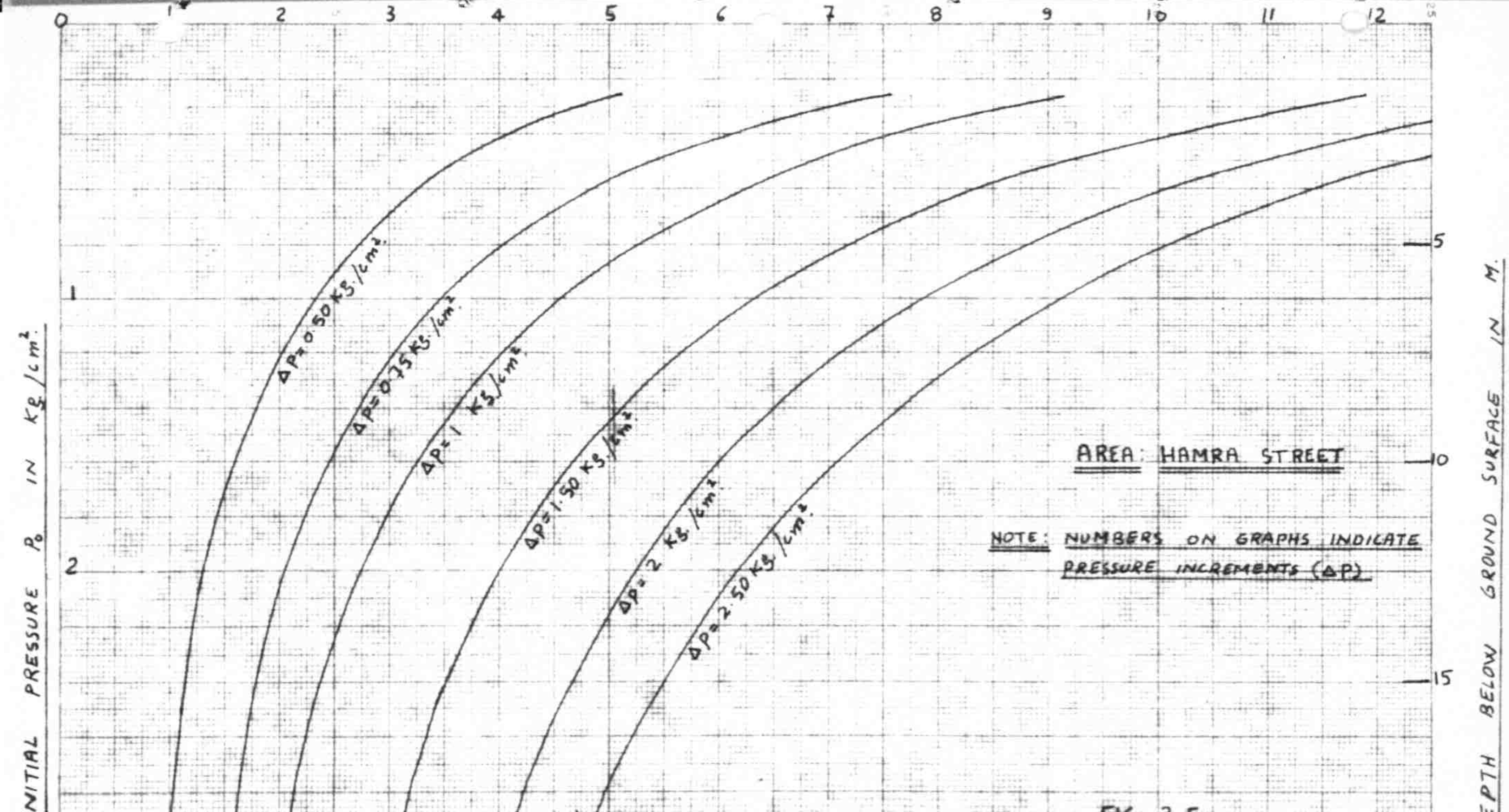
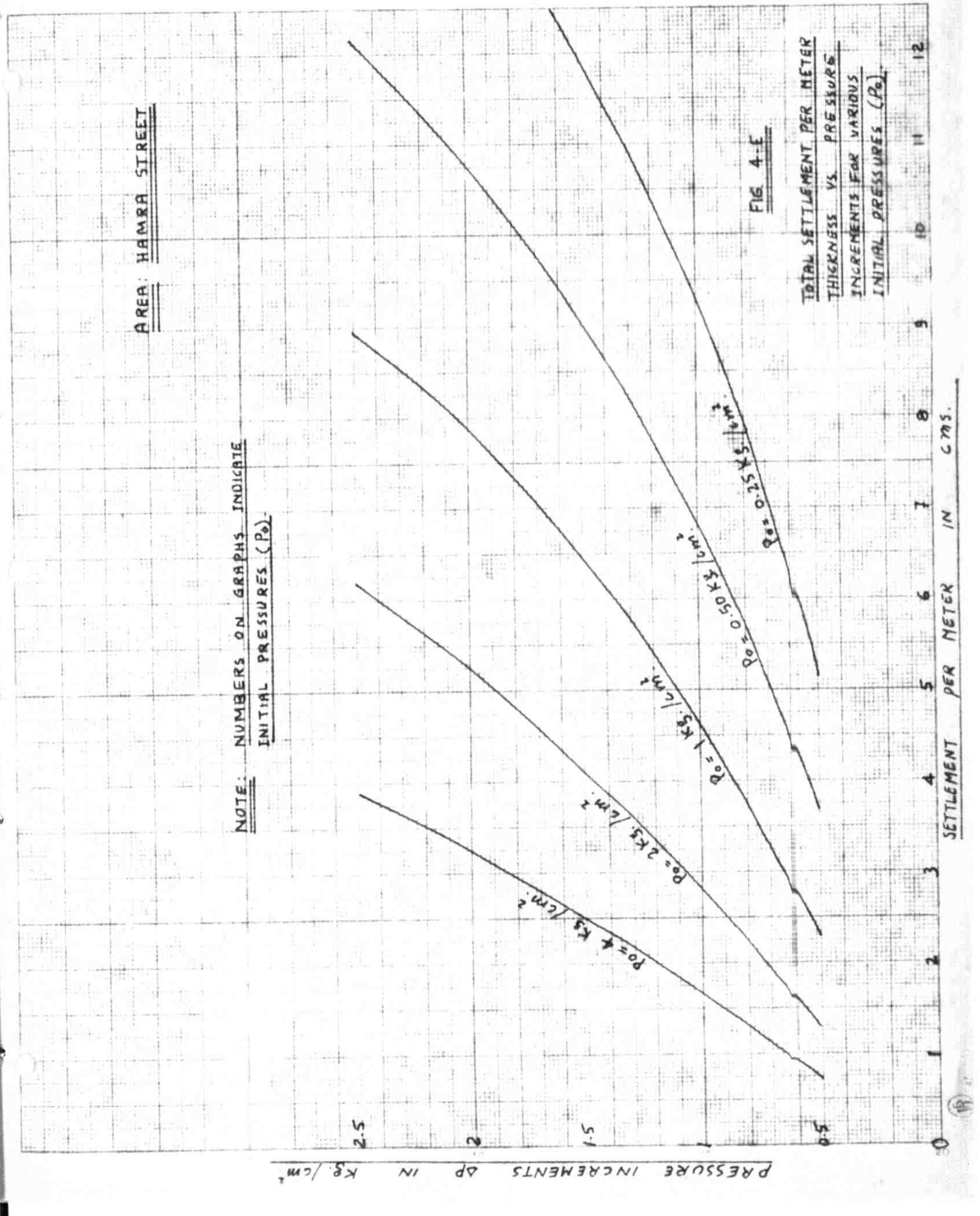


FIG. 3-E

TOTAL SETTLEMENT PER METER THICKNESS VS. DEPTH FOR VARIOUS PRESSURE INCREMENTS (ΔP) FOR HAMRA STREET SOILS.


AREA: HAMRA STREET
NOTE: NUMBERS ON GRAPHS INDICATE INITIAL PRESSURES (Po)
Po = 4 Kg/cm²
Po = 2 Kg/cm²
Po = 1 Kg/cm²
Po = 0.50 Kg/cm²
Po = 0.25 Kg/cm²
FIG 4-E
TOTAL SETTLEMENT PER METER THICKNESS VS PRESSURE INCREMENTS FOR VARIOUS INITIAL PRESSURES (Po)
SETTLEMENT PER METER IN CMS.
PRESSURE INCREMENTS ΔP IN Kg./cm²
0
0.5
1
1.5
2
2.5
1
2
3
4
5
6
7
8
9
10
11
12

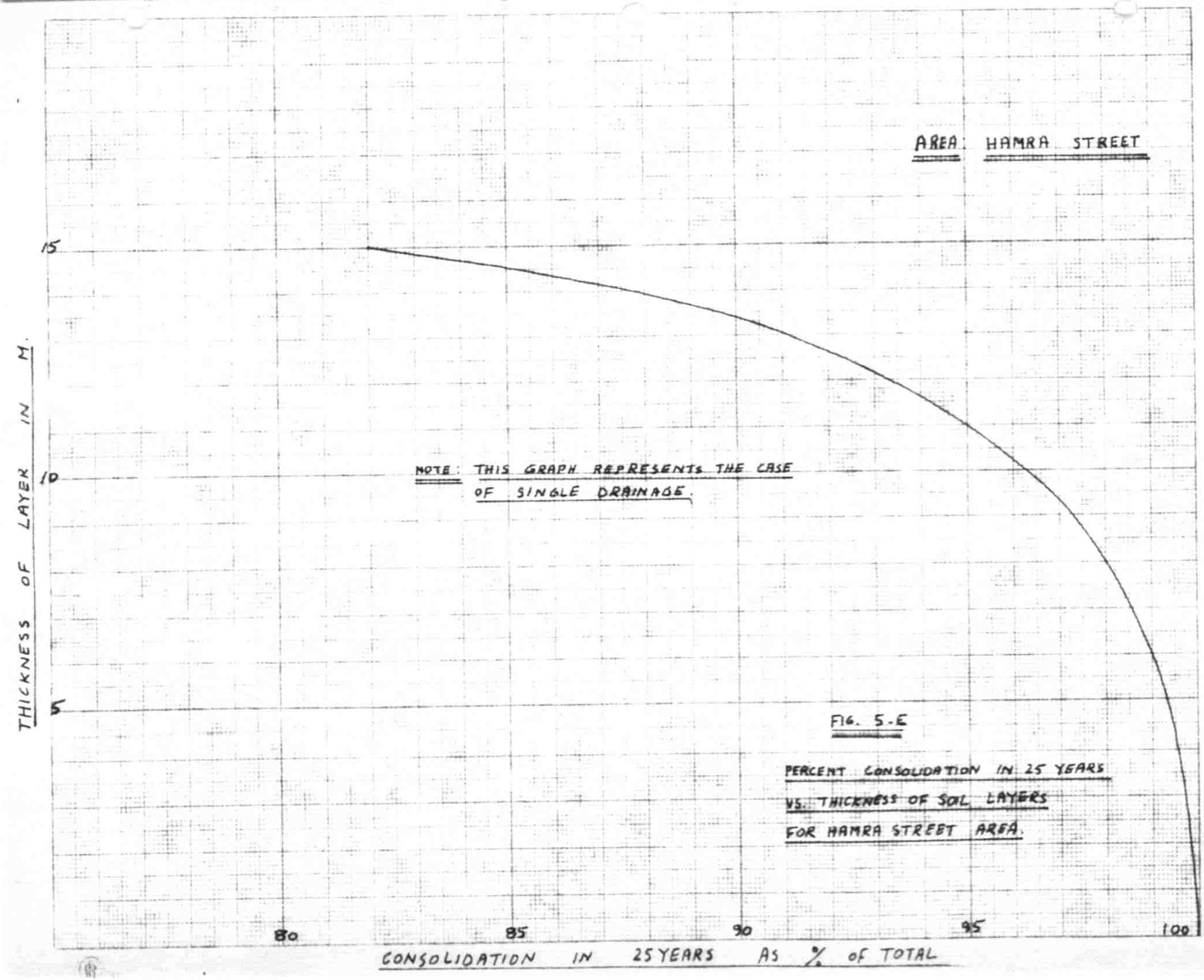
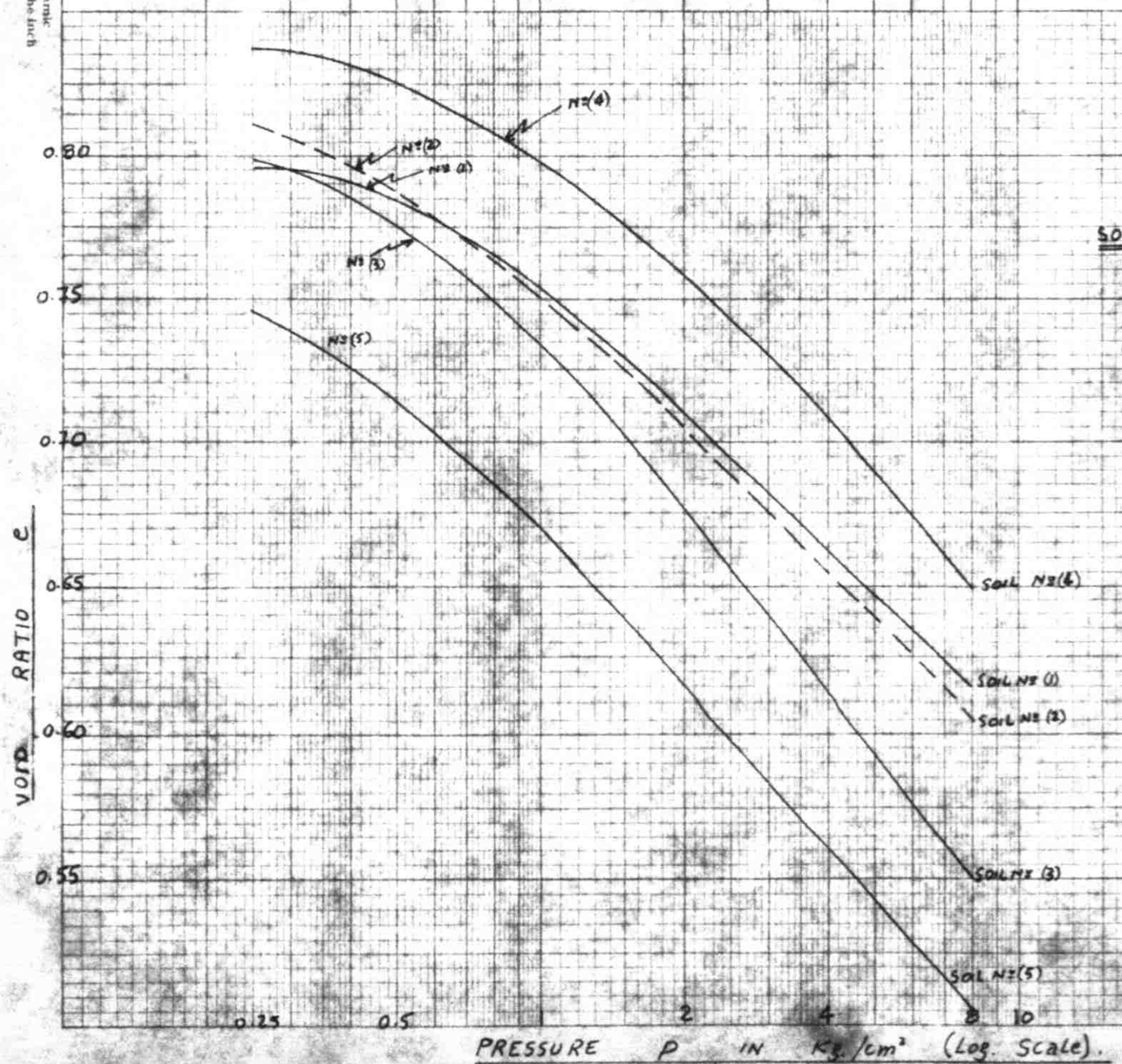


FIG. 5-E

PERCENT CONSOLIDATION IN 25 YEARS VS. THICKNESS OF SOIL LAYERS FOR HAMRA STREET AREA.

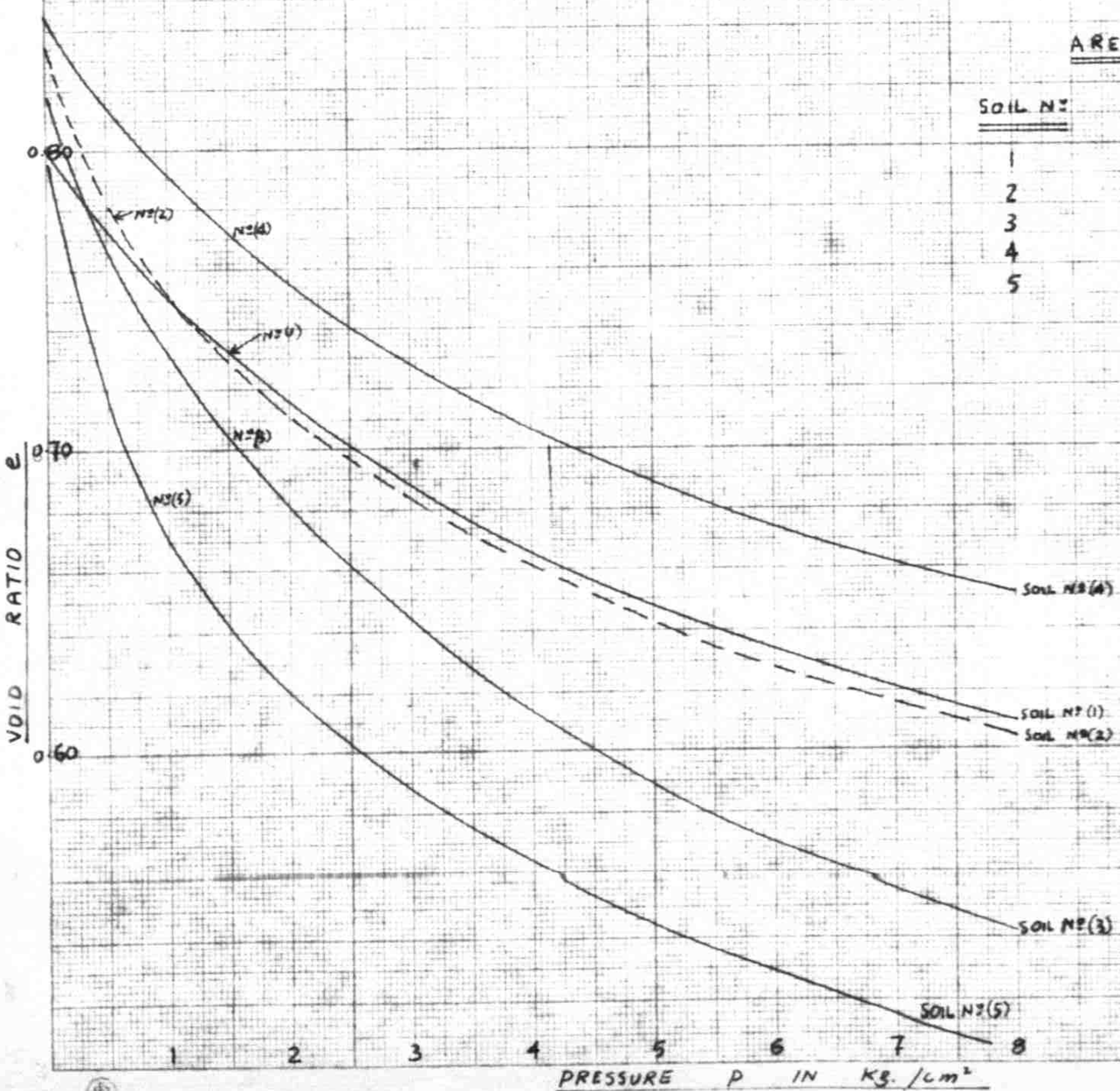


AREA: MAAMARI STREET

SOIL N°	C_{c1}	C_{c2}
1	0.067	0.180
2	0.087	0.190
3	0.070	0.238
4	0.050	0.180
5	0.110	0.207

FIG. 1-F

VOID RATIO – LOG. PRESSURE CURVES FOR MAMARI STREET SOILS



AREA : MAAMARI STREET

SOIL Nº	a_v ; cm²/g.	m_v ; cm²/g.	k ; cm/sec.
1	3.8×10^{-5}	2.11×10^{-5}	1.41×10^{-8}
2	4.2×10^{-5}	2.29×10^{-5}	1.69×10^{-8}
3	4.9×10^{-5}	2.70×10^{-5}	1.51×10^{-8}
4	3.4×10^{-5}	1.85×10^{-5}	1.82×10^{-8}
5	5.2×10^{-5}	2.92×10^{-5}	2.52×10^{-8}

NOTE: ALL THE VALUES TABULATED ABOVE ARE FOR A PRESSURE INCREMENT OF 1-2 Kg./cm².

FIG. 2-F

VOID RATIO - PRESSURE CURVES OF MAAMARI STREET SOILS

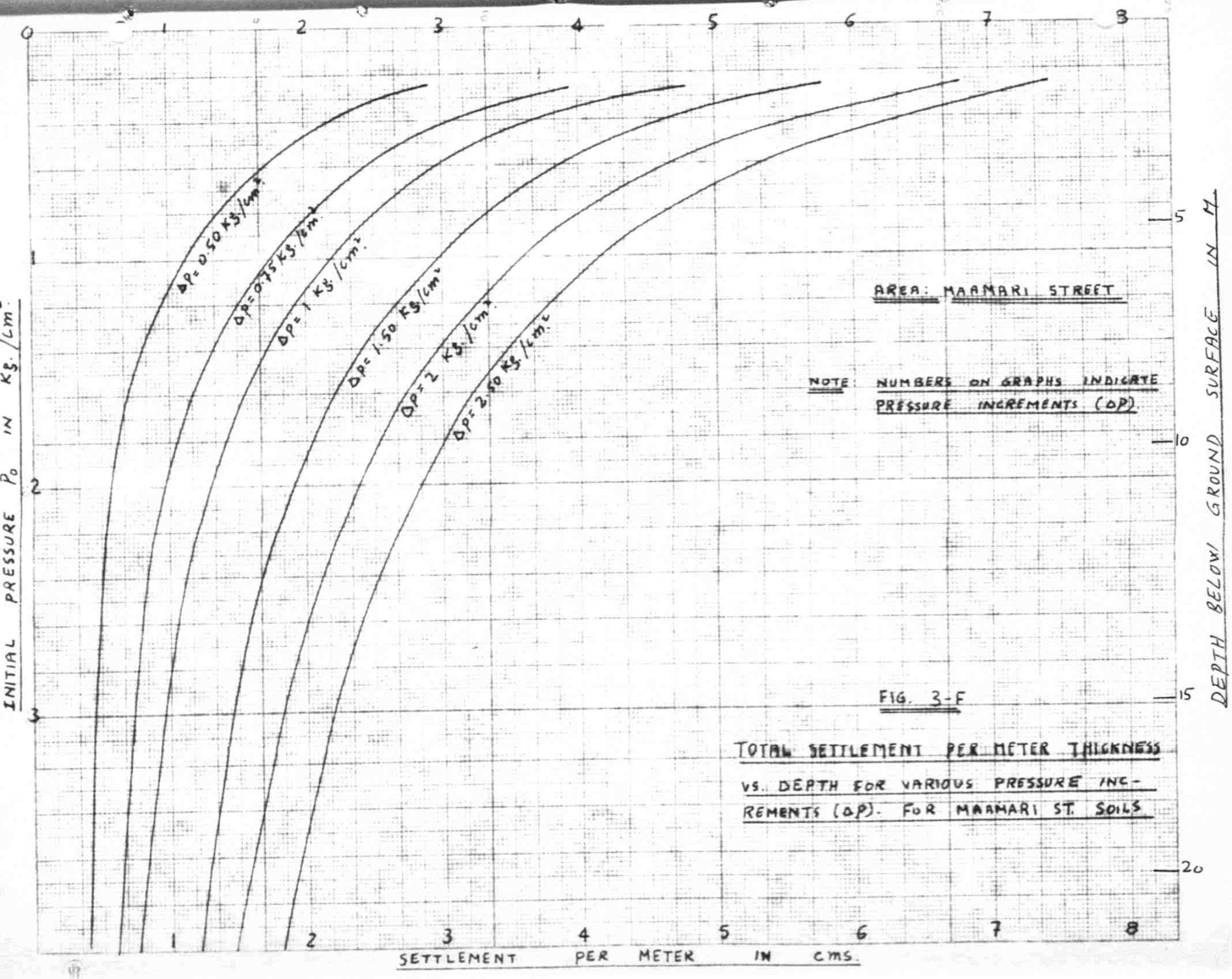


FIG. 3-F

TOTAL SETTLEMENT PER METER THICKNESS VS. DEPTH FOR VARIOUS PRESSURE INCREMENTS (ΔP). FOR MAAMARI ST. SOILS

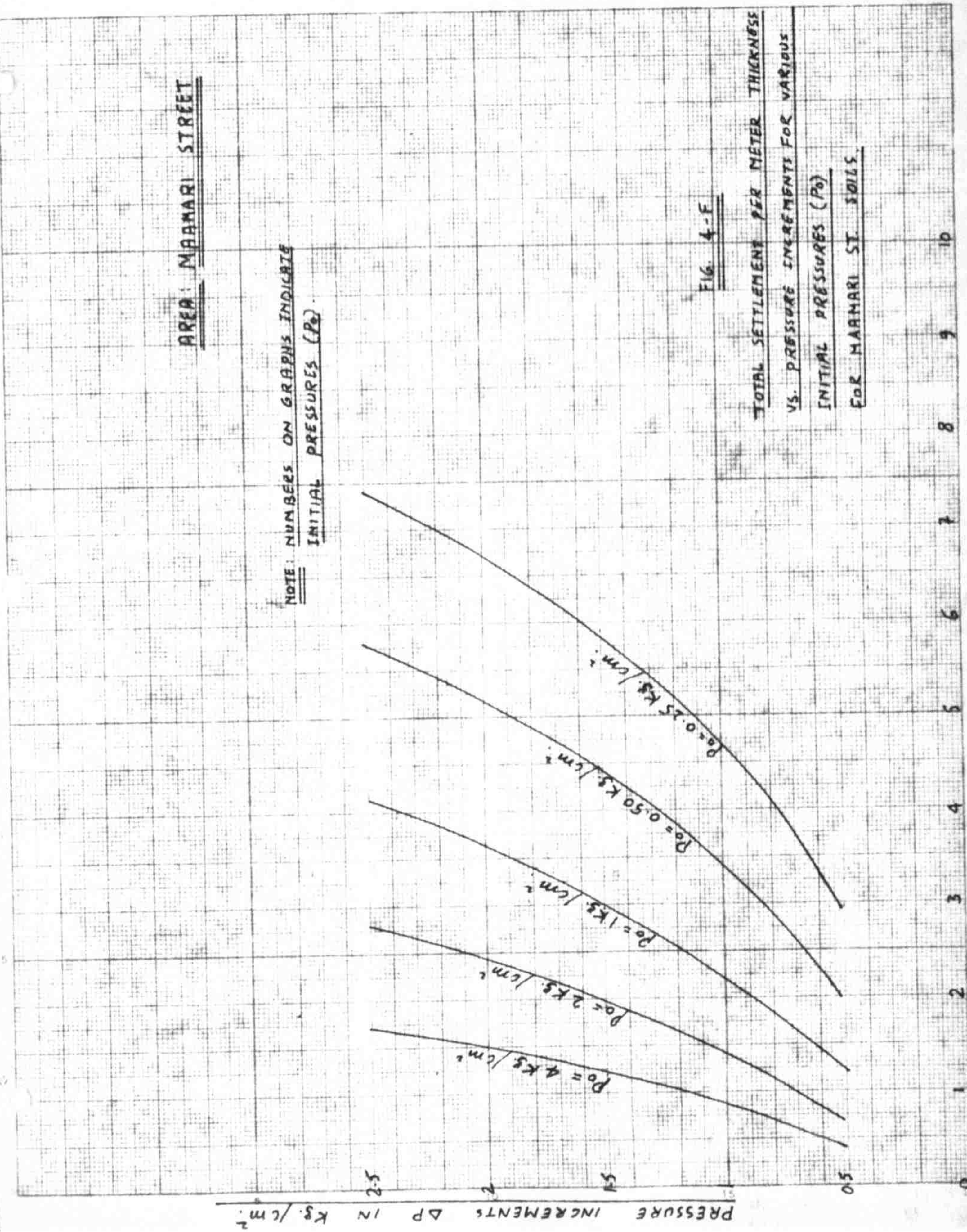


FIG. 4-F

TOTAL SETTLEMENT PER METER THICKNESS VS. PRESSURE INCREMENTS FOR VARIOUS INITIAL PRESSURES (Po) FOR MAAMARI ST. SOILS.

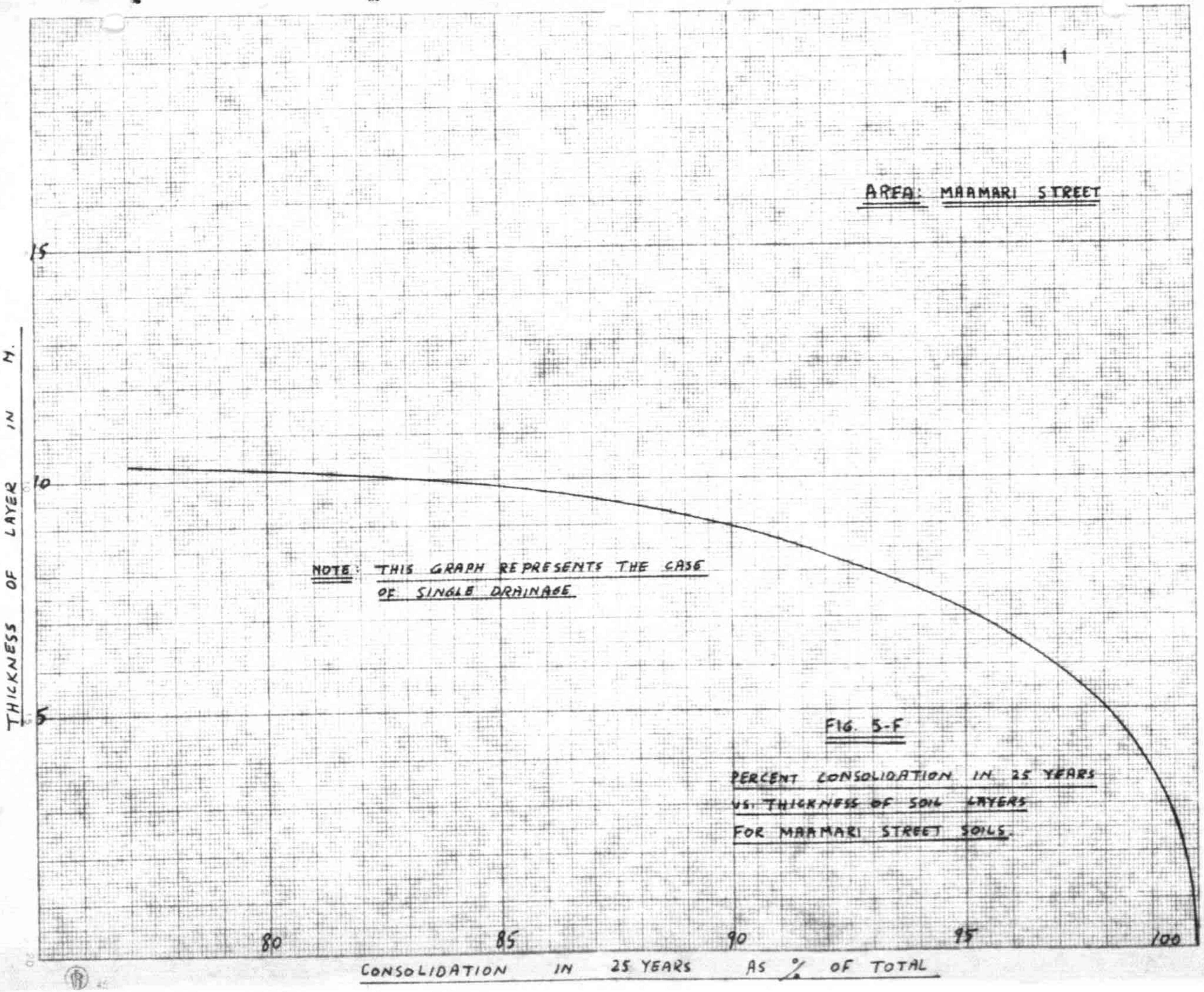


FIG. 5-F

PERCENT CONSOLIDATION IN 25 YEARS
VS. THICKNESS OF SOIL LAYERS
FOR MAAMARI STREET SOILS.

CHAPTER VI

SUMMARY AND CONCLUSIONS

This report is based on the test results of 29 soil samples obtained from six areas within Beirut. A consolidation test and an unconfined compression test were performed on every soil. Identification, sieving, and Atterberg limits tests were performed on each group of soil.

The results of these tests were presented mainly in graphical form as follows:

1) Void Ratio vs. Log. pressure curves.
2) Void Ratio vs. pressure curves.
3) Settlement vs. pressure curves.
4) Settlement vs. pressure increment curves.
5) Percent consolidation in 25 years vs. thickness of soil layer curves.

The last three groups of curves actually summarize the findings of this report.

It can be concluded from the graphs that the soils examined and tested do present a settlement problem especially if they occur in thick layers. Thus the foundation designer is called upon to investigate such settlement by identifying the soil he meets and testing it. Knowledge of the thickness of the soil layers is obviously essential to estimate the amount of settlement that could be expected.

In order to reduce the amount of settlement, the designer has to choose convenient pressure increments on the soil layers considered, by judiciously selecting the type and dimensions of the footings and their depth. The amounts of the tolerable settlement depend on the type of structure to be built and a discussion of this problem is beyond the scope of this work.

The following general conclusions could be made:

1 - Amounts of settlement

The soils from Hamra street showed maximum amounts of settlement, and were followed by soils from the other areas as follows: Bechara El-Khoury street, Maamari street, Nahr, Achrafiyeh and Baalbeck street.

2 - Percent consolidation in 25 years was highest for Nahr Area followed by Achrafiyeh, Maamari street, Bechara El-Khoury street, Baalbeck street and Hamra street.

3 - All the soils tested were found to have very low sensitivities (1.05 to 1.40).

4 - With the exception of the Achrafiyeh soils, the percentages passing sieve No. 200 were close for the soils tested (ranging from 73% to 81%). For Achrafiyeh the value was 58%.

5 - Liquid limits varied between 25% and 42%.

6 - Plastic limits varied between 16% and 28%.

7 - Unit weights varied between 1.60 and 2.04 g/cc.

8 - Specific gravities varied between 2.64 and 2.72.

9 - The values of the coefficient of permeability k ranged between 0.41×10^{-8} cm/sec. and 3.7×10^{-8} cm/sec.

10 - The existing intergranular pressures ranged between 0.35 kg/cm^2 and 1.00 kg/cm^2.

11 - The preconsolidation pressures ranged between 0.90 kg/cm^2 and 1.65 kg/cm^2.

RESERVATIONS

From the foregoing summaries of results, it can be noticed that the properties of the soils generally varied in a relatively narrow range. This, and the fact that some soils showed similar results as far as some properties are concerned and different results as far as others, lead us to put some emphasis on the fact that the engineer should study the soil properly and that the graphs and tables should be used judiciously, and only after thorough comparisons have been made between the given soil and the ones studied here. In brief, the reservation here boils down to the fact that the results should not be used automatically, but only after careful consideration.

A P P E N D I X

SAMPLE CALCULATIONS

A sample calculation is shown here for the Achrafiyeh Soil.

A - CALCULATION OF PARAMETERS

1 - The Coefficient of Consolidation c_v

This coefficient was found from the deformation-time curves by the logarithm-of-time fitting method. A sample construction for Achrafiyeh soil No. 2 is attached (Fig. 6).

c_v for Achrafiyeh soil No. 2 = 0.025 cm^2/min.

2 - The Coefficient of Compressibility a_v

This was computed for the range 1-2 kg/cm^2 from the e-p curves. (See e-p curves: Achrafiyeh). Fig 2-A

a_v for soil No.2 = 2.5×10^{-5} cm^2/g.

3 - The Coefficient of Volume Compressibility m_v

Being defined as:

$$m_v = \frac{a_v}{1 + e_o}$$

For Achrafiyeh soil No. 2, e_o = 1.04

$$m_v = \frac{2.5 \times 10^{-5}}{1 + 1.04} = \frac{2.5 \times 10^{-5}}{2.04}$$

$$= 1.2 \times 10^{-5} \ cm^2/g$$

4 - The Coefficient of Permeability, k

$$k = c_v \times \gamma_w \times m_v$$

$$= \frac{0.025}{60} \times 1 \times 1.2 \times 10^{-5} = 0.50 \times 10^{-8} \ cm/sec.$$

5 - The Compression Index C_c

The attached sample construction, (Fig. 7) shows how C_{c1} and C_{c2} were obtained from the e-log p curves. The angle between the tangent to the e-log p curve at the point of maximum curvature and the horizontal line at that point was bisected. The intersection of this bisector with the backward extension of the straight portion of the e-log p curve gave the pre-consolidation load p_c.

From (p_o, e_o) a line was drawn parallel to the initial portion of the e-log p curve, meeting the vertical line through p_c. The arithmetic value of the slope of this line was taken to be C_{c1}.

To find C_{c2}, a line was drawn between the point just established on the p_c line and the point of 0.4 e_o on the e-log p curve produced. The slope of this line was similarly taken to be C_{c2}.*3

For soils from Achrafiyeh, the average results are:

$C_{c1} = 0.046$ $\qquad$ $p_c = 1.40$ kg/cm²

$C_{c2} = 0.240$ $\qquad$ $p_o = 0.90$ jg/cm²

B - AMOUNT OF TOTAL EXPECTED SETTLEMENT

The value $p_c - p_o = 1.40 - 0.90 = 0.50$ kg/cm² is assumed constant throughout the depth.

It is further assumed that the compression indices do not vary with depth. A similar assumption is made for unit weight. Moreover, the soil layer considered is assumed to be uniform throughout it thickness.

For different values of initial pressure p_o, the value of p_c was found by adding the $(p_c - p_o)$ value computed to the p_o values. Pressure increments Δ p's were then added to p_o to obtain the final pressure $p_o + \Delta p$.

Settlement computations were then made as follows:

For Achrafiyeh soil: $p_c - p_o = 0.50$ kg/cm^2

let $p_o = 0.25$ kg/cm^2 and $\Delta p = 1.0$ kg/cm^2

For the case considered:

$$p_c = 0.25 + 0.50 = 0.75 \text{ kg/cm}^2$$

$$p = (p_o + \Delta p) = 0.25 + 1.00 = 1.25 \text{ kg/cm}^2$$

Now since $e = 0.85$ at $p = 0.25$ kg/cm^2

and $e = 0.82$ at $p = 0.75$ kg/cm^2

and since

$$\Delta H_1 = \frac{H}{1 + e_o} \cdot C_{c1} \cdot \log_{10} \frac{p_c}{p_o}$$

$$\Delta H_2 = \frac{H}{1 + e_{pc}} \cdot C_{c2} \cdot \log_{10} \frac{p}{p_c}$$

For a layer 1 m thick:

$$\Delta H_1 = \frac{100}{0.85} \times 0.046 \times \log_{10} \frac{0.75}{0.25}$$

$$= \frac{4.6}{1.85} \times \log_{10} 3$$

$$\Delta H_1 = 1.20 \text{ cm}$$

Similarly:

$$\Delta H_2 = \frac{100}{1.82} \times 0.240 \times \log_{10} \frac{1.25}{0.75}$$

$$= 2.90 \text{ cm}$$

Hence $\Delta H = \Delta H_1 + \Delta H_2 = 1.20 + 2.90 = 4.10$ cm

This is repeated for all pressure increments and assumed pressures.

The results of the computations are tabulated. Moreover, total expected settlement is plotted against p_o and Δp and the graphs are shown elsewhere in this report.

C - DEGREE OF CONSOLIDATION IN 25 YEARS

The values of c_v for the increment 1-2 kg/cm^2 for the different soils from the same area were averaged.

For Achrafiyeh Area: $c_v = 0.024$ cm^2/min.

In the equation:

$$T_v = c_v \frac{t}{H^2}$$

Taking t = 25 years, and expressing H in meters:

$$T_v = \frac{0.024 \times 25 \times 365 \times 24 \times 60}{H \times 100 \times 100}$$

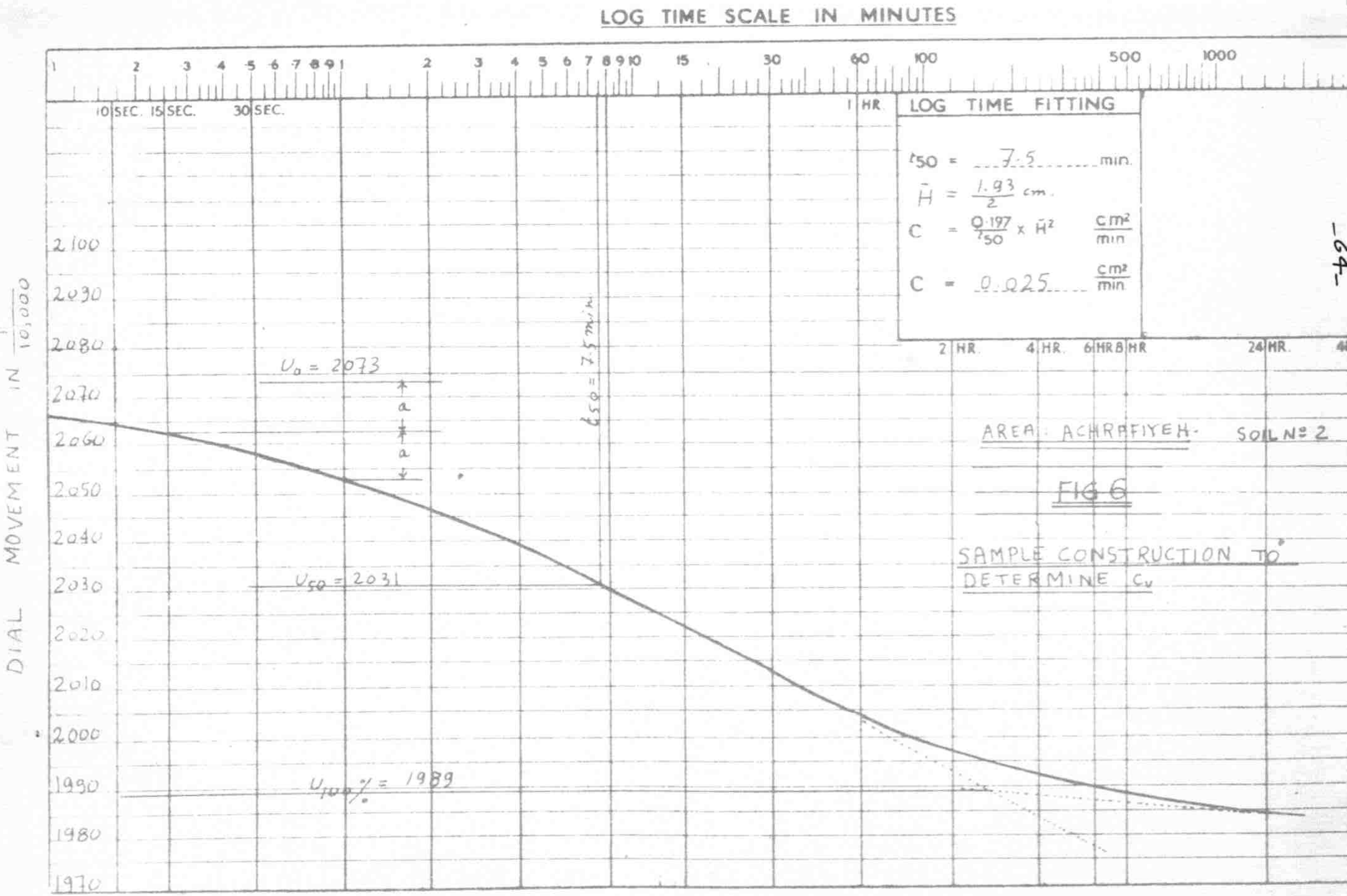
$$= \frac{31.6}{H^2}$$

For varying values of H, the values of T_v were computed. The corresponding values of average percent consolidation U were found from graphs [1] for the case of linear variation of initial excess hydrostatic pressure.

Percentage consolidation in 25 years was then plotted versus layer thickness, for single drainage.

For Achrafiyeh:

Layer thickness (m) →	1	2	4	6	8	10
T_v	31.6	7.8	1.95	0.88	0.50	0.31
U%	99.5	99.0	98.0	90.0	77.5	62.0


LOG TIME SCALE IN MINUTES
1 2 3 4 5 6 7 8 9 1 2 3 4 5 6 7 8 9 10 15 30 60 100 500 1000
10 SEC. 15 SEC. 30 SEC. 1 HR. 2 HR. 4 HR. 6 HR 8 HR 24 HR. 48
LOG TIME FITTING
t50 = 7.5 min.
H̄ = 1.93/2 cm.
C = 0.197/t50 x H̄² cm²/min
C = 0.025 cm²/min
DIAL MOVEMENT IN 1/10,000
2100 2090 2080 2070 2060 2050 2040 2030 2020 2010 2000 1990 1980 1970
Uo = 2073
a
a
t50 = 7.5 min
U50 = 2031
U100% = 1989
AREA: ACHRAFIYEH- SOIL No 2
FIG 6
SAMPLE CONSTRUCTION TO DETERMINE Cv

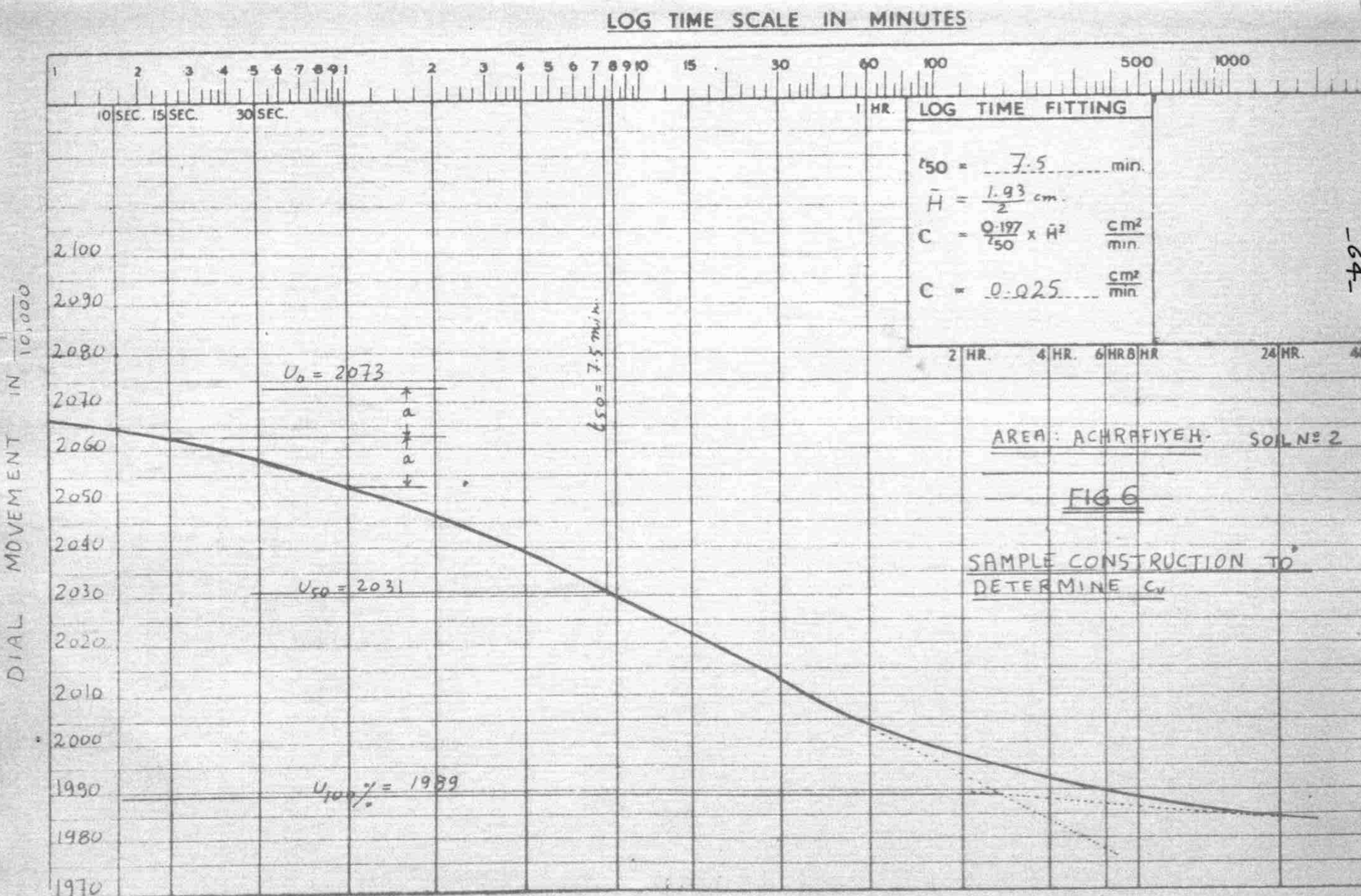

LOG TIME SCALE IN MINUTES
1 2 3 4 5 6 7 8 9 1 2 3 4 5 6 7 8 9 10 15 30 60 100 500 1000
10 SEC. 15 SEC. 30 SEC. 1 HR. 2 HR. 4 HR. 6 HR 8 HR 24 HR. 48
LOG TIME FITTING
t50 = 7.5 min.
H̄ = 1.93/2 cm.
C = 0.197/t50 x H̄² cm²/min.
C = 0.025 cm²/min
DIAL MOVEMENT IN 1/10,000
2100 2090 2080 2070 2060 2050 2040 2030 2020 2010 2000 1990 1980 1970
U0 = 2073
a
a
U50 = 2031
t50 = 7.5 min.
U100% = 1989
AREA: ACHRAFIYEH- SOIL No 2
SAMPLE CONSTRUCTION TO DETERMINE Cv

FIG 6

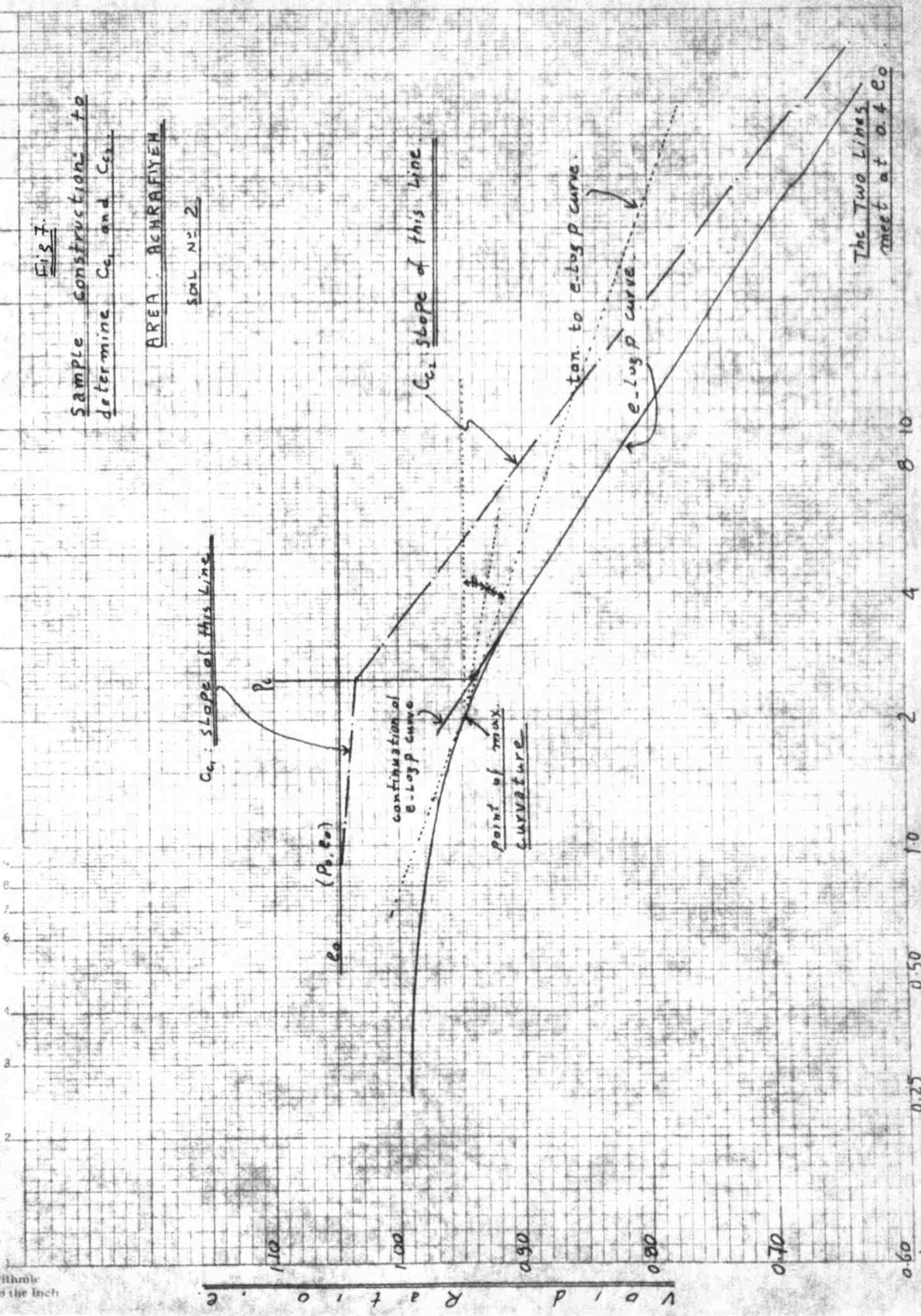


Fig 7.
Sample construction to determine C_{c_1} and C_{c_2}
AREA: ACHRAFIYEH
SOIL N° 2
C_{c_2} slope of this line
tan. to e-Log p curve
e-Log p curve
The Two Lines meet at 0.4 e_0
Pressure p in kg/cm² (Log. scale)
C_{c_1} slope of this Line
P_c
(P_0, e_0)
e_0
continuation of e-Log p curve
point of max curvature
Void Ratio, e
0.10
0.25
0.50
1.0
2
4
8
10
1.10
1.00
0.90
0.80
0.70
0.60

RESULTS OF

TESTS AND COMPUTATIONS

ACHRAFIYEH AREA

SUMMARY OF TEST RESULTS

Table 1-A
Unit Weights

Soil No.	Natural Unit Weight g/cc
1	1.78
2	1.64
3	1.70
4	1.91
5	1.81

Table 2-A
Unconfined Compressive Strength

Soil No.	Unconfined Compressive Strength kg/cm2		Sensitivity
	Undisturbed	Remoulded	
1	2.95	2.45	1.20
2	3.35	3.10	1.08
3	3.05	2.65	1.15
4	2.82	2.69	1.05
5	3.48	3.10	1.12

ACHRAFIYEH AREA (Cont.)

Table 3-A

Void Ratios

Soil No \ p_o*	0.25	0.50	1	2	4	8
1	0.776	0.760	0.735	0.689	0.629	0.563
2	0.990	0.985	0.975	0.950	0.900	0.831
3	0.962	0.950	0.924	0.875	0.817	0.746
4	0.745	0.730	0.706	0.660	0.580	0.520
5	0.768	0.759	0.726	0.680	0.625	0.571

* p_o : initial pressure in kg/cm^2

Table 4-A

Results of Consolidation Test

	Soil Number				
	1	2	3	4	5
p_o, kg/cm^2	0.90	0.90	0.90	0.90	0.90
p_c, kg/cm^2	1.20	2.50	1.00	1.20	1.10
C_{c1}	0.052	0.030	0.056	0.050	0.040
C_{c2}	0.272	0.255	0.225	0.264	0.225
c_v, cm^2/min.	0.0113	0.0250	0.0190	0.0265	0.0387
a_v, cm^2/g	4.7×10^{-5}	2.5×10^{-5}	4.5×10^{-5}	4.5×10^{-5}	3.7×10^{-5}
m_v, cm^2/g	2.5×10^{-5}	1.2×10^{-5}	2.3×10^{-5}	2.5×10^{-5}	2.1×10^{-5}
k, cm/sec.	0.48×10^{-8}	0.50×10^{-8}	0.97×10^{-8}	1.34×10^{-8}	1.33×10^{-8}

ACHRAFIYEH AREA (Cont.)

Table 5-A1

Total Settlement Per Meter Thickness of Soil

p_o	p_c =	Δp = 1/2				Δp = 3/4				Δp = 1			
	p_o+0.50	$p_o+\Delta p$	ΔH_1	ΔH_2	ΔH	$p_o+\Delta p$	ΔH_1	ΔH_2	ΔH	$p_o+\Delta p$	ΔH_1	ΔH_2	ΔH
0.25	0.75	0.75	1.20	0	1.20	1.00	1.20	1.64	2.84	1.25	1.20	2.90	4.10
0.50	1.00	1.00	0.75	0	0.75	1.25	0.75	1.28	2.03	1.50	0.75	2.34	3.09
1	1.50	1.5	0.45	0	0.45	1.75	0.45	0.91	1.36	2.00	0.45	1.65	2.10
2	2.50	2.5	0.25	0	0.25	2.75	0.25	0.55	0.80	3.00	0.25	1.09	1.34
4	4.50	4.5	0.13	0	0.13	4.75	0.13	0.34	0.47	5.00	0.13	0.63	0.76
8	8.50	8.5	0.07	0	0.07	8.75	0.07	0.17	0.24	9.00	0.07	0.37	0.44

Note: All pressures in kg/cm^2

All settlements in cm

ACHRAFIYEH AREA (Cont.)

Table 5-A2

Total Settlement Per Meter Thickness of Soil

p_o	$p_c = p_o + 0.50$	$\Delta p = 1\ 1/2$				$\Delta p = 2$				$\Delta p = 2\ 1/2$			
		$p_o + \Delta p$	ΔH_1	ΔH_2	ΔH	$p_o + \Delta p$	ΔH_1	ΔH_2	ΔH	$p_o + \Delta p$	ΔH_1	ΔH_2	ΔH
0.25	0.75	1.75	1.20	4.85	6.05	2.25	1.20	6.27	7.47	2.75	1.20	7.45	8.65
0.50	1.00	2.0	0.75	4.00	4.75	2.50	0.75	5.25	6.00	3.0	0.75	6.32	7.07
1	1.50	2.5	0.45	2.95	3.40	3.0	0.45	4.05	4.50	3.5	0.45	4.92	5.37
2	2.50	3.5	0.25	2.00	2.25	4.0	0.25	2.80	3.05	4.5	0.25	3.50	3.75
4	4.50	5.5	0.13	1.21	1.34	6.0	0.13	1.75	1.88	6.5	0.13	2.22	2.35
8	8.50	9.5	0.07	0.72	0.79	10.0	0.07	1.00	1.07	10.5	0.07	1.37	1.44

Note: All pressures in kg/cm^2

All settlements in cm

BECHARA EL-KHOURY STREET AREA

SUMMARY OF TEST RESULTS

Table 1-B

Unit Weights

Soil No.	Natural Unit Weight g/cc
1	1.71
2	1.70
3	1.77
4	1.72
5	1.73

Table 2-B

Unconfined Compressive Strength

Soil No.	Unconfined Compressive Strength kg/cm2		Sensitivity
	Undisturbed	Remoulded	
1	2.15	1.64	1.31
2	1.90	1.57	1.21
3	1.95	1.56	1.25
4	1.88	1.34	1.40
5	1.78	1.51	1.18

BECHARA EL-KHOURY STREET AREA (Cont.)

Table 3-B

Void Ratios

Soil No \ p_o*	0.25	0.50	1	2	4	8
1	1.020	1.000	0.970	0.924	0.858	0.788
2	1.090	1.045	1.005	0.971	0.908	0.837
3	1.020	0.988	0.962	0.918	0.860	0.801
4	1.020	0.970	0.936	0.878	0.814	0.738
5	1.058	1.038	1.002	0.953	0.894	0.832

* p_o : initial pressure in kg/cm^2

Table 4-B

Results of Consolidation Test

	Soil Number				
	1	2	3	4	5
p_o, kg/cm^2	1.00	1.00	1.00	0.90	0.90
p_c, kg/cm^2	1.35	1.35	1.40	1.20	1.15
C_{c1}	0.075	0.072	0.060	0.094	0.073
C_{c2}	0.275	0.267	0.227	0.300	0.235
c_v, $cm^2/min.$	0.1290	0.0745	0.0437	0.0281	0.0775
a_v, cm^2/g	$4.7x10^{-5}$	$6.2x10^{-5}$	$4.2x10^{-5}$	$5.0x10^{-5}$	$4.8x10^{-5}$
m_v, cm^2/g	$2.23x10^{-5}$	$2.91x10^{-5}$	$2.07x10^{-5}$	$2.41x10^{-5}$	$2.30x10^{-5}$
k, cm/sec.	$4.80x10^{-8}$	$3.62x10^{-8}$	$1.50x10^{-8}$	$1.13x10^{-8}$	$2.90x10^{-8}$

BECHARA EL-KHOURY STREET AREA (Cont.)

Table 5-B1

Total Settlement Per Meter Thickness of Soil

p_o	$p_c = p_o + 0.35$	$\Delta p = 1/2$				$\Delta p = 3/4$				$\Delta p = 1$			
		$p_o + \Delta p$	ΔH_1	ΔH_2	ΔH	$p_o + \Delta p$	ΔH_1	ΔH_2	ΔH	$p_o + \Delta p$	ΔH_1	ΔH_2	ΔH
0.25	0.60	0.75	1.40	1.25	2.65	1.00	1.40	2.86	4.26	1.25	1.40	4.14	3.54
0.50	0.85	1.0	0.86	0.94	1.80	1.25	0.86	2.19	3.05	1.5	0.86	3.25	4.11
1	1.35	1.5	0.49	0.60	1.09	1.75	0.49	1.51	2.00	2	0.49	2.26	2.75
2	2.35	2.5	0.27	0.34	0.61	2.75	0.27	0.91	1.18	3	0.27	1.44	1.71
4	4.35	4.5	0.15	0.18	0.33	4.75	0.15	0.52	0.67	5	0.15	0.85	1.00
8	8.35	8.5	0.07	0.12	0.19	8.75	0.07	0.25	0.32	9	0.07	0.48	0.55

Note: All pressures in kg/cm^2

All settlements in cm

BECHARA EL-KHOURY STREET AREA (Cont.)

Table -B2

Total Settlement Per Meter Thickness of Soil

p_o	$p_c = p_o + 0.35$	$\Delta p = 1\ 1/2$				$\Delta p = 2$				$\Delta p = 2\ 1/2$			
		$p_o + \Delta p$	ΔH_1	ΔH_2	ΔH	$p_o + \Delta p$	ΔH_1	ΔH_2	ΔH	$p_o + \Delta p$	ΔH_1	ΔH_2	ΔH
0.25	0.60	1.75	1.40	6.05	7.45	2.25	1.40	7.45	8.85	2.75	1.40	8.60	10.0
0.50	0.85	2	0.86	4.88	5.74	2.50	0.86	6.15	7.01	3	0.86	7.14	8.0
1	1.35	2.50	0.49	3.58	4.07	3	0.49	4.60	5.09	3.50	0.49	5.51	6.0
2	2.35	3.50	0.27	2.33	2.60	4	0.27	3.03	3.30	4.50	0.27	3.76	4.03
4	4.35	5.50	0.15	1.46	1.61	6	0.15	1.96	2.11	6.50	0.15	2.46	2.61
8	8.35	9.50	0.07	0.82	0.89	10	0.07	1.15	1.22	10.50	0.07	1.51	1.58

Note: All pressures in kg/cm^2

All settlements in cm

BAALBECK STREET AREA

SUMMARY OF TEST RESULTS

Table 1-C

Unit Weigths

Soil No.	Natural Unit Weight g/cc
1	2.01
2	2.02
3	2.04
4	1.99
5	2.13

Table 2-C

Unconfined Compressive Strength

Soil No.	Unconfined Compressive Strength kg/cm^2		Sensitivity
	Undisturbed	Remoulded	
1	2.48	2.00	1.24
2	2.68	2.06	1.30
3	2.35	2.14	1.10
4	2.32	1.93	1.20
5	2.40	2.08	1.15

BAALBECK STREET AREA (Cont.)

Table 3-C

Void Ratios

Soil No \ p_o*	0.25	0.50	1	2	4	8
1	0.652	0.635	0.615	0.588	0.555	0.521
2	0.660	0.650	0.627	0.605	0.571	0.535
3	0.632	0.624	0.598	0.587	0.550	0.505
4	0.661	0.654	0.635	0.610	0.572	0.530
5	0.545	0.532	0.518	0.490	0.457	0.423

* p_o : initial pressure in kg/cm^2

Table 4-C

Results of Consolidation Test

	Soil Number				
	1	2	3	4	5
p_o, kg/cm2	1.00	1.00	1.00	1.00	1.00
p_c, kg/cm2	1.50	1.70	2.10	1.80	1.20
C_{c1}	0.010	0.010	0.008	0.005	0.010
C_{c2}	0.125	0.140	0.160	0.150	0.130
c_v, cm^2/min.	0.1070	0.1230	0.0832	0.0695	0.0726
a_v, cm^2/g	$2.8x10^{-5}$	$2.8x10^{-5}$	$2.5x10^{-5}$	$2.5x10^{-5}$	$2.6x10^{-5}$
m_v, cm^2/g	$1.68x10^{-5}$	$1.66x10^{-5}$	$1.52x10^{-5}$	$1.99x10^{-5}$	$1.67x10^{-5}$
k, cm/sec.	$2.03x10^{-8}$	$1.92x10^{-8}$	$2.11x10^{-8}$	$3.06x10^{-8}$	$2.98x10^{-8}$

BAALBECK STREET AREA (Cont.)

Table 5-C1

Total Settlement Per Meter Thickness of Soil

p_o	$p_c = p_o + 0.65$	$\Delta p = 1/2$				$\Delta p = 3/4$				$\Delta p = 1$			
		$p_o + \Delta p$	ΔH_1	ΔH_2	ΔH	$p_o + \Delta p$	ΔH_1	ΔH_2	ΔH	$p_o + \Delta p$	ΔH_1	ΔH_2	ΔH
0.25	0.90	0.75	2.52	-	2.52	1.00	2.98	0.40	3.38	1.25	2.98	1.25	4.23
0.50	1.15	1.00	1.60	-	1.60	1.25	1.89	0.33	2.22	1.50	1.89	1.00	2.89
1	1.65	1.50	0.95	-	0.95	1.75	1.17	0.22	1.39	2.00	1.17	0.73	1.90
2	2.65	2.50	0.52	-	0.52	2.75	0.67	0.15	0.82	3.00	0.67	0.48	1.15
4	4.65	4.50	0.27	-	0.27	4.75	0.36	0.08	0.44	5.00	0.36	0.31	0.67
8	8.65	8.50	0.14	-	0.14	8.75	0.20	0.04	0.24	9.00	0.20	0.16	0.36

Note: All pressures in kg/cm^2

All settlements in cm

BAALBECK STREET AREA (Cont.)

Table 5-C2

Total Settlement Per Meter Thickness of Soil

p_o	$p_c = p_o + 0.65$	Δp = 1.5				Δp = 2				Δp = 2.5			
		$p_o + \Delta p$	ΔH_1	ΔH_2	ΔH	$p_o + \Delta p$	ΔH_1	ΔH_2	ΔH	$p_o + \Delta p$	ΔH_1	ΔH_2	ΔH
0.25	0.90	1.75	2.98	2.54	5.52	2.25	2.98	3.48	6.46	2.75	2.98	4.25	7.23
0.50	1.15	2.0	1.89	2.10	3.99	2.5	1.89	2.96	4.85	3.0	1.89	3.66	5.55
1	1.65	2.5	1.17	1.61	2.78	3	1.17	2.31	3.48	3.5	1.17	2.98	4.07
2	2.65	3.5	0.67	1.10	1.77	4	0.67	1.62	2.29	4.5	0.67	2.08	2.75
4	4.65	5.5	0.36	0.67	1.03	6	0.36	1.03	1.39	6.5	0.36	1.35	1.71
8	8.65	9.5	0.20	0.39	0.59	10	0.20	0.60	0.80	10.5	0.20	0.78	0.98

Note: All pressures in kg/cm^2

All settlements in cm

NAHR AREA

SUMMARY OF TEST RESULTS

Table 1-D

Unit Weights

Soil No.	Natural Unit Weight g/cc
1	2.01
2	2.06
3	2.02
4	2.04

Table 2-D

Unconfined Compressive Strength

Soil No.	Unconfined Compressive Strength kg/cm2		Sensitivity
	Undisturbed	Remoulded	
1	2.14	1.86	1.15
2	1.85	1.52	1.22
3	2.20	1.75	1.26
4	1.90	1.68	1.13

NAHR AREA (Cont.)

Table 3-D

Void Ratios

Soil No \ p_o*	0.25	0.50	1	2	4	8
1	0.580	0.565	0.531	0.496	0.430	0.382
2	0.705	0.685	0.636	0.562	0.472	0.400
3	0.775	0.747	0.705	0.629	0.522	0.412
4	0.735	0.707	0.672	0.592	0.510	0.429

* p_o : initial pressure in kg/cm^2

Table 4-D

Results of the Consolidation Test

	Soil Number			
	1	2	3	4
p_o, kg/cm^2	0.30	0.40	0.40	0.40
p_c, kg/cm^2	1.45	0.87	1.40	0.98
C_{c1}	0.110	0.060	0.090	0.070
C_{c2}	0.360	0.285	0.270	0.292
c_v, $cm^2/min.$	0.0186	0.0041	0.0035	0.0063
a_v, cm^2/g	$4.6x10^{-5}$	$6.1x10^{-5}$	$6.2x10^{-5}$	$6.4x10^{-5}$
m_v, cm^2/g	$2.64x10^{-5}$	$3.57x10^{-5}$	$3.52x10^{-5}$	$3.73x10^{-5}$
k, cm/sec.	$0.82x10^{-8}$	$0.24x10^{-8}$	$0.20x10^{-8}$	$0.39x10^{-8}$

NAHR AREA (Cont.)

Table 5-D1

Total Expected Settlement per Meter

p_o	$p_c = p_o + 0.80$	$\Delta p = 1/2$				$\Delta p = 3/4$				$\Delta p = 1$			
		$p_o + \Delta p$	ΔH_1	ΔH_2	ΔH	$p_o + \Delta p$	ΔH_1	ΔH_2	ΔH	$p_o + \Delta p$	ΔH_1	ΔH_2	ΔH
0.25	1.05	0.75	2.26	-	2.26	1.00	2.86	0	2.86	1.25	2.96	1.39	4.35
0.50	1.30	1.0	1.47	-	1.47	1.25	1.94	0	1.94	1.5	2.03	1.13	3.16
1	1.80	1.5	0.88	-	0.88	1.75	1.21	0	1.21	2	1.27	0.86	2.13
2	2.80	2.5	0.50	-	0.50	2.75	0.71	0	0.71	3	0.76	0.58	1.34
4	4.80	4.5	0.27	-	0.27	4.75	0.42	0	0.42	5	0.44	0.35	0.79
8	8.80	8.5	0.14	-	0.14	8.75	0.22	0	0.22	9	0.24	0.18	0.42

Note: All pressures are in kg/cm^2

All settlements are in cm

NAHR AREA (Cont.)

Table 5-D2

Total Expected Settlement per Meter

p_o	$p_c = p_o + 0.80$	$\Delta p = 1\ 1/2$				$\Delta p = 2$				$\Delta p = 2\ 1/2$			
		$p_o + \Delta p$	ΔH_1	ΔH_2	ΔH	$p_o + \Delta p$	ΔH_1	ΔH_2	ΔH	$p_o + \Delta p$	ΔH_1	ΔH_2	ΔH
0.25	1.05	1.75	2.96	4.08	7.04	2.25	2.96	6.06	9.02	2.75	2.96	7.70	10.66
0.50	1.30	2	2.03	3.48	5.51	2.5	2.03	5.25	7.28	3.0	2.03	6.75	8.78
1	1.80	2.50	1.27	2.73	4.00	3	1.27	4.13	5.40	3.5	1.27	5.54	6.81
2	2.80	4.50	0.76	1.91	2.67	4	0.76	3.06	3.82	4.5	0.76	4.08	4.84
4	4.80	5.50	0.44	1.17	1.61	6	0.44	1.98	2.42	6.5	0.44	2.67	3.11
8	8.80	9.50	0.24	0.72	0.96	10	0.24	1.23	1.67	10.5	0.24	1.63	1.87

Note: All pressures are in kg/cm^2

All settlements are in cm

HAMRA STREET AREA

SUMMARY OF TEST RESULTS

Table 1-E

Unit Weights

Soil No.	Natural Unit Weight g/cc
1	1.62
2	1.62
3	1.62
4	1.55
5	1.57

Table 2-E

Unconfined Compressive Strength

Soil No.	Unconfined Compressive Strength kg/cm2		Sensitivity
	Undisturbed	Remoulded	
1	2.85	2.38	1.20
2	3.10	2.36	1.31
3	2.90	2.28	1.27
4	2.79	2.23	1.25
5	2.85	2.40	1.19

HAMRA STREET AREA (Cont.)

Table 3-E

Void Ratios

Soil No. \ p_o*	0.25	0.50	1	2	4	8
1	1.170	1.170	1.160	1.120	1.081	1.033
2	1.141	1.090	1.070	1.032	0.985	0.925
3	1.128	1.092	1.040	0.970	0.900	0.826
4	1.202	1.180	1.133	1.052	1.017	0.952
5	1.228	1.180	1.148	1.103	1.060	1.010

* p_o : initial pressure in kg/cm^2

Table 4-E

Results of the Consolidation Test

	Soil Number				
	1	2	3	4	5
p_o, kg/cm^2	1.35	0.90	0.55	0.70	0.60
p_c, kg/cm^2	1.65	1.10	0.75	0.80	0.71
C_{c1}	0.025	0.080	0.110	0.083	0.065
C_{c2}	0.185	0.182	0.255	0.190	0.190
c_v, $cm^2/min.$	0.0693	0.1190	0.1390	0.1040	0.1400
a_v, cm^2/g	$2.3x10^{-5}$	$3.6x10^{-5}$	$5.7x10^{-5}$	$5.1x10^{-5}$	$3.6x10^{-5}$
m_v, cm^2/g	$1.06x10^{-5}$	$1.68x10^{-5}$	$2.61x10^{-5}$	$2.30x10^{-5}$	$1.61x10^{-5}$
k, cm/sec.	$1.22x10^{-8}$	$3.33x10^{-8}$	$6.15x10^{-8}$	$4.00x10^{-8}$	$3.76x10^{-8}$

HAMRA STREET AREA (Cont.)

Table 5-E1

Total Expected Settlement per Meter

p_o	$p_c = p_o + 0.20$	$\Delta p = 1/2$				$\Delta p = 3/4$				$\Delta p = 1$			
		$p_o + \Delta p$	ΔH_1	ΔH_2	ΔH	$p_o + \Delta p$	ΔH_1	ΔH_2	ΔH	$p_o + \Delta p$	ΔH_1	ΔH_2	ΔH
0.25	0.45	0.75	1.60	3.55	5.15	1.00	1.60	5.95	7.55	1.25	1.60	7.50	9.10
0.50	0.70	1.0	0.93	2.74	3.76	1.25	0.93	4.50	5.43	1.5	0.93	5.84	6.77
1	1.20	1.5	0.52	1.76	2.28	1.75	0.52	2.98	3.50	2	0.52	4.05	4.57
2	2.20	2.5	0.29	1.01	1.30	2.75	0.29	1.84	2.13	3	0.29	2.52	2.81
4	4.20	4.5	0.15	0.58	0.73	4.75	0.15	1.05	1.20	5	0.15	1.50	1.65
8	8.20	8.5	0.10	0.36	0.46	8.75	0.10	0.61	0.71	9	0.10	0.87	0.97

Note: All pressures are in kg/cm^2

All settlements are in cm

HAMRA STREET AREA (Cont.)

Table 5-E2

Total Expected Settlement per Meter

p_o	$p_c = p_o + 0.20$	$\Delta p = 1\ 1/2$				$\Delta p = 2$				$\Delta p = 2\ 1/2$			
		$p_o + \Delta p$	ΔH_1	ΔH_2	ΔH	$p_o + \Delta p$	ΔH_1	ΔH_2	ΔH	$p_o + \Delta p$	ΔH_1	ΔH_2	ΔH
0.25	0.45	1.75	1.60	10.30	11.90	2.25	1.60	12.20	13.80	2.75	1.60	13.70	15.30
0.50	0.70	2	0.93	8.10	9.03	2.50	0.93	9.80	10.73	3	0.93	11.20	12.13
1	1.20	2.50	0.52	5.80	6.32	3	0.52	7.23	7.75	3.50	0.52	8.45	8.97
2	2.20	3.50	0.29	3.82	4.11	4	0.29	4.95	5.24	4.50	0.29	5.87	6.16
4	4.20	5.50	0.15	2.32	2.47	6	0.15	3.07	3.22	6.50	0.15	3.76	3.81
8	8.20	9.50	0.10	1.35	1.45	10	0.10	1.81	1.91	10.50	0.10	2.24	2.34

Note: All pressures are in kg/cm^2

All settlements are in cm

MAAMARI STREET AREA

SUMMARY OF TEST RESULTS

Table 1-F

Unit Weights

Soil No.	Natural Unit Weight g/cc
1	1.86
2	1.88
3	1.86
4	1.77
5	1.90

Table 2-F

Unconfined Compressive Strength

Soil No.	Unconfined Compressive Strength kg/cm2		Sensitivity
	Undisturbed	Remoulded	
1	3.10	2.30	1.35
2	2.90	2.08	1.40
3	2.88	2.25	1.28
4	3.18	2.43	1.31
5	2.95	2.22	1.33

MAAMARI STREET AREA (Cont.)

Table 3-F

Void Ratios

Soil No. \ p_o*	0.25	0.50	1	2	4	8
1	0.795	0.778	0.756	0.710	0.664	0.610
2	0.815	0.779	0.754	0.709	0.659	0.602
3	0.798	0.779	0.726	0.675	0.609	0.543
4	0.836	0.826	0.797	0.756	0.707	0.650
5	0.748	0.715	0.666	0.617	0.559	0.498

* p_o : initial pressure in kg/cm^2

Table 4-F

Results of the Consolidation Test

	Soil Number				
	1	2	3	4	5
p_o, kg/cm^2	0.75	0.60	1.25	0.70	0.45
p_c, kg/cm^2	1.06	0.90	0.70	1.12	0.60
C_{c1}	0.067	0.087	0.070	0.050	0.110
C_{c2}	0.180	0.190	0.238	0.180	0.207
c_v, $cm^2/min.$	0.0388	0.0437	0.0492	0.0592	0.0519
a_v, cm^2/g	$3.8x10^{-5}$	$4.2x10^{-5}$	$4.9x10^{-5}$	$3.4x10^{-5}$	$5.2x10^{-5}$
m_v, cm^2/g	$2.11x10^{-5}$	$2.29x10^{-5}$	$2.70x10^{-5}$	$1.85x10^{-5}$	$2.92x10^{-5}$
k, cm/sec.	$1.36x10^{-8}$	$1.67x10^{-8}$	$1.51x10^{-8}$	$1.82x10^{-8}$	$2.52x10^{-8}$

MAAMARI STREET AREA (Cont.)

Table 5-F1

Total Expected Settlement per Meter

p_o	$p_c = p_o + 0.15$	$\Delta p = 1/2$				$\Delta p = 3/4$				$\Delta p = 1$			
		$p_o + \Delta p$	ΔH_1	ΔH_2	ΔH	$p_o + \Delta p$	ΔH_1	ΔH_2	ΔH	$p_o + \Delta p$	ΔH_1	ΔH_2	ΔH
0.25	0.40	0.75	0.85	2.13	2.98	1.00	0.85	3.10	3.95	1.25	0.85	3.90	4.75
0.50	0.65	1.0	0.49	1.50	1.99	1.25	0.49	2.29	2.78	1.5	0.49	2.90	3.39
1	1.15	1.50	0.26	0.92	1.18	1.75	0.26	1.46	1.72	2	0.26	1.95	2.21
2	2.15	2.5	0.15	0.53	0.68	2.75	0.15	0.89	1.04	3	0.15	1.21	1.36
4	4.15	4.5	0.08	0.29	0.38	4.75	0.08	0.48	0.56	5	0.08	0.67	0.75
8	8.15	8.5	0.04	0.15	0.19	8.75	0.04	0.26	0.30	9	0.04	0.37	0.41

Note: All pressures are in kg/cm^2

All settlements are in cm

MAAMARI STREET AREA (Cont.)

Table 5-F2

Total Expected Settlement per Meter

p_o	$p_c = p_o + 0.15$	$\Delta p = 1\ 1/2$				$\Delta p = 2$				$\Delta p = 2\ 1/2$			
		$p_o + \Delta p$	ΔH_1	ΔH_2	ΔH	$p_o + \Delta p$	ΔH_1	ΔH_2	ΔH	$p_o + \Delta p$	ΔH_1	ΔH_2	ΔH
0.25	0.40	1.75	0.85	5.04	5.89	2.25	0.85	5.90	6.75	2.75	0.85	6.56	7.41
0.50	0.65	2	0.49	3.91	4.40	2.5	0.49	4.68	5.17	3.0	0.49	5.30	5.79
1	1.15	2.50	0.26	2.72	2.98	3.0	0.26	3.38	3.64	3.5	0.26	3.90	4.10
2	2.15	3.50	0.15	1.76	1.91	4.0	0.15	2.23	2.38	4.5	0.15	2.68	2.83
4	4.15	5.50	0.08	1.03	1.18	6	0.08	1.37	1.45	6.5	0.08	1.67	1.75
8	8.15	9.50	0.04	0.60	0.64	10	0.04	0.80	0.84	10.5	0.04	0.98	1.02

Note: All pressures are in kg/cm^2

All settlements are in cm

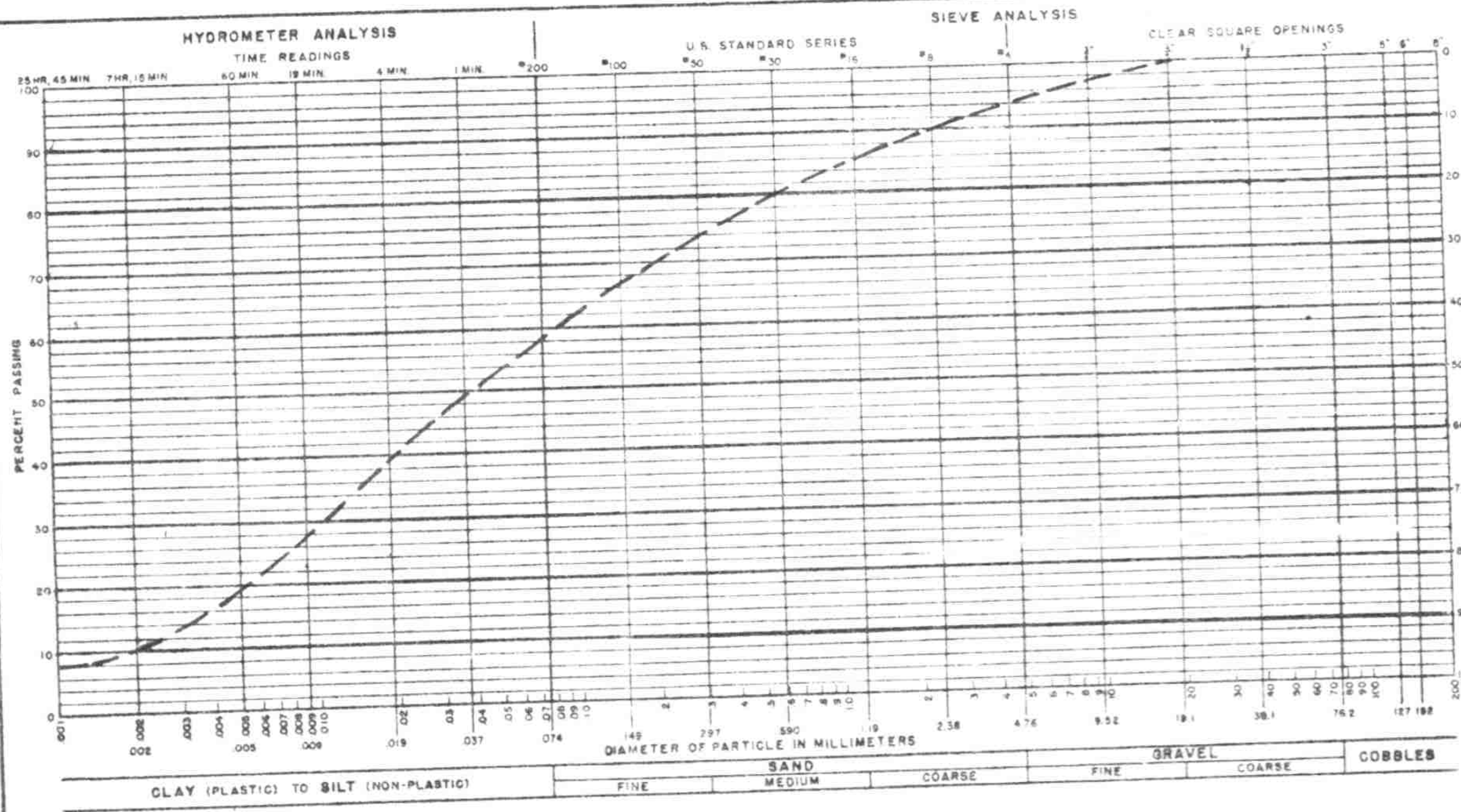


FIG. 2A. GRAIN SIZE CURVE OF ACHRAFIYEH SOIL.

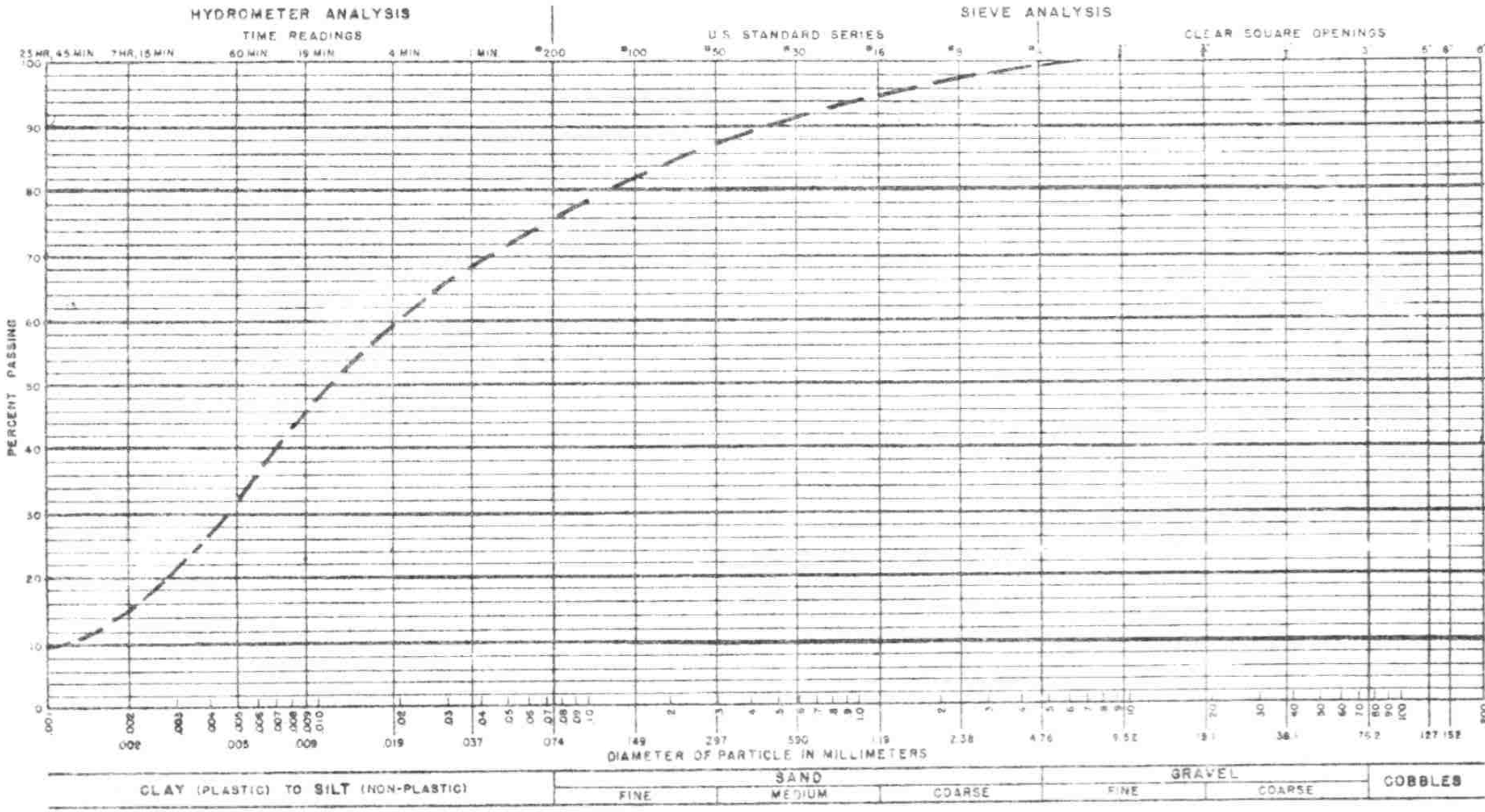


FIG 2-B GRAIN SIZE CURVE OF BECHARA EL-KHOURY STREET SOIL.

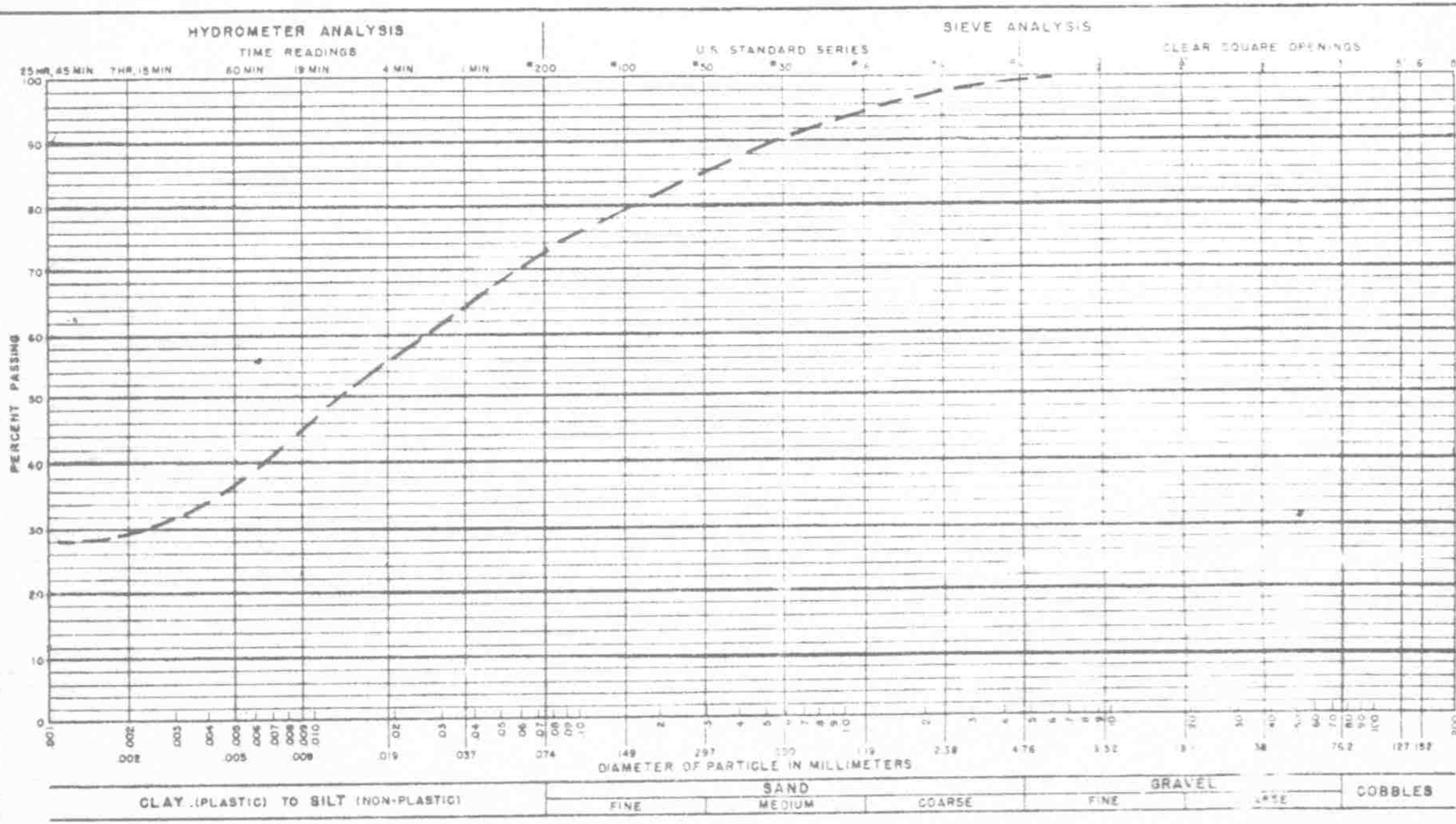


FIG. 8-C   GRAIN SIZE CURVE of BAALBECK STREET SOIL

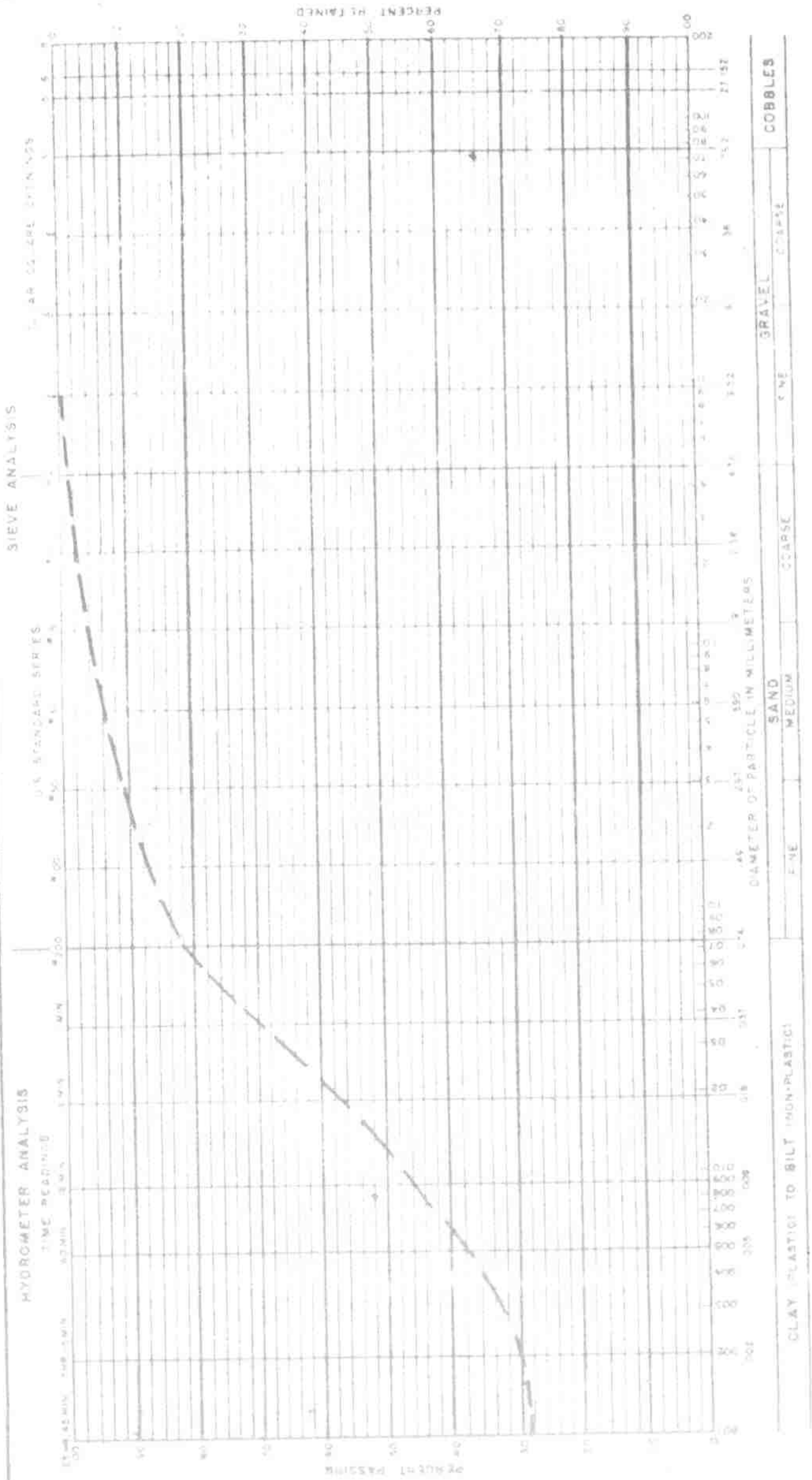


FIG. 8.D GRAIN SIZE CURVE OF NAHR SOILS

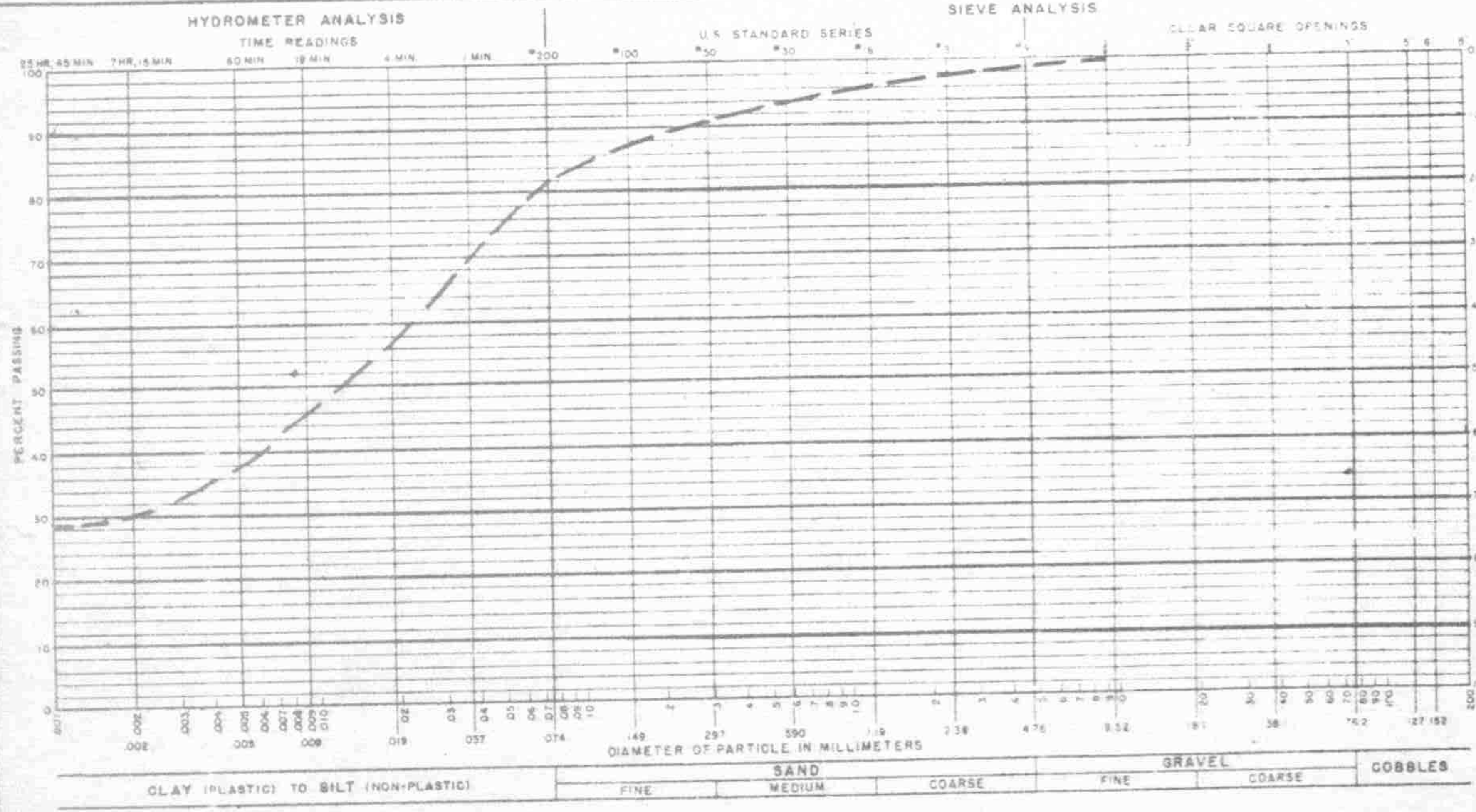


FIG. 8.D GRAIN SIZE CURVE OF NAHR SOILS

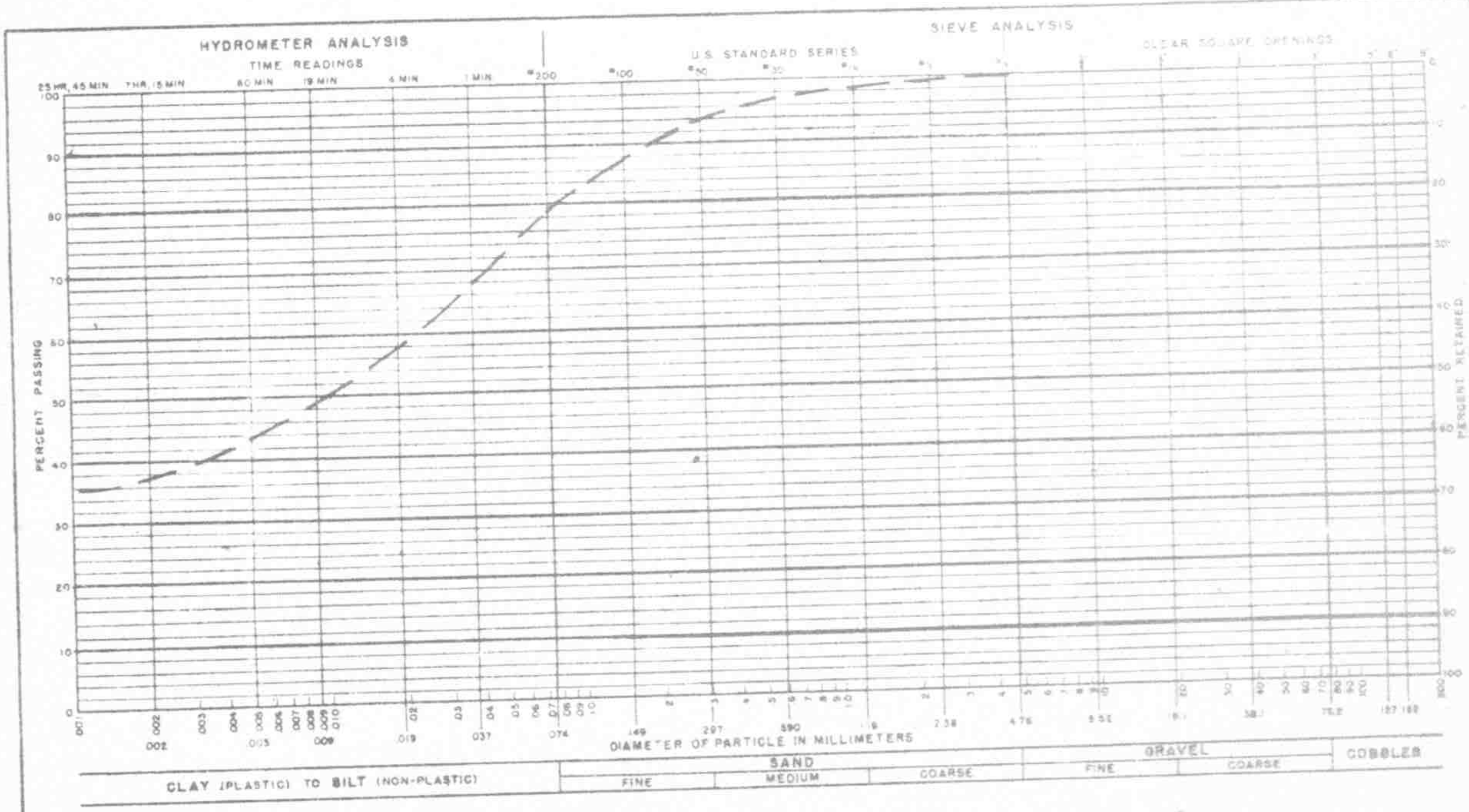


FIG. 8E GRAIN SIZE CURVE OF HAMRA STREET SOILS

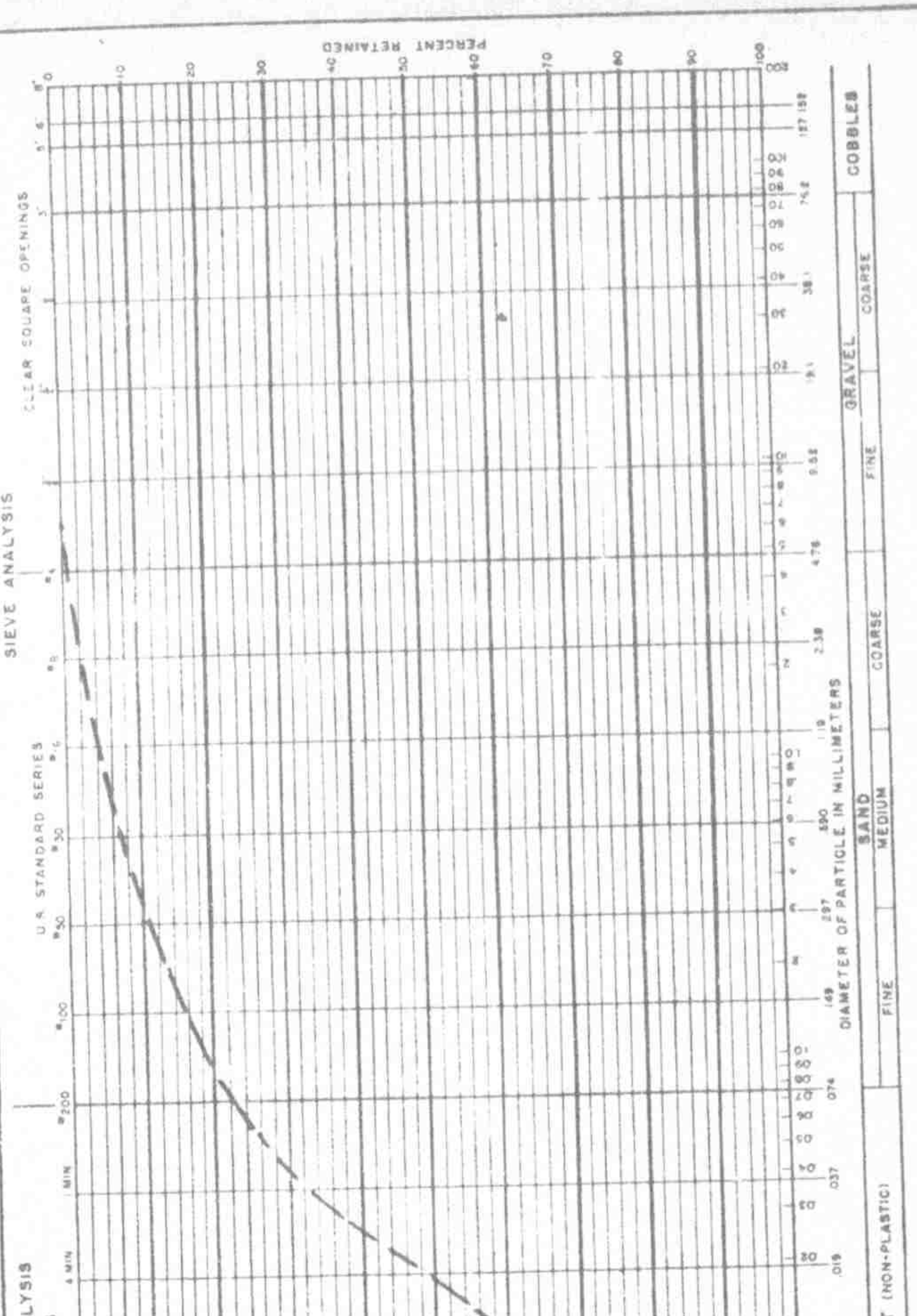


FIG. 8F GRAIN SIZE CURVE OF MAAMARI STREET SOILS

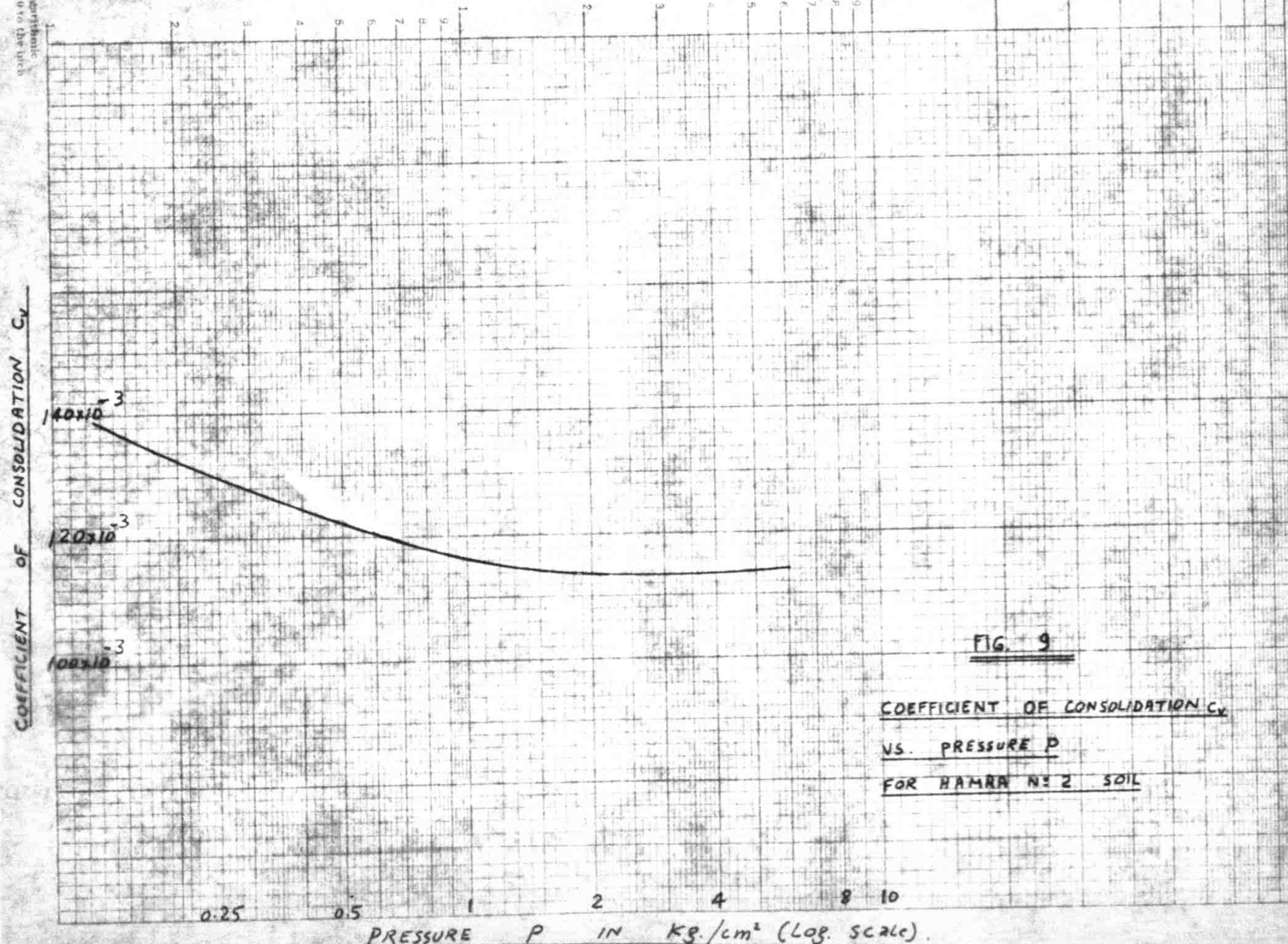


FIG. 9

COEFFICIENT OF CONSOLIDATION C_v
VS. PRESSURE P
FOR HAMRA No. 2 SOIL

TABLE 6

PARAMETERS FOR HAMRA No. 2 SOIL

Pressure Range kg/cm²	a_v cm²/g	m_v cm²/g	k cm/sec.
0-1/4	9.6×10^{-5}	4.46×10^{-5}	10.32×10^{-8}
1/4-1/2	6.8×10^{-5}	3.17×10^{-5}	6.60×10^{-8}
1/2-1	5.8×10^{-5}	2.70×10^{-5}	5.30×10^{-8}
1 - 2	3.6×10^{-5}	1.68×10^{-5}	3.33×10^{-8}
2 - 4	3.4×10^{-5}	1.66×10^{-5}	3.18×10^{-8}
4 - 8	1.4×10^{-5}	0.65×10^{-5}	2.65×10^{-8}

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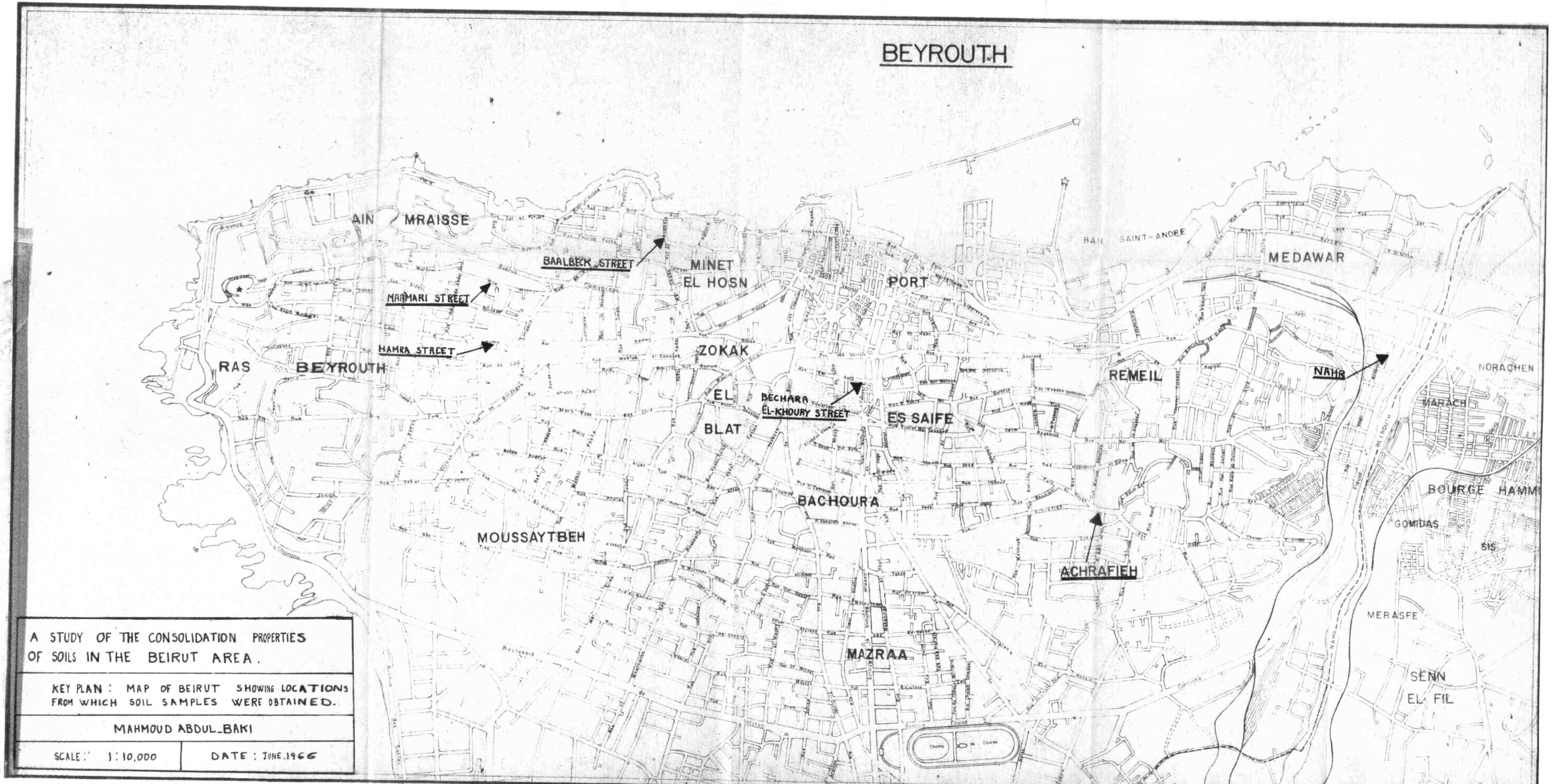

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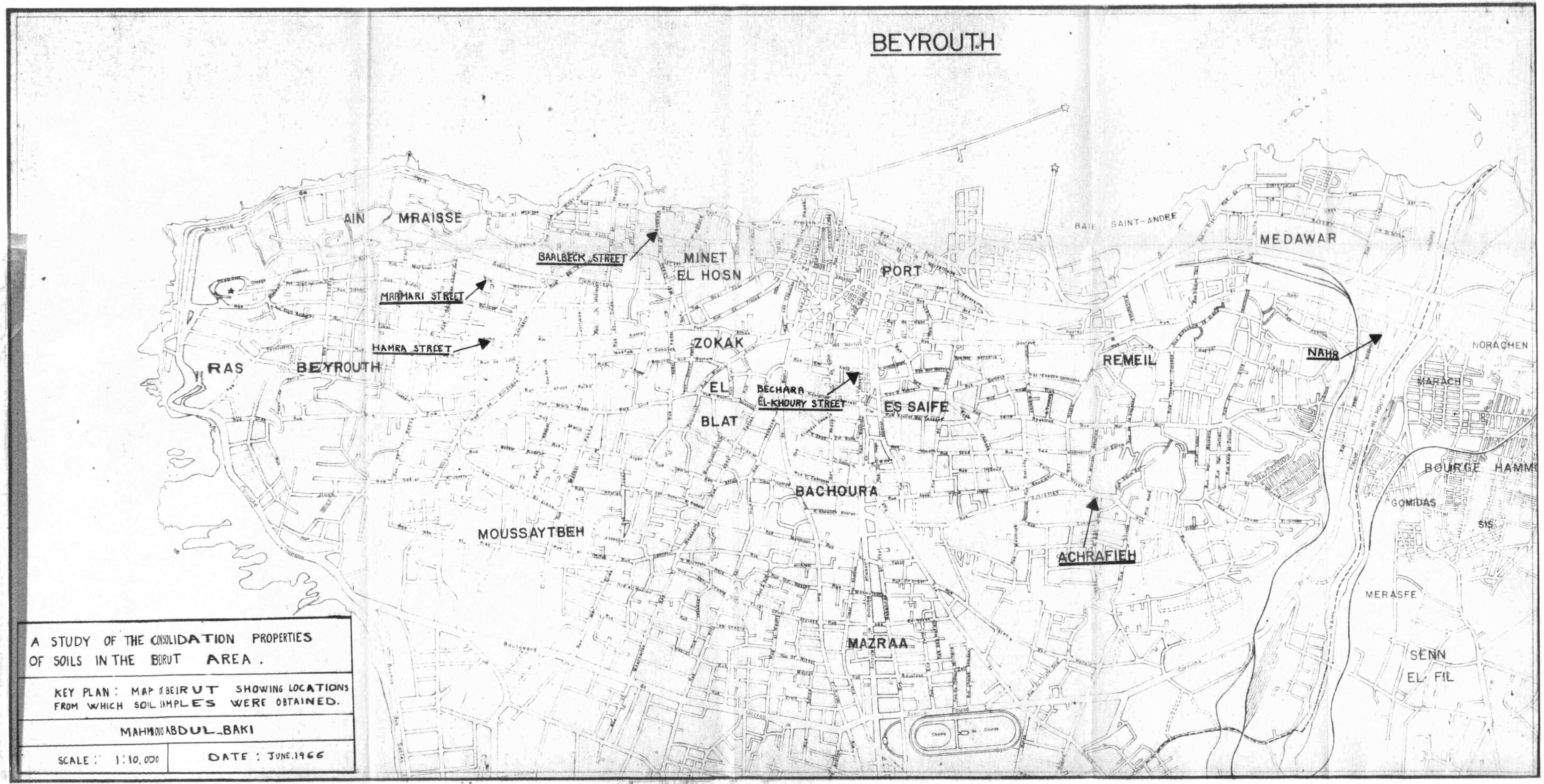
KEY PLAN : MAP OF BEIRUT SHOWING LOCATIONS FROM WHICH SOIL SAMPLES WERE OBTAINED.

MAHMOUD ABDUL_BAKI

SCALE : 1 : 10,000 | DATE : JUNE, 1966



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