

DIGEST #11  
APRIL 1989

Many miscellaneous items of interest to DMT users have accumulated since No. 10 in May, 1988. The following gives a TABLE OF CONTENTS for this DIGEST, with the items generally increasing in importance going down the TABLE:

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11.A NTIS Publication of PennDOT Reports

Item 10.B in DIGEST #10 noted a series of guideline reports written by Schmertmann & Crapps, Inc. and Campanella and Robertson, submitted to PennDOT at the completion of a research project by Schmertmann & Crapps, Inc. The

National Technical Information Service, U.S. Dept. of Commerce, Springfield, VA 22161, now prints these reports and you may purchase directly from them using the following numbers and prices:

Volume I (Summary) - Accession No. PB88-211636AS, price \$14.95

Volume II (Electronic CPT) - A. No. PB88-211644AS, price \$32.95

Volume III (DMT maintenance, data reduction) - A. No. PB88-211651AS,  
price \$19.95

Volume IV (DMT design) - A. No. PB88-211669AS, price \$19.95

#### 11.B New Papers on Sand Modulus and Settlement

Baldi et. al. (1988) have just published a paper summarizing ten years of laboratory work, primarily in calibration chambers, comparing CPT and DMT penetrometer data vs. modulus in the pluviially placed sands used in such chambers. They reached the strong conclusion that penetrometers in such sands are very insensitive to the modulus increases resulting from prestress applied to the chamber sand. Leonards and Frost (1988) start with the same conclusion and propose a sand-settlement analysis procedure based on using  $E_D$  from the DMT in the Schmertmann (ASCE, May 1970) strain factor analysis method, but then applying a major correction for prestressing effects. They also use the  $K_D$  from the same DMT data to determine the magnitude of the prestressing. The editor has submitted a discussion to Leonards and Frost, primarily pointing out their paper lacks field data that supports their method. Marchetti has also submitted a discussion in which he points out, among other things, that the chamber sands may not behave the same as aged sands in the field. The ASCE has not yet published these discussions.

These papers raise important questions for DMT users because the rapid and economical prediction of settlements with acceptable accuracy gives the DMT perhaps its most generally useful advantage. Engineers often use it in sands for this purpose. The laboratory chamber studies appear to contradict many years of generally successful use of penetrometers such as the SPT, CPT and DMT for this purpose. Stay tuned for further developments.

#### 11.C DMT Bibliography Update

Our DMT bibliography (Mar 88) now has 125 references, or 46 more than the last DIGEST #6, dated July 85, to include a bibliography. We have included herein as Table 11.C a listing of those added since the ISOPT-1 update in D-10.

#### 11.D - Membrane Fit

In DIGEST item 10.E we pointed out temporary problems with the new, high strength membrane fit, exercising and calibrations. These problems have now been corrected by small modifications in the machining of the blade and a new, slightly thicker membrane gasket.  $\Delta B$  values for the high strength H-membranes have now reduced into the 0.2-0.6 range and all membranes now require very little preliminary manipulation or exercising before attaining stable  $\Delta B$  values. G.P.E. blades with serial number GB-69 and higher include the modification. Owners with blades older than this may still use the new "H" membrane and greatly reduce the problems by installing a spacer gasket or one of the new membrane gaskets. We recommend everyone use the H-membranes because of their now well-established much superior durability.

#### 11.E Regulator Safety Note

We have had one instance of an old nitrogen regulator not holding the regulator pressure. It allowed the pressure to increase slowly. We did not notice this until one of the lines under the control panel burst. We found that rust from the tank had gotten past the filter in the regulator and jammed it open. Operators need to periodically check and clean this filter as well as the regulator mechanism. We also suggest you periodically inspect the nylon tubing from the regulator to the control unit for small nicks and replace the tubing if you find any. Also check your regulator to make sure it properly holds the set pressure after subjecting it to extreme temperature.

#### 11.F Possibly remove friction reducer ring with CPT rods

Different types of friction reducers, including projecting rings, have long proven very effective in reducing rod friction and thus improving the penetration capability of CPT equipment. We have more or less assumed the same for the DMT. However, now Professor Marchetti reports that most DMT users in Europe no longer use the friction reducer ring and suggests that we can perhaps eliminate the ring now supplied with the equipment and used routinely in North America. When using the DMT with CPT rods the DMT blade already opens the soil approximately 14 cm<sup>2</sup> vs. the 10 cm<sup>2</sup> area of the rods, and thus already reduces the rod friction. The reducer may not give a significant further reduction, and it comes at the cost of added bearing taking away some of the available thrust for penetration. If you use CPT rods, we suggest you have the reducer ring on one adaptor machined off and see if this results in improved blade penetration capability.

Even if removing the ring achieves little or no penetration improvement, its removal would retain soil contact and therefore more stability for the first adaptor/rod joint. Some users, particularly when using heavy CPT trucks, non-hardened steel blades and adaptors, and old rods, have reported the male rod at this joint as the weakest link and susceptible to sudden breakage and possible loss of the blade. Removing the reducer ring might help with this problem.

Those using the DMT with AW rods, which have a displacement area of 15.5 cm<sup>2</sup>, will probably (we are not sure) still derive a net benefit from the use of a reducer ring on the adaptor. No one using AW rods has reported losing a blade due to rod breakage.

#### 11.G Average 1/M for Settlement

One of the best uses for the DMT is for settlement computations. For example, by the method in Schmertmann (ASCE, Insitu 86, 1986). Favorable comparisons between predicted and measured settlements continue to slowly accumulate. A recent one, involving a large prestressed-mat-loaded area over a 70 ft thick deposit of very variable Miocene deposit of clays, silty clays, clayey sands, etc. gave us a predicted settlement of 1.0". We subsequently also measured 1.0". However, this example called our attention to the importance of averaging the values of 1/M rather than averaging M itself when computing the settlement contribution of various selected sublayers. In this case the average M for all sublayers, from 64 tests with each considered a sublayer, gave 400 b when using 1/M and 1100 b when averaging M itself. Had we averaged M directly, we would have incorrectly predicted a settlement of only 0.4". Remember: AVERAGE 1/M BUT, ALSO NOTE THAT VERY LOW VALUES OF M WILL DOMINATE SUCH AN AVERAGE. Before using such low values in the average make sure that each value comes from a valid test.

#### 11.H Campanella and Robertson Research Paper

Most readers know that Professors Campanella and Robertson built a highly instrumented research DMT blade at the Univ. of British Columbia in the early 80's and used it in several research projects. They have already reported important results, such as the p<sub>2</sub>-pore pressure relationships previously noted in DIGEST items 5A and 10B. They have now compiled the results from their research with this blade in Campanella and Robertson (1989). The following briefly notes two of the other contributions in this paper:

11.H.1 Correlation between p<sub>0</sub> and thrust in sands: Previous items 1B, 1F and 7B have discussed the desirability of and problems with

the measurement of thrust in the DMT as a necessity for providing additional data to permit the separation of  $K$  and  $\phi$  in free draining soils (sands). C&R presents data that show at least useable local correlation between  $p_0$  and thrust. It thus may be possible to estimate thrust ( $F$ ) with sufficient accuracy from  $p_0$  provided that one has correlation information available. They obtained the following correlations in one 15m thick, NC sand with  $I_D > 2$ :

$$F = 6.25 p_0$$

$$F = 8.33 (p_0 - u_0)$$

(with  $F$  in kgf and  $p_0$  and  $u_0$  in kPA)

Professor Peter Wroth also presented research data to the DMT Specialty Session at ISOPT-1 that showed a good correlation between  $p_0$  and thrust.

11.H.2 Comparing  $q_c$  and  $q_D$ :  $q_D$  equals the bearing capacity pressure on the horizontal projected cross sectional area of the tip of the DMT blade (approximately 14.3 cm<sup>2</sup>). They observed at one of their research sites that  $q_D$  approximately equalled 1.1  $q_c$  in a sand. More on this in 11.I.

### 11.I Comparing $q_c$ and $q_D$ in Sands

A 1988 Master's thesis research project at the University of Florida, under Professor John Davidson, among other things compared adjacent  $q_c$  and  $q_D$  in Florida fine sands above and below the water table. The research student, Mr. Curtis Basnett, obtained  $q_c$  via electric CPT soundings and  $q_D$  via the measurement of thrust at the top of the rods and using the various corrections for thrust dissipation described by Schmertmann (ESOPT-2, 1982). The computer program used to reduce DMT data with thrust measurement in sands obtains  $q_D$  routinely but does not print this item. Basnett measured thrust with a load cell at the surface, so any rod/sand friction would introduce error. However, C&R (1989) also showed only small rod/sand friction to their greater depths of 15 m. Figure 11.I presents the best-agreement  $q_c/q_D$  comparison from Basnett's thesis. All his data showed that  $q_D$  approximately equals  $q_c$  in all sands tested.

The above result supports that noted in 11.H.2. It also supports the assumption used in the Marchetti (1985) (see DIGEST 7B) suggested method for evaluating  $\phi$  from the DMT by using the CPT  $q_c$  as a substitute for  $q_D$ , and thus avoiding the need to measure thrust to obtain  $\phi$ . It also opens up the possibilities for using the CPT design correlations with DMT data by using  $q_D$  as a substitute for  $q_c$ . However, this approach assumes that an adjacent CPT tests the same sand as the DMT. The often great variability in natural sands may make this a questionable assumption when comparing individual tests.

Remember that the value of  $\phi$  to use depends on stress level, peak vs. residual strain, and plane strain vs. axisymmetric conditions. The DMT "DILLY" data reduction programs used by G.P.E. give the peak, plane strain value of  $\phi$  at the reference normal stress of 2.72 bar. See previous DIGEST items 2B and 3E for a more detailed discussion.

#### 11.J Effects of Dynamic (hammer impact) Blade Insertion

As noted previously in DIGEST items 1C and 3G, hammer insertion can seriously affect the results from the DMT. The 11.J research focused primarily on the effects of hammer vs. quasi-static insertion methods. Basnett found that insertion by hammer impact dramatically reduced  $p_0$  (and therefore  $K_D$ ) in most sands, both above and below the water table. While  $p_0$  experiences much greater proportional effects,  $P_1$  also reduces by approximately the same as the reduction in  $p_0$ . Figures 11.J.1 and .2 show examples. Thus, the difference between the two, and therefore  $E_D$ , stays relatively unaffected. On the average ( $p_1 - p_0$ ), and therefore  $E_D$ , increases by 10%. But,  $M = R_M E_D$  and  $R_M$  decreases with the decrease in  $K_D$  and the overall effect of driving insertion conservatively reduces the calculated M and increases settlement. Figure 11.J.3 shows how  $K_D$  can drastically decrease.

Engineers will most likely use dynamic insertion methods in soils too strong for the capacity of the quasi-static (usually hydraulic) equipment available. This usually means medium to dense sands and/or stiff to hard clays. Basnett observed the above described effects in dense as well loose and very loose sands. He also tested some stiff clays, but with inconclusive results because of limited data and site variability. However, he did suggest that the damaging affects of driving appeared much less severe, and perhaps negligible, when using hammer insertion methods in stiff to hard clays. The editor's favorable experience with using DMT data in the hard clays tested for the Skyway Bridge foundations across Tampa Bay, where all the DMTs involved hammer insertion, tends to support Basnett's suggestion (see Schmertmann, 1988a).

Table 11.J presents our current summary of the effects of dynamic (hammer) DMT insertion on the interpreted geotechnical properties.

#### 11.K More on Pore Pressure Dissipation From the DMT

Much research interest continues to focus on the possibilities for using DMT time-dissipation data to evaluate insitu pore pressure and the coefficients of consolidation and permeability. Previous DIGEST item 10B discussed this use in detail. The reader may find these recent findings of interest:

##### 11.K.1 $p_2$ dissipation sometimes does not result in $u_0$ , but $t_{50}$ OK:

The editor assisted in the performance of CPTU and DMT soundings at a site in Wilkes-Barre, Penn. in July 1987. We obtained  $u$ - and  $p_2$ -dissipation data with mysterious results for the extrapolated values of equilibrium water pressure,  $u_0$ .  $U_0$  seemed too high from the CPTUs and too low (sometimes even negative) from the DMTs. These seemingly incorrect results did not appear related to problems with insufficient dissipation times or saturation of the CPTU. The  $t_{50}$  times varied from only approximately 0.5 to 2 minutes. Because of the mystery, we repeated the tests even more carefully at a part of the same site (undisturbed) in October 1988 -- with essentially the same results. We then installed a string of 4 vibrating wire piezometers in March 1989 (site still undisturbed) in one of the boreholes very near our 1988 soundings so as to obtain  $u_0$  ground truth. Figure 11.K presents comparative results for the soundings within 10 ft of the piezometers. It shows 2 of the negative  $u_0$  values from the DMTs and 5 of the clearly too-high  $u_0$  values from the CPTUs. We do not know the reasons for this strange behavior. It does tell us that in certain soils we should not rely on dissipations to get  $u_0$ . Powell & Uglow (ISOPT 1, 1988, p. 561) had a similar caution.

The Wilkes-Barre soil consisted of a variably cohesive inorganic silt with  $w = 25-50\%$ ,  $LL = 23-45\%$ ,  $PI = 1-16\%$ , and  $-200 = 45-100\%$ . It had a higher  $w$ ,  $LL$ ,  $PI$ ,  $-200$  layer 10-20 ft thick within the above ranges. It had a  $q_T$  strength = 5-15 tsf,  $I_D$  approx. 0.5, and field vane sensitivities of 5-10. This layer produced most of the mysterious  $u_0$  results.

Concerning the DMT, we speculate that every A-B-C sequence opens a cavity which is progressively less likely to refill with water at the  $u_0$

pressure within the 15-30 sec. used for deflating from B to C. This may occur because of the overall dissipation of the surrounding hydraulic gradient feeding water back into the cavity. As the surrounding gradients approach 0 the pressure in the cavity also approaches 0 or even negative (suction) values. This is not likely to occur in sands because of their very high permeability, nor in clays because of their very low permeability. However, it seems a distinct possibility in cohesive silts.

Although the  $p_2$  dissipation from the DMT and the U dissipation from the CPTU may not become asymptotic to the correct  $u_0$  in such soils, it appears that the  $t_{50}$  times using the extrapolated apparent  $u_0$  nevertheless produce approximately correct  $t_{50}$  data. For example, see Schmertmann (1988b, Table 2, Site D) for comparative data from the above site. Powell & Uglow (1988, p. 560) also noted that although  $p_2$  may dissipate to a displaced  $u_0$  in some stiff clays because of test procedures, soil behavior controls the shape of the  $p_2$  dissipation curve. Thus, a reference dissipation time such as  $t_{50}$  remained approximately correct when compared with push-in spade cells even though  $p_2$  did not dissipate to the correct  $u_0$ .

11.K.2 Using  $p_0$  dissipation: Marchetti and Totani in "Ch evaluations from DMTA dissipation curves" (paper submitted to XII ICSMFE) suggest using the dissipation of  $p_0$  for a qualitative evaluation of the coefficient of consolidation. He suggests various values of  $t_i$  at the point of inflection on a graph of  $p_0$  vs. log time, for a qualitative evaluation of  $c_h$ , as follows:

less than 10	10-30	30-80	80-200	greater than 200 minutes
very fast	fast	medium	slow	very slow

They point out that for some practical problems such a qualitative distinction might be adequate -- for example in deciding whether or not to seriously consider wick drainage aids. They also made the preliminary suggestion that  $c_{hoc} = (5 \text{ to } 10 \text{ cm}^2)/t_i$ .

Campanella and Robertson (1989) suggest a quantitative method for  $c_h$  based on  $p_0$  dissipation following an initial  $p_0$ - $p_2$  ordinary DMT sequence. This method is simpler than a  $p_0$ - $p_2$  cycle for each measurement. It avoids the continuing need to refill any cavity produced by the deflating membrane and thus possibly the problem noted in 11.K.1, but time may allow the reestablishment of effective stress pressure against the membrane after its initial expansion if one does not have one



or more subsequent re-expansions.

#### 11.L More on Limit Pressure and Theoretical $s_u$

Some engineers have criticized the Marchetti (1980) correlation between  $s_u$  and  $K_D$  as too empirical and too dependent on the similar correlation for OCR. The following presents a simple correlation equation between  $s_u$  and  $K_D$  based on the well recognized theory of cavity expansion. It produces a result similar to, but more conservative than, the Marchetti (1980) correlation.

As previously noted in DIGEST item 9A.1, insertion of the DMT blade in some clays appears to produce a  $p_0$  expansion pressure that approximately equals the limit pressure as defined for a pressuremeter test. Figure 11.L.1 from Lutenegger (1988) (see D-10A.1) presents more data to support the correlation between  $p_0$  and  $p_L$ . These data from the small Pencil full displacement pressuremeter suggest that  $p_0 = p_L$  when the OCR is  $< 2.5$  (or when  $K_D < \text{approximately } 5$ ). The DMT blade may not expand to the limit pressure in higher OCR, and therefore stronger clays. If so, then in such stronger clays one would predict a too-low  $s_u$  based on limit pressure.

Figure 11.L.1 also shows data from Clarke & Wroth (1988) suggesting that  $p_0 \cong \text{SBPM } p_L$  even in stronger OC clays. The authors compare  $p_1$  with  $p_L$ . They did not present enough data to permit comparing  $p_0$  with  $p_L$ . The writer used the same  $p_0/p_1 = 0.67$  ratio obtained from tests in other English clays and used in 9A.1, to determine the  $p_p = p_L$  line shown.

Any correlation with limit pressure has importance because it provides a theoretical basis for the expectation that  $p_0$ , and therefore  $K_D$ , should correlate with the undrained strength in clays. If the DMT insertion produces an expansion to a limit pressure  $p_L$ , and if  $p_L = f(s_u)$  then one might expect  $s_u = f(K_D)$ . Figure 11.L and the derivation therein demonstrate that:

$$\frac{s_u}{\sigma_v'} \approx \frac{K_D}{8}$$

A simple  $s_u/\sigma_v' = K_D/8$  usually gives a conservative prediction for  $s_u$  as shown by the three correlation plots in Figure 11.L.2. We suggest this equation as suitable for most preliminary design in non-fissured clays.

#### 11.M Subgrade Modulus Under Mats

The structural designers of mat foundations often request a value of vertical subgrade modulus to use in their computer programs for the structural

design of a mat. Two recent experiences suggest that the DMT may provide a good value for this otherwise difficult-to-evaluate design parameter. Schmertmann pointed out in a discussion of a mat foundation case history in Fredericton, Canada (see Landva, et. al., 1988), that the following correlation formula, previously presented in DIGEST item 4G (Jun 84), would have produced very good agreement with actual deflection measurements of the mat. The authors agreed in their closure.

$$k_v = \frac{0.5}{K_0} \left( \frac{B+1}{2B} \right)^2 \frac{(K_D - K_0) p_0'}{0.5d}$$

d = blade thickness

B = mat width

$p_0'$  = effective vertical normal stress at depth = B/2

The Editor recently experienced another favorable case history where the measured deflection of the mat matched well with the computed deflection using an average  $k_v = 35 \text{ lb/in}^3$  determined from 104 DMTs using the above equation with each. The structural engineer used this  $35 \text{ lb/in}^3$  for the design. These data came from the same case history described in Item 11.G.


  
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 John H. Schmertmann, Editor

TABLE 11.C - BIBLIOGRAPHY UPDATE SINCE D-10

- Baldi, G., R. Bellotti, N. Ghionna and M. Jamiolkowski (1988)  
"Stiffness of sands from CPT, SPT and DMT", ICE, Proc. Penetration Testing in the UK, Univ. of Birmingham, July, paper 42, pp. 145-152.
- Bowles, J. E. (1988)  
Foundation Analysis and Design, Fourth Ed., McGraw-Hill, pp. 157-160.
- Campanella, R. G. and P. K. Robertson (1989)  
"Use and Interpretation of a Research DMT", Paper submitted for review for publication.
- Clarke, B. G., and Wroth, C. P. (1988)  
"Comparison between results from flat dilatometer and self-boring pressuremeter tests", ICE, Proc. Penetration Testing in the UK, Univ. of Birmingham, July, paper 41, pp. 141-144.
- Konrad, J. M. (1988)  
"Interpretation of flat plate dilatometer tests in sands in terms of state parameter", Geotechnique, Vol. 38, No. 2, June, pp. 263-277.
- Landva, A. O., A. J. Valsangkar, J. C. Alkins and P. D. Charalanbous (1988)  
"Performance of a Raft Foundation Supporting a Multi-storey Structure", Canadian Geotechnical Journal, Vol. 25, No. 1, Feb., pp. 138-149. (Discussion by J. Schmertmann and Closure in Vol. 26, No. 1).
- Leonards, G. A. and Frost, J. D. (1988)  
"Settlement of Foundations on Granular Soils, A.S.C.E. Journal of GE, Vol. 114, No. 7, July, p. 791.
- Motan, E.S. and Khan, A.Q., "In-Situ Shear Modulus of Sands by a Flat- Plate Penetrometer: A Laboratory Study," Geotechnical Testing Journal, GTJODJ, Vol. 11, No. 4, Dec. 1988, pp. 257-262.
- Powell, J.J.M. and I.M. Uglow (1988)  
"The interpretation of the Marchetti dilatometer test in UK clays", ICE, Proc. Penetration Testing in the UK, Univ. of Birmingham, July, paper 34, pp. 121-125.
- Schmertmann, J. H. (1988)  
"Dilatometers Settle In", CIVIL ENGINEERING, ASCE, March, pp. 68-70. Discussion: C. Santamarina and D. Frost, Jun 88, p. 28. Closure: J. Schmertmann, Jul 88, p. 30.
- Schmertmann, J. H. (1988-a)  
"Dilatometers Settle In", CIVIL ENGINEERING, ASCE, March, pp. 68-70. Discussion: C. Santamarina and D. Frost, Jun 88, p. 28. Closure: J. Schmertmann, Jul 88, p. 30.
- Schmertmann, J. H. (1988-b)  
"The Coefficient of Consolidation Obtained from p<sub>2</sub> Dissipation in the DMT", paper distributed at ISOPT Specialty Session 2 and also included in DMT DIGEST #10, Mar., also in Proc. Developments in Geotechnical Engineering, Conf. by Central PA Section ASCE and PennDOT, Hersey, PA, 7-8 Sep., 18 p.
- Schmertmann & Crapps, Inc. (1988)  
"Guideline Summary for Using the CPT and Marchetti DMT for Geotechnical Design", Rept. No. FHWA-PA-87-014+84-24 submitted to PennDOT, Office of Research and Special Studies, Harrisburg, PA, Feb., in 4 volumes with the three below concerning primarily the DMT.
- Vol. I - Summary (78 pp.)  
Vol. III - DMT Test Methods and Data Reduction (183 pp.)  
Vol. IV - DMT Design Methods and Examples (135 pp.)

**TABLE 11.J. - APPROX. EFFECTS OF HAMMER INSERTION<sup>1</sup>  
ON DMT RESULTS**

Soil	$I_D$	$K_0$	OCR	$s_u$	$\phi$	M
Sand, loose ( $D_r \approx 50\%$ )	>10*	d-nu**	d-nu		+10%	-35%
dense ( $D_r \approx 90\%$ )		d-nu	d-nu		+5%	-10%
Clayey silt v. sensitive	-60%	-25%	-20%	-20%		-70%
Clays, stiff-hard	0	-15%	-30%	-10%		-5to10%

**Notes:** 1. Height of hammer drop does not have a significant impact on the above effects.

\* Use  $I_D$  greater than 10 as an indicator of serious disturbance from hammer insertion.

\*\* denotes: "decreases severely and not useable."

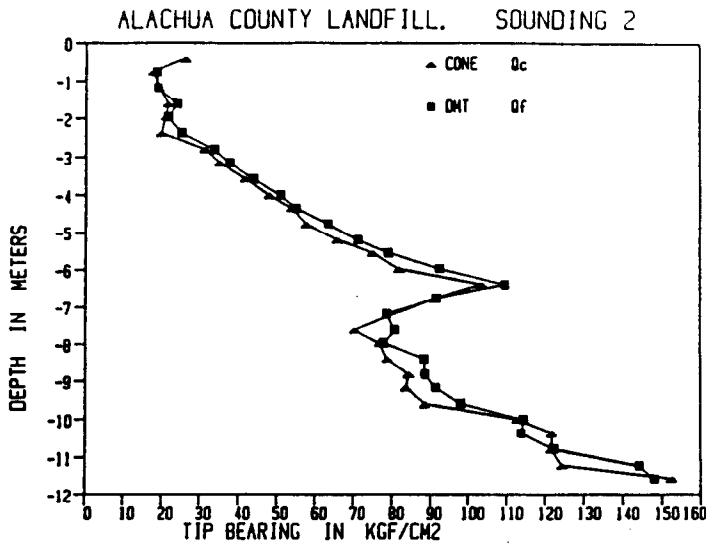


FIGURE 11.I

DATA FROM BASNETT (1988) SHOWING CORRESPONDENCE BETWEEN CPT  $q_c$  (electric tip) and DMT  $q_D$

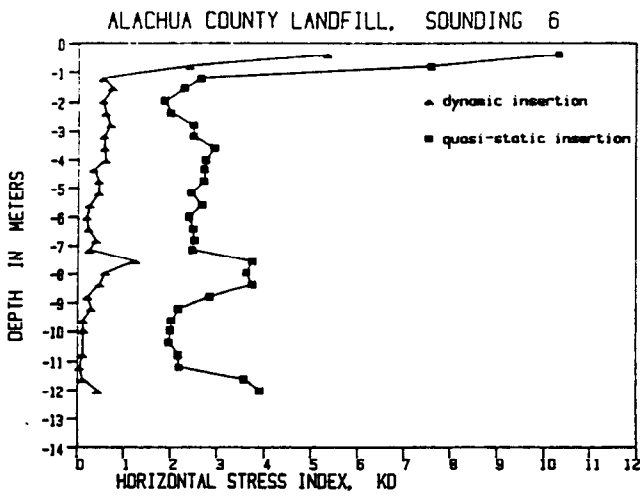
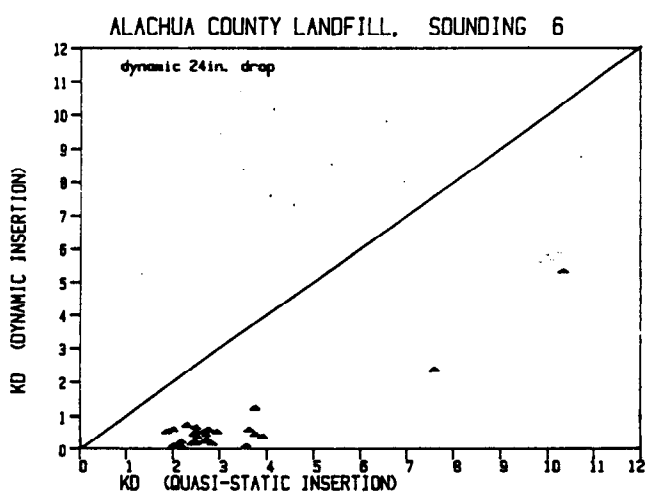


FIGURE 11.J.3

DATA FROM BASNETT (1988) SHOWING EXAMPLE OF DRASTIC EFFECT OF HAMMER INSERTION OF THE DMT ON  $K_D$  IN LOOSE SAND



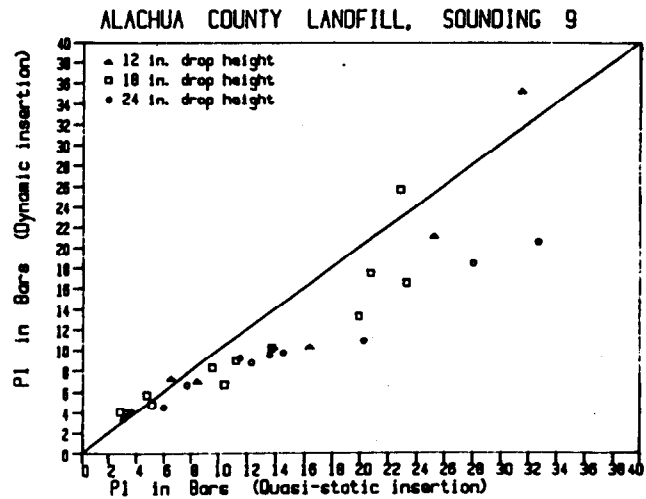
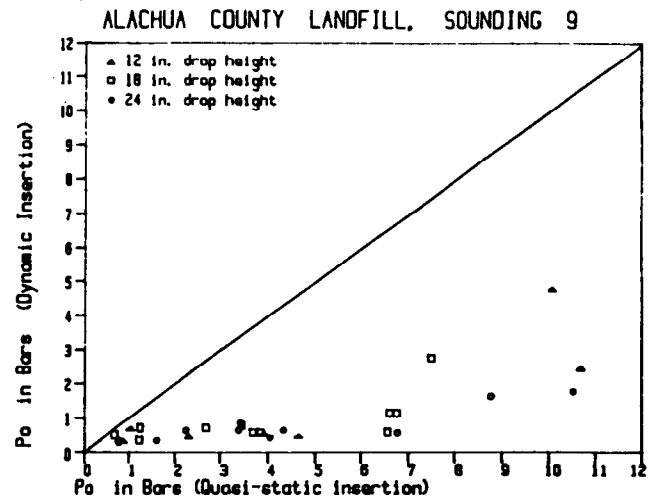
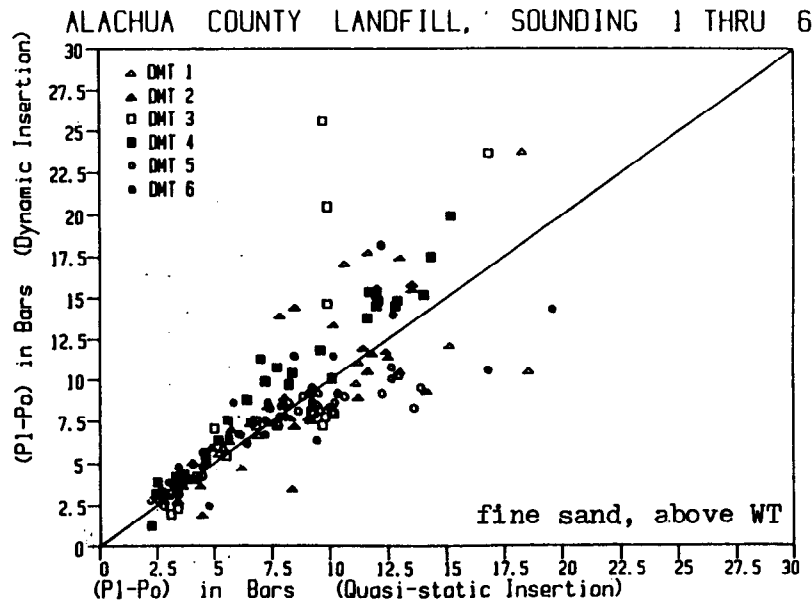


FIGURE 11.J.1 - EXAMPLES OF THE EFFECTS

OF HAMMER PENETRATION ON THE  $p_o$ ,  $p_1$

and  $p_1-p_o$  RESULTS FROM DMT RESEARCH

SOUNDINGS IN SAND

( $p_o$  seriously affected,  $p_1-p_o$  relatively unaffected)

(from: Basnett, 1988)

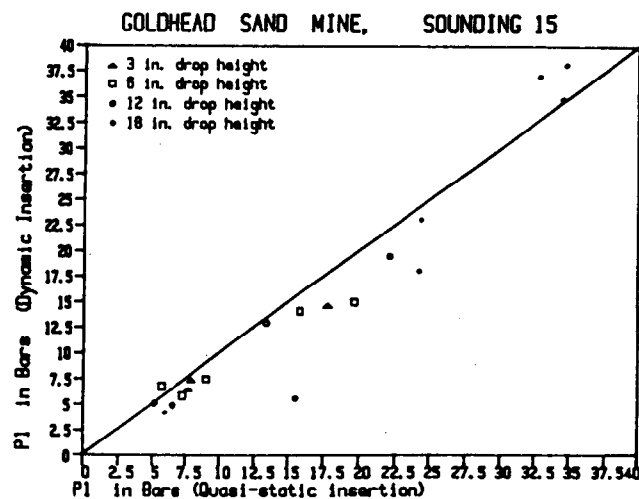
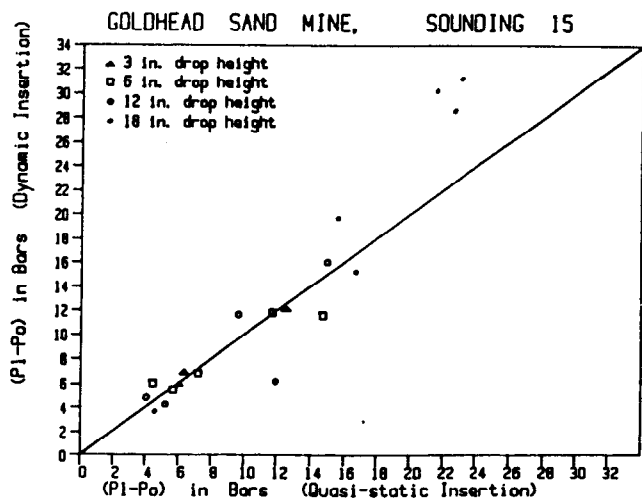
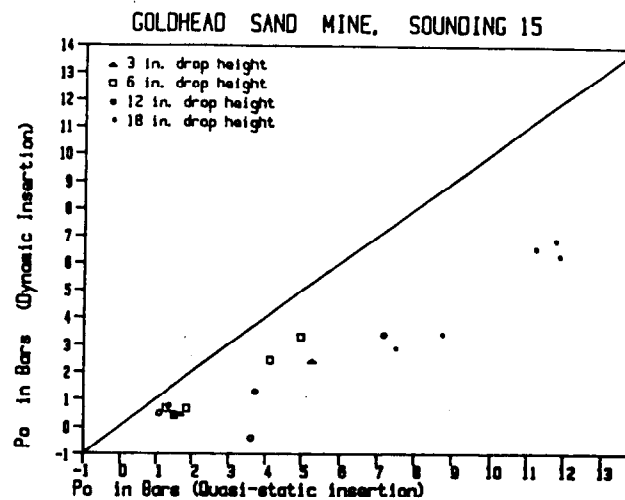
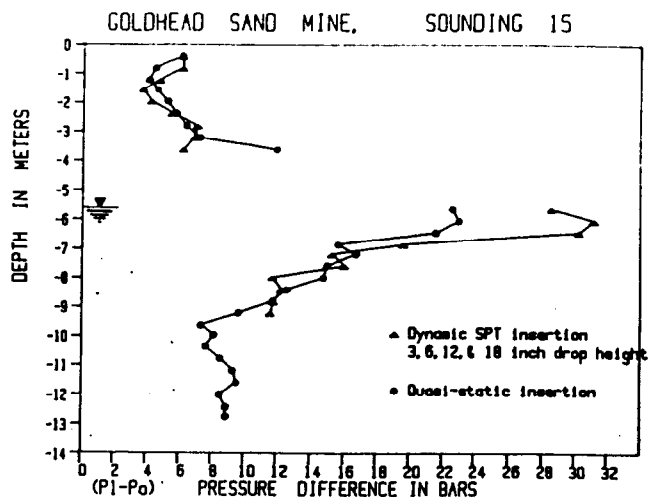
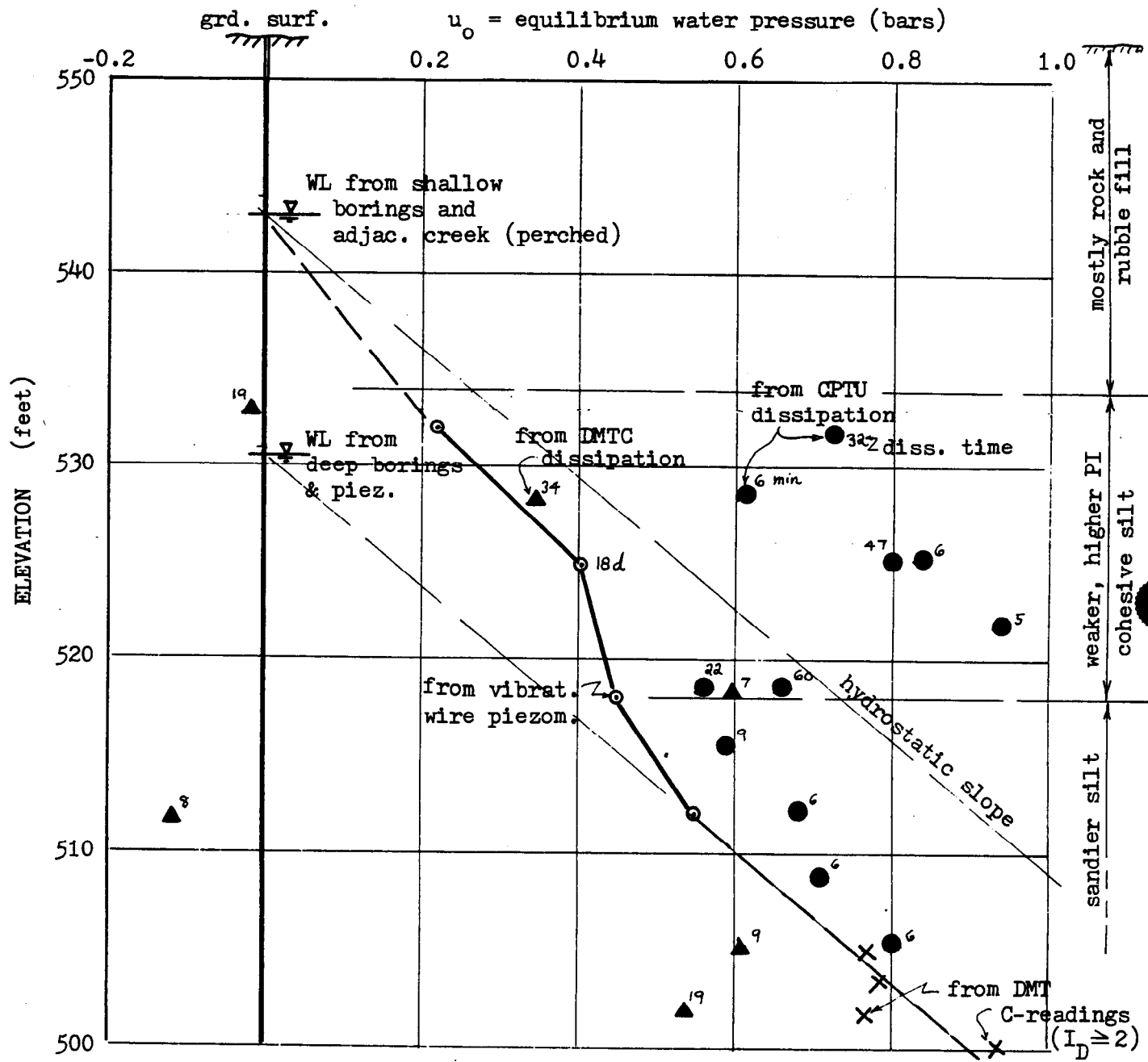


FIGURE 11.J.2 - ANOTHER EXAMPLE OF HAMMER INSERTION OF DMT BLADE SERIOUSLY AFFECTING  $p_0$  BUT WITH RELATIVELY MINOR EFFECT ON  $p_1-p_0$  IN SANDS

(from Basnett, 1988)



- Notes: a. Vibrating wire piezometer data obtained in April, 1989.
- b. All other data obtained in October, 1988.
- c. Similar data obtained in July, 1987.
- d. No apparent change in site conditions from Jul 87 to Apr 89.
- e. Extrapolation for  $u_o$  from dissipation data made mathematically using a hyperbolic function.



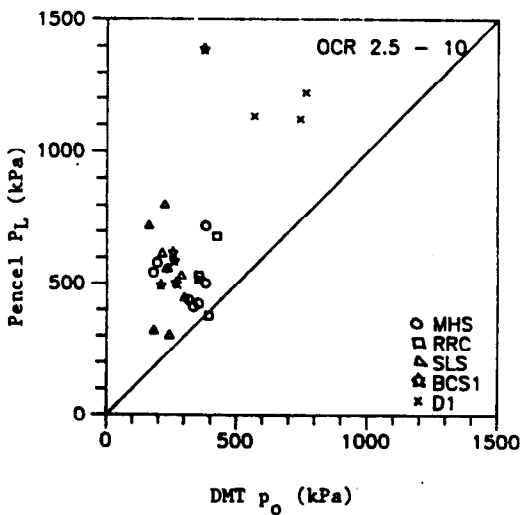
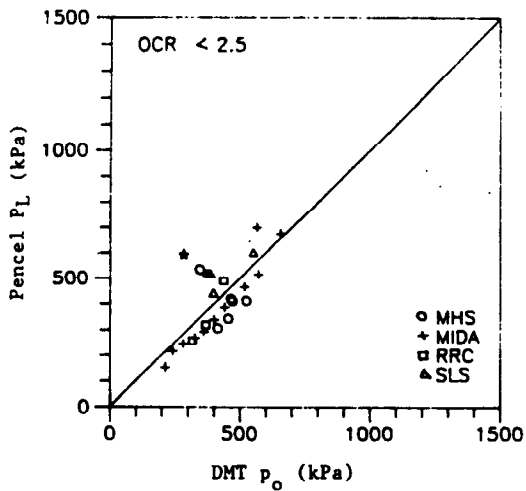


Figure 19. Comparison Between  $P_L$  (full displacement PMT) and  $p_0$

(a) From Lutenegger (ISOPT1 1988)

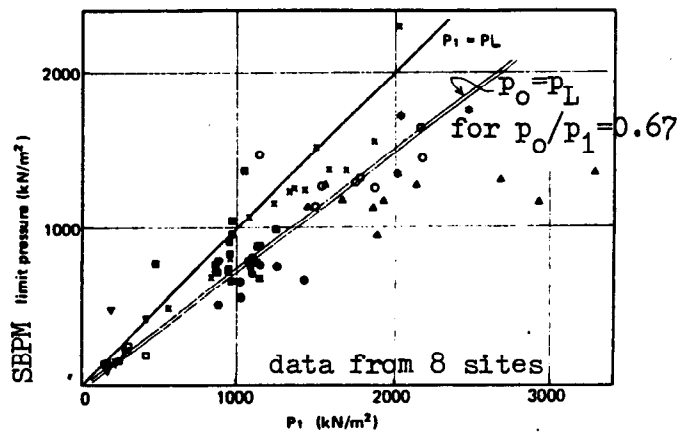


Fig. 5 Comparison between  $p_1$  and limit pressure

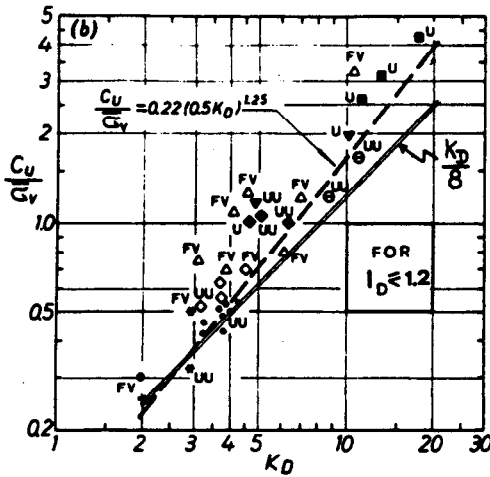
(b) From Clarke & Wroth (1988)

FIGURE 11.L.1

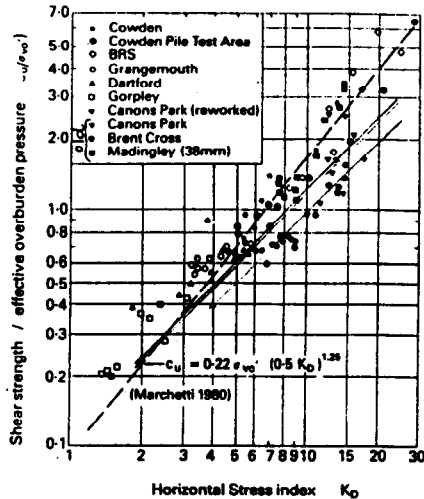
MORE DATA SHOWING CORRESPONDENCE  
BETWEEN  $p_0$  AND  $P_L$  IN CLAYS

Problem: Theoretical correlation for  $s_u$

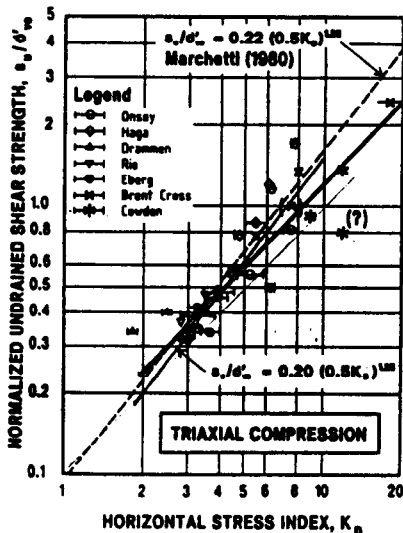
by: JHS date: \_\_\_\_\_



(a) From Marchetti (1980)



(b) From Powell & Uglow (88)



(c) From Lacasse & Lunne (ISOPT1 88)

A THEORETICAL BASIS FOR CORRELATING  $K_D$  vs.  $s_u$  based on limit pressure from cavity expansion

from: Ideal elastic-plastic, cylindrical cavity expansion, and P's ratio = 0.5

$$s_u = \frac{p_L}{1 + \ln\left(\frac{E}{3s_u}\right)} = \frac{p_L^*}{\beta} \quad \dots \quad (1)$$

where:  $p_L^*$  = net limit expansion pressure  
 $= p_L - (k_0 \sigma'_v + u_0)$

$$\beta = 1 + \ln\left(\frac{E}{3s_u}\right) = 5.2 \text{ to } 7.5 \text{ with } 200 \leq \frac{E}{s_u} \leq 2000$$

then:  $\frac{s_u}{\sigma'_v} = \frac{(p_L - u_0 - k_0 \sigma'_v)}{\beta}$

now using  $p_L = p_0$  from data such as Fig. 11.L.1

and noting that:  $\frac{p_0 - u_0}{\sigma'_v} = K_D$

gives:  $\frac{s_u}{\sigma'_v} = \frac{K_D - k_0}{\beta} \quad \dots \quad (2)$

but  $K_0 = f(\text{OCR}) = f(K_D)$   
 with  $K_0 \approx 0.50$  when  $K_D = 2$   
 $\approx 1.2$  when  $K_D = 5$   
 $\approx 2.5$  when  $K_D = 20$

$\beta$  often taken = 5.5 when using the Menard  $p_L$   
 say  $\beta = 6.0$  for conservatism

then:  $\frac{s_u}{\sigma'_v} = 0.25$  when  $K_D = 2$   
 $0.63$  when  $K_D = 5$   
 $2.9$  when  $K_D = 20$

note that approx. good that  $\frac{s_u}{\sigma'_v} \approx \frac{K_D}{8.0} \quad \dots \quad (3)$

Comparing eqn (3) with the correlation data accumulated by others suggests it is conservative but reasonably accurate in a great variety of clays