PROGRESS REPORT NO. 13

June 1978

EVALUATION OF FRENCH PRESSUREMETER

by

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for

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1. INTRODUCTION

This thirteenth progress report describes the work accomplished during June, 1978. Table 1 lists the work tasks and presents the schedule as revised in June 1978. Task A (in Table 1) having been completed, June was devoted to Task B and C as follows:

Task B: Measurement of in situ horizontal stress

Task C: Interpretation of PAFSOR tests

1) Establishment of in situ soil parameters
2) Analysis of pressuremeter (PAFSOR) test data
3) Literature Survey

2. WORK ACCOMPLISHED AND SUMMARY OF RESULTS

The principal activities during June 1978 are summarized in Table 2 and described more fully below.

Task B: Measurement of In Situ Horizontal Stress

Readings on the three earth pressure cells inserted at El.-50 ft were taken approximately every three days until removal on June 6. The cells were checked for external damage and leakage in the MIT laboratory. Slight moisture had infiltrated the housing of the symmetrical 40° cell through a loose connection, which was subsequently tightened. Cell response was aslo checked. The three devices behaved satisfactorily.

The three probes were then pushed down to El.-80 ft, about 10 ft in the soft Boston Blue Clay layer. Figure 1 plots the increase in horizontal total stress and pore pressure during continuous insertion. The two symmetrical cells were pushed down a distance of 5 ft to eliminate the possibility of hydraulic shorting above the cell. The third cell (with an enlarged tip) was pushed down a distance of 6 ft. As seen in Figure 1 for the enlarged cell, the increase in pore pressure (u) is much less than the total horizontal stress increase (σ_h) for the first 18 in insertion, probably due to hydraulic shorting caused by upward water flow along the cell plate and cylindrical housing to the preaugered hole. After a 2-ft insertion, the pore pressure becomes

approximately equal to the total stress, indicating that the opening behind the cell closed up and that a steady state condition was reached. Figure 2 shows the equilibration rates of horizontal stress and pore pressure and estimated values of σ_{ho} and u_o based on elastic theory and values of K_o measured in the laboratory.

Figures 1 and 2 show the following:

1) The sharp (20°) symmetrical cell developed a higher initial pressure than the blunt (40°) cell, in disagreement with the behavior observed at El.-50 ft in the medium Boston Blue clay.
2) The two symmetrical cells reached equilibrium at essentially the same time and exhibited nearly identical dissipation behavior.
3) Pore pressure dissipation and total stress equilibration were reached quickly (about 50 hours). This result appears very satisfactory, since previous studies (Massarsch, 1975; Massarsch et al., 1975; Tavenas et al., 1975) mention times on the order of 4 to 10 days required for equilibration in soft clays (they used earth pressure devices working on the same general principle as those used by MIT, but with different geometries and insertion procedures).
4) The measurement cell of the enlarged tip device appears defective. As shown in Figure 2, σ_h decreased consistently with time after 100 hours and yielded values below the pore pressure value at that depth. It is believed that the cell may have been punctured upon insertion. Since the cell and connecting water to the diaphram of the electrical transducer were backpressured (to approximately 0.5 kg/cm^2), the inner pressure will be slowly released after puncture and the transducer will eventually come to equilibrium with the groundwater pressure at the elevation. However, this implies that the zero of the transducer will change by a large amount (approximately 0.5 kg/cm^2). The data in Figure 2 used the original backpressured zero of the cell, which explains the much too low σ_h values plotted.

However if one assumes that after 600 hours, the backpressure of 0.5 kg/cm^2 and completely disappeared and computes a σ_h value with the transducer reading for zero pressure as reference zero, a "corrected" σ_h can be obtained. This value was used in Figure 3 where σ_h is plotted versus elevation. However, final interpretation of the enlarged tip horizontal stress results must await cell retrieval to ascertain the zero value of the transducer at removal time and the extent or existence of damage.

Figure 3 presents measurements of σ_{ho} and P_o obtained from earth pressure cell tests and pressuremeter tests. The equilibrium values indicate the following:

1) The sharp (20°) symmetrical tip resulted in an equilibrium σ_{ho} within the range predicted from laboratory data.
2) The blunt (40°) symmetrical tip resulted in an equilibrium σ_{ho} less than the predicted range. The difference between measured σ_{ho} by the two symmetrical cells is even more pronounced than at El.-50 ft.
3) The enlarged tip resulted in extremely low equilibrium σ_{ho} values, even after making correction for the possible zero shift. Again this value is close to the initial pressures from the PAFSOR.
4) The equilibrium pore pressure at El.-80 ft indicates an artesian head of 6.5 ft in the till at El.-148 ft, if the water table is taken at El. 0 ft (as observed in 1978). For a water table at El.+2.5 ft (as observed in 1977), the measured u_o at El.-80 ft falls slightly above hydrostatic conditions.

The three earth pressure cells were inserted at El.-80 ft on June 13 and 14. They will be left in the ground at least until early August, and if possible for a longer period of time. Upon removal, the cells and electrical transducers will be recalibrated and compared to the constants used for the present calculations.

Figure 4 summarizes the values of K_o obtained from the three series of measurements (El.-30, -50, -80 ft) with the new MIT earth pressure cells. The results of the symmetrical 20° tip compare fairly well with the best estimate of K_o obtained from laboratory measurements and the stress history. The range of possible K_o at each elevation reflects possible variations in (1) laboratory K_o, (2) in situ total stress (horizontal and vertical), (3) in situ pore pressure and (4) maximum past pressure.

As mentioned in Table 2, most of the field and laboratory data necessary for review of the I-95 test site conditions were summarized in a small report which will be included to the final research report on results of pressuremeter tests at the I-95 site. Both Sta. 246 and 263 were reviewed.

Task C: Interpretation and Analysis of Pressuremeter Data

1) Establishment of In Situ Parameters

In addition to the horizontal stress and pore pressure readings the cells were equipped with thermistors to record ground temperature. The following table summarizes the temperatures obtained at the three elevations tested. The deposit appears to have a uniform temperature of approximately 10.5°C over its entire depth.

El. (ft)	Ground Temperature Sym 20°	Sym 40°	Enlarged
-30	10.9	10.95-10.6	
-37			10.15
-51	10.7	11.5 -10.85	9.9
-80	10.8	11.0	10.3

Recalibrations of the thermistors will also be done upon final removal of the cells from the ground.

2) Interpretation and Analysis of Pressuremeter Test

During June, we began evaluating soil parameters from the pressuremeter test results, using the best estimate* of the total

*From elastic theory, stress history and laboratory measurements of K_o.

horizontal stress, σ_{ho}, as initial point on the field curves rather than the P_o value measured or deduced from the field PAFSOR curves. Through this systematic evaluation, problems due to improper insertion of the measurement cell will hopefully be minimized. Figure 5 summarizes the undrained shear strength (s_u) values resulting from this approach. Whether s_u is estimated by:

$$s_u = \frac{P_1 - \sigma_{ho}}{5.5} \quad \text{or} \quad s_u = \frac{P_1 - \sigma_{ho}}{6.5}$$

does not make much difference as the derived s_u is much too large (generally double the field vane value). The change in the initial points using the above equations therefore did not affect s_u to a great extent (Note that P_1 was obtained by the ln method). Of particular importance, the results indicate that the Gibson and Anderson (1961) equation would predict much lower P_1 values than those obtained by the ln method. Undrained shear strength based on the Prevost and Hoeg and subtangent methods will be presented in the July Progress Report.

In a meeting held in June with Dr. M. Jamiolkowski, Professor at University of Torino, Italy, Dr. M. Randolph, of Cambridge University, England, and Mr. Carl Ealy, of DOT, the MIT group shared field experience and discussed interpretation and evaluation of the pressuremeter test (both PAF and Camkometer devices). The meeting proved especially beneficial as Dr. Jamiokowski has run and interpreted several hundred pressuremeter tests in soft clays in various countries. Based on his experience, he has established several trends in the data reduction process . Examples are:

1. $$1.6 \leq \frac{s_{u(PMT)}}{s_{u(lab)}} \leq 2 \qquad \text{(Eq. 1)}$$

2. $$1.4 \leq \frac{E_{u50}{}^{PMT}}{E_{u50}{}^{CK_oUC(L)}} \leq 1.7 \qquad \text{(Eq. 2)}$$

3. $$P_1\ (ln) = 1.2\ P_1(1/V) \qquad \text{(Eq. 3)}$$

where s_u(PMT) = undrained shear strength from pressuremeter tests
s_u(lab) = undrained shear strength from laboratory tests (average of CK_oU triaxial compression and extension tests)
E_{u50} = Secant undrained Young's modulus at 50% peak stress.
PMT = from pressuremeter test
$CK_oUC(L)$ = from CK_oU triaxial compression test, for a loading stress path
P_1(ln) = limit pressure from ln method
P_1(1/V) = limit pressure from 1/V method

Dr. Randolph worked with stiffer clays, concentrating on the theoretical aspects of the pressuremeter test interpretation and provided some useful guidance, especially in possible explanations for the excessively high pressure limit values which lead to the high s_u values presented in Figure 5.

Based on the discussions held, the various suggestions will be applied to the MIT PAFSOR and Camkometer data.

Figure 6 shows preliminary results of estimating pressure limit (P_1) values from the Camkometer tests by two different methods. The straight line represents Dr. Jamiolkowski's relationship (Eq. 3). The MIT data points plot on or below his line. Since the P_1 values from the inverse volume method are much less than P_1 values from the ln method, the s_u values will decrease substantially if the inverse method is used. It is interesting to note that the pressure limit from the inverse method approaches the P_1 values obtained from inspection of the field curves.

Since Dr. Jamiolkowski had such wide experience with the pressuremeter test, MIT suggested to Mr. Carl Ealy that DOT incorporate a review of his case studies with our research effort. The contract research report on the evaluation of the pressuremeter test would then be divided into three phases:

Report I: report on test results and evaluation of French pressuremeter and Camkometer tests at Sta. 246 and 263 (I-95 test site).

Report 2: A report presenting Dr. Jamiolkowski best documented pressuremeter case studies (minimum of three, maximum of six)

Report 3: A final report evaluating the pressuremeter tests based on MIT and Dr. Jamiolkowski experience.

The Phase 1 report would present most of the proposed work contained in the present contract and will still be due by the end of the contracting period, in November 1978. An estimated 6 to 9 months would be necessary for Dr. Jamiolkowski and MIT to assemble and review his case studies, and Report 3 would then be submitted about mid-1979. Dr. Jamiolkowski and MIT are now working on a proposal and revised budget for this work.

3) Literature Review

Drs. Ladd, Lacasse and Mr. Germaine undertook assimilation of the recently published excellent book on the pressuremeter test by Baguelin, Jezequel and Shields.

3. WORK PLANNED FOR NEXT THREE MONTHS

The work items planned for the coming months include:

1) Retrieve and recalibrate all measurement devices of three earth pressure cells. Ascertain state of enlarged tip cell and evaluate whether it can be repaired.
2) Evaluate results of in situ horizontal stress measurement program at Sta. 246.
3) Continue internal report on laboratory test results on 1977 specimens of Boston Blue clay.
4) Continue evaluation of pressuremeter test data and obtain undrained shear strength and undrained modulus from pressuremeter stress-strain curves.
5) Continue study of book "The Pressuremeter and Foundation Engineering" by Baguelin et al.
6) Compare PAFSOR and Camkometer test results.
7) Prepare draft of research reports.

4. COSTS INCURRED

At the end of June 1978, total expenditures progressed according to schedule, amounting to approximately $67,500.00.

5. REFERENCES

Massarsch, K.R. (1975), "New Method for Measurement of Lateral Earth Pressure in Cohesive Soils", Canadian Geotechnical Journal, Vol. 12, No. 1, pp. 142-145.

Massarsch, K.R., Holtz, R.D., Holm, B.G. and Fredricksson, A. (1975), "Measurement of Horizontal In Situ Stresses", Proc. ASCE Spec. Conf. on In Situ Measurement of Soil Properties, Raleigh, Vol. I, pp. 266-286.

Tavenas, F.A., Blanchette, G., Leroueil, S., Roy, M., and La Rochelle, P. (1975), "Difficulties in the In Situ Determination of K_o in Soft Sensitive Clays", Proc. ASCE. Spec. Conf. on In Situ Measurement of Soil Properties, Raleigh, Vol. I, pp. 450-476.

Table 2. Principal Activities During June 1978

Task B: Measurement of In Situ Horizontal Stress

1) Retrieve three earth pressure cells from test holes at Sta. 246.
2) Check cell pressure response and any possible damage to measurement devices of pressure cells.
3) Push three devices down to approximately El.-80 ft.
4) Monitor performance of each earth pressure cell and reduce field data.

Task C: Interpretation of PAFSOR Tests.

Establishment of In Situ Parameters

1) Establish ground temperature versus elevation at Sta. 246 based on thermistor readings from earth pressure cell measurements.
2) Summarize the I-95 case study pertinent data, including geology, index properties, stress history and results of field and laboratory strength tests, and embankment performance at both Sta. 246 and 263.

Interpretation and Analysis of Pressuremeter Data

1) Begin evaluation of PAFSOR tests using best estimate of initial horizontal stress, σ_{ho} as initial point rather than P_o values given by field pressuremeter curve.
2) Compare limit pressure (P_l) obtained by this method to other determinations of P_l.
3) Hold meeting on interpretation and evaluation of pressuremeter tests (PAF and Camkometer) with Dr. Michael Jamiolkowski, Professor at University of Torino, Dr. M. Randolph, of Cambridge University, England and Mr. Carl Ealy, of DOT.

Literature Survey

Assimilate wealth of information in Baguelin et al. (1978), new book on the pressuremeter test.

6-14-78

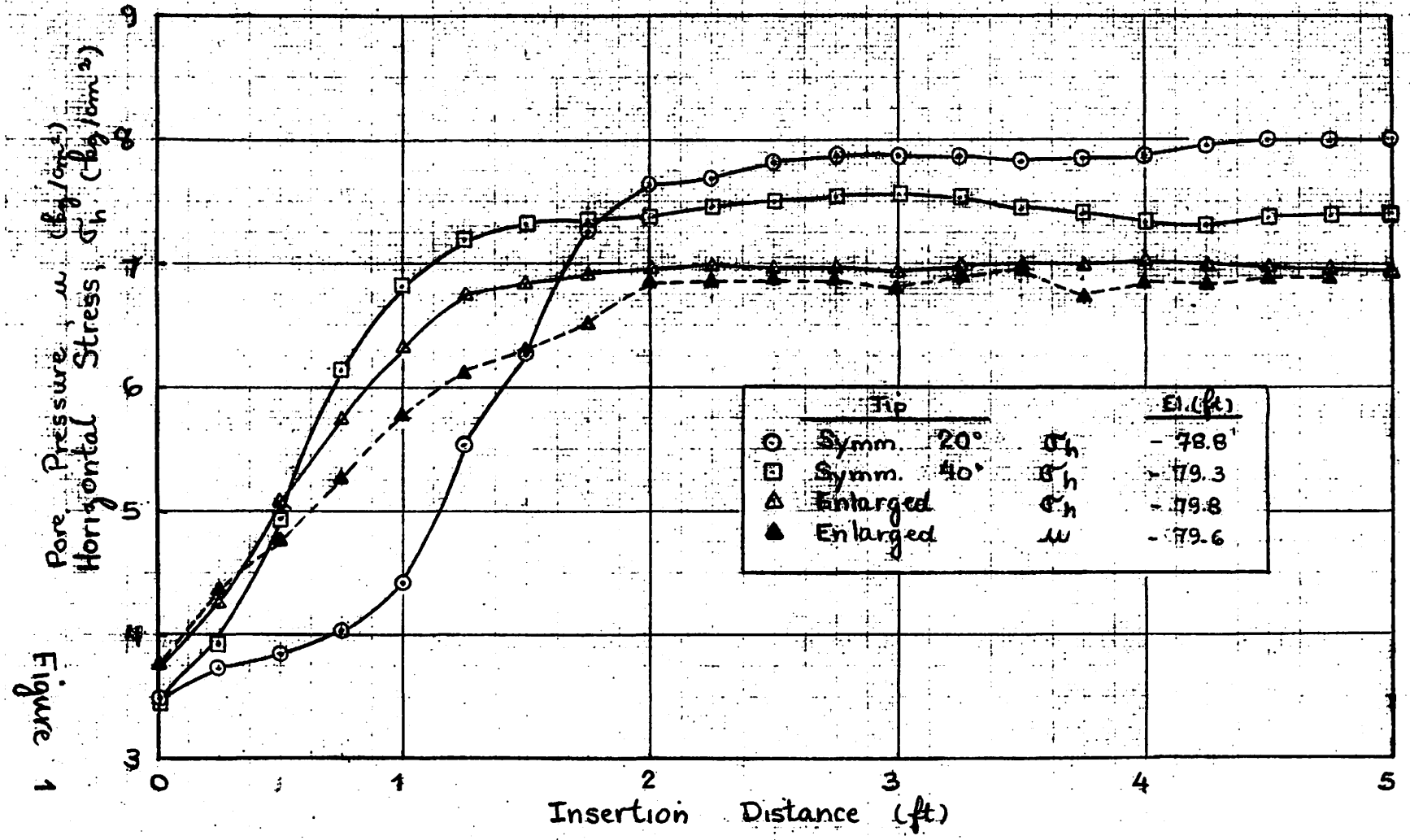


Figure 1 angle

STRESS INCREASE DURING EARTH PRESSURE CELL PENETRATION

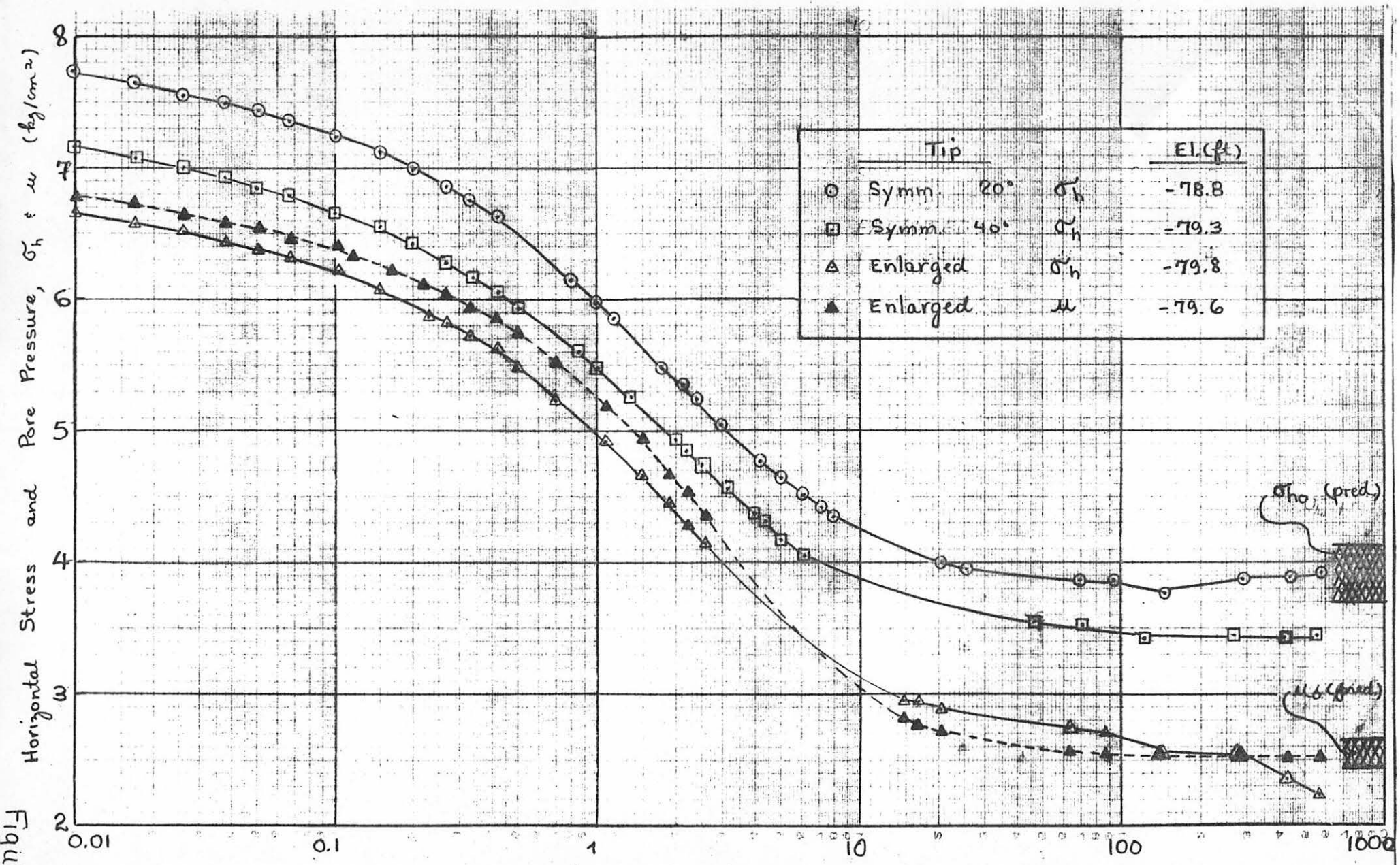
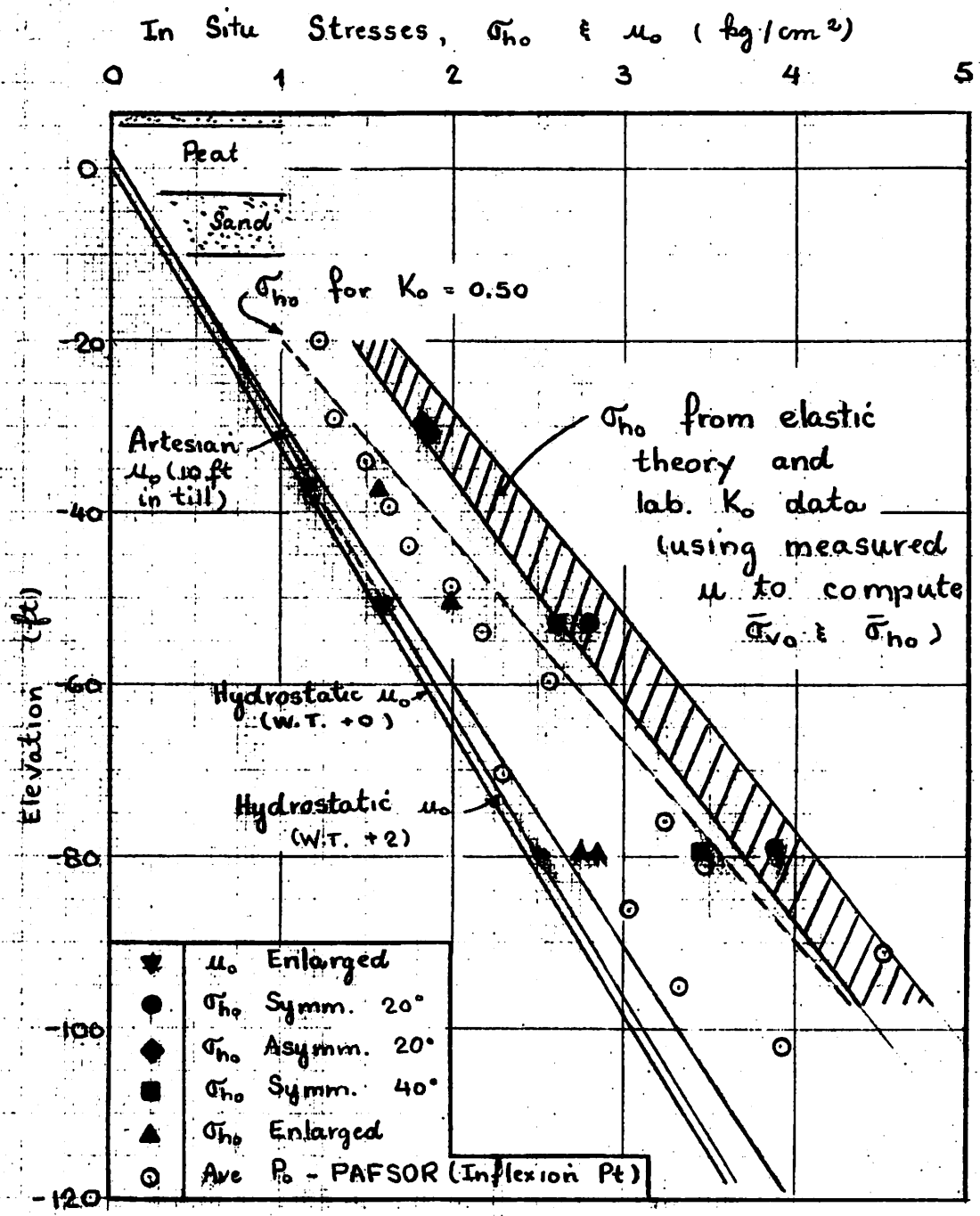


Figure 2

TOTAL HORIZONTAL STRESS AND PORE PRESSURE EQUILIBRATION



MEASURED AND PREDICTED HORIZONTAL STRESS AT STA. 246.

Figure 3

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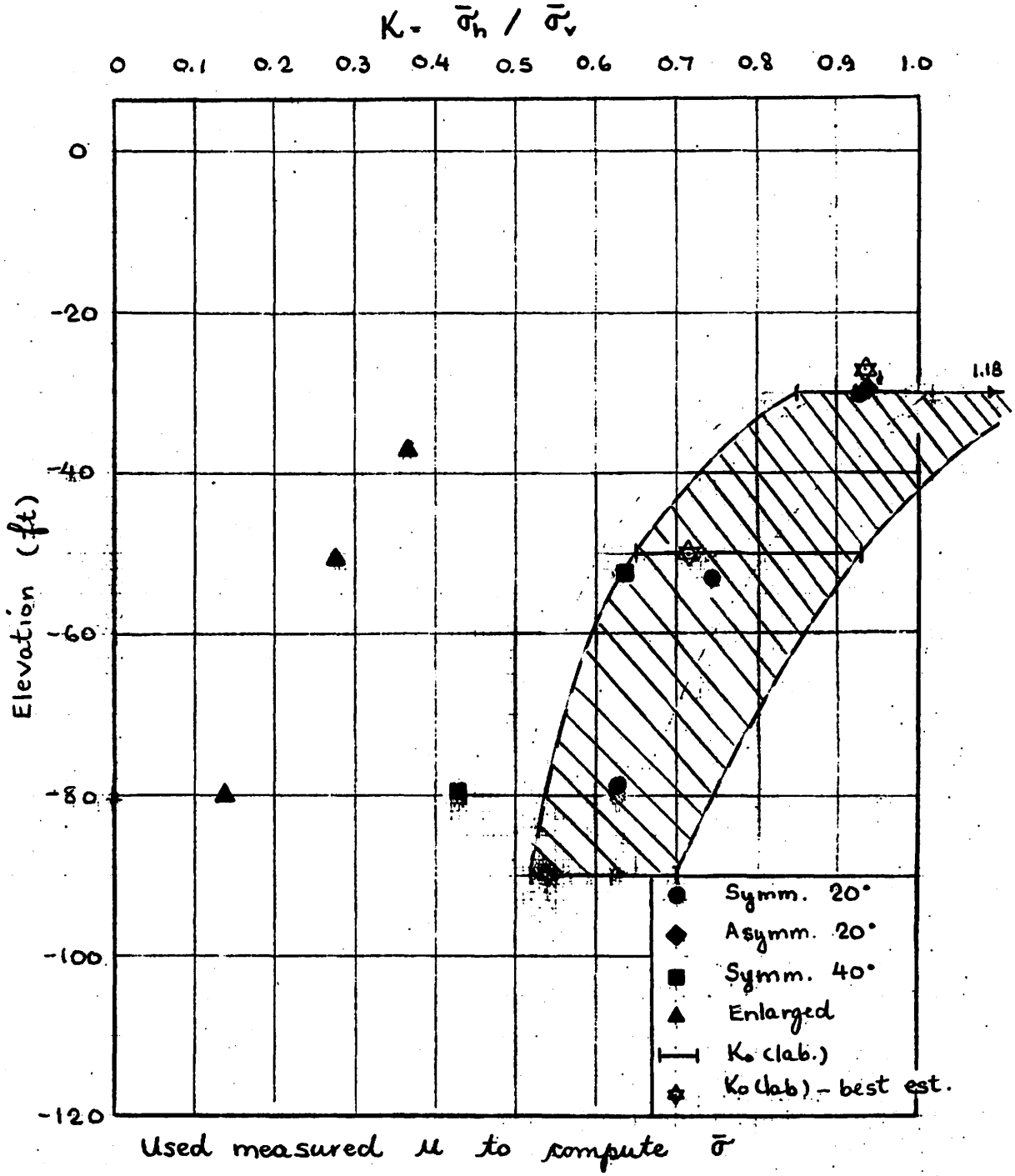

COEFFICIENT OF EARTH PRESSURE
AT STA. 246

Figure 4

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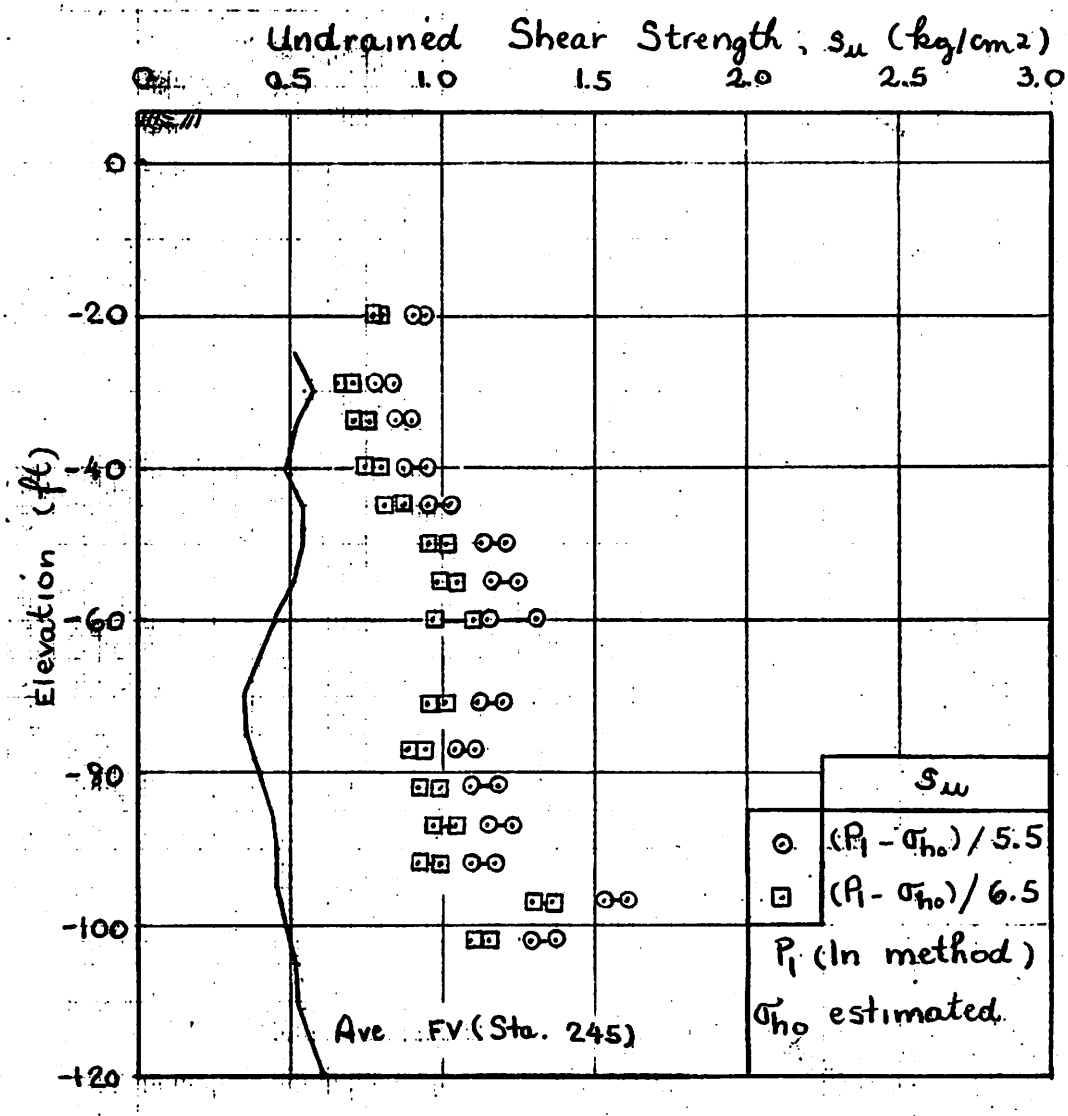
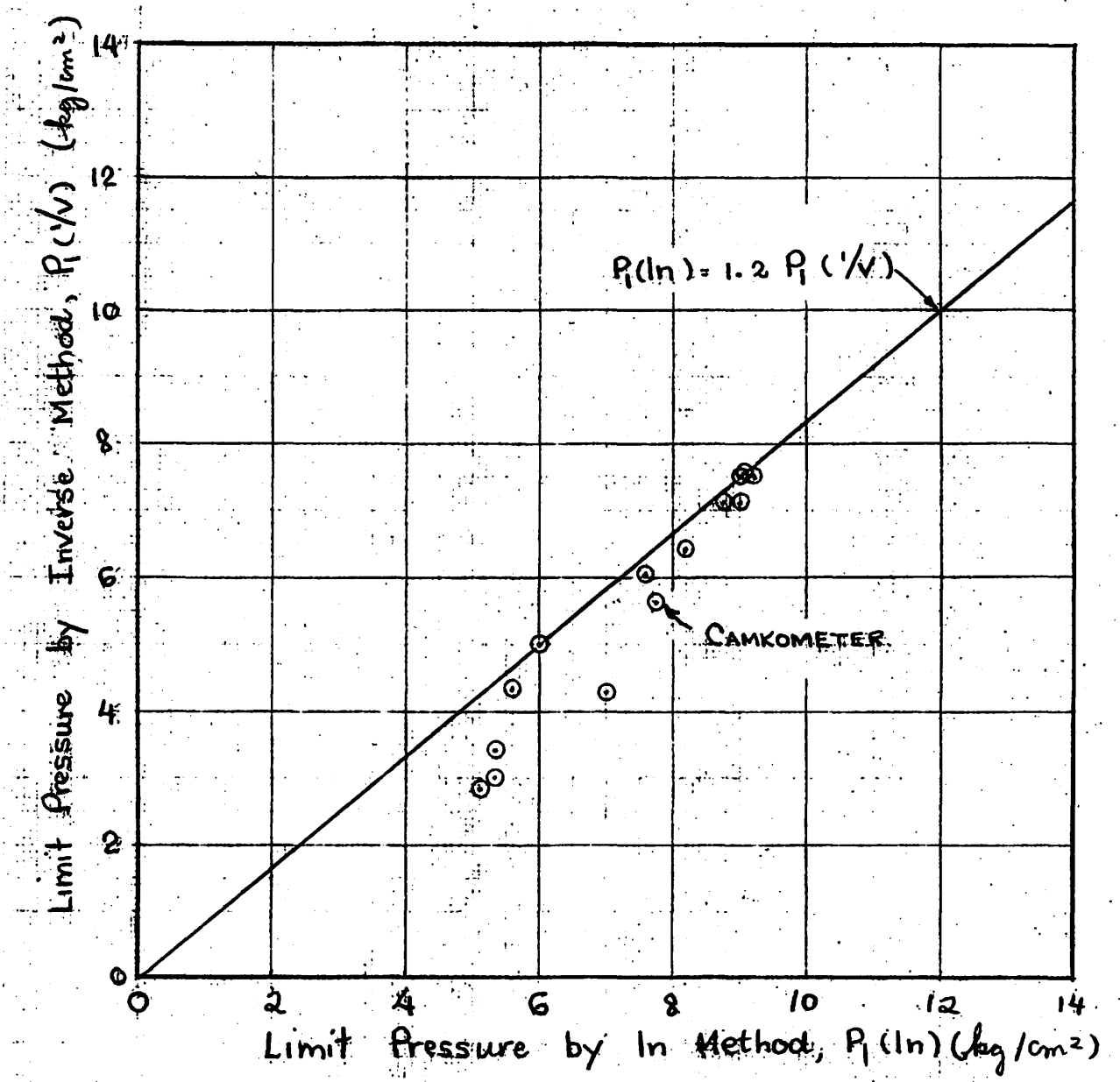


UNDRAINED SHEAR STRENGTH FROM RAESOR TESTS AT STA. 246 USING BEST σ_{ho} ESTIMATE

Figure 5



LIMIT PRESSURE FROM CAMKOMETER TESTS AT STA. 263

Figure 6

TABLE 1: WORK TASKS AND SCHEDULE

(revised 6/78)