DMT DIGEST NO. 3
(Feb 84)
(13 pp. + Appendix)

3A - DATA REDUCTION IN BASIC LANGUAGE

Dr. Ramesh Gupta, working for the Hayward-Baker Company, has written a DMT data reduction program, with graphics, in the M-BASIC language. Drs. Gupta and Wally Baker, the President of Hayward-Baker, have kindly permitted a listing of this program to be included with this DIGEST. Dr. Gupta wrote the program for use with an Osborne 1 computer connected to an EPSON printer and an HP-7470A plotter. The Appendix 3A herein contains a listing of this program and example tabular and graphic output. They welcome you to adapt the program to your own small-computer system and to use it as their contribution to DMT technology without any special acknowledgement to Hayward-Baker.

Note that this program does not include the modifications in format, nor the normalization of the plane strain Ø calculation to the reference 2.72 bar stress level (see D-2B). It does include eliminating the double iteration for K_o and Ø which experience has shown to be unnecessary (item 3D). Dr. Gupta reported that the calculation of the example included with the program listing took about 40 minutes on his Osborne 1 computer.

3B - POSSIBLE SPECIAL USEFULNESS IN PEAT SOILS

The writer made an investigation of a shallow, surface peat deposit in the Miami area and found the results for compressibility and strength surprisingly good considering that Marchetti did not include peat in the soils that he used to establish the DMT correlations for soil type, undrained strength and constrained modulus. John Hayes reported in his contribution to the Dilatometer Conference Proceedings (DM-2, Item E) that he also had seemingly good settlement and shear strength predictions in a peat using the DMT. He has subsequently had additional favorable experience with the DMT in peaty soils at another site. The enclosed Table 3B-1 briefly summarizes these favorable experiences to date. To date we know of no unfavorable experiences with the DMT in peat soils.

It thus appears that the DMT may have a good, and possibly somewhat unique, application in peat soils. Because of their macro and micro fiber content, and the reinforcement effects of many of these fibers in other types of laboratory and field tests, these tests often give misleading results. The use of the vane shear test for insitu measurement of shear strength can be

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particularly misleading, as sites 1 and 2 in Table 3B-1 also show, because the vane blades tend to test the fiber reinforcement rather than the massive soil in which the fibers may just act as a filler rather than a reinforcement. The comprehensive dissertation by Landva [partly included and referenced in A. Landva and P. LaRochelle, "Compressibility and Shear Characteristics of Radforth Peats", ASTM STP 820, 1983, pp. 157-191] discusses in great detail the many types of peat, and the difficulties with the lab and field testing of such fibrous material. It seems possible that the sharp cutting edge of the dilatometer blade (JHS especially sharpened this edge prior to the Miami tests) that the blade slices through the peat fibers and in large part thus avoids their reinforcing effect on the DMT results.

The editor would welcome the details of any other DMT experiences in peat soils, favorable or unfavorable, that you might like to share.

Note of caution: The weakness and compressibility of peat generally produce small values of pressure for the A and B readings. Good results depend on accurate A and B readings and accurate ΔA and ΔB calibrations. For this reason we recommend the 0-16 bar gage for DMTs in peat. For even better accuracy we have also used the Bourdon gage used with the calibration unit after resetting the pointer so that -1.00 becomes 0, giving a positive gage range of 2.5 bar. In addition, when computing results you will need to enter the total unit weights manually rather than rely on the Marchetti unit weight matrix that we have incorporated into all the computer programs. The total unit weight for peats typically has a much lower value than when taken from the Marchetti matrix and this can have a very important effect on the quality of the results.

3C - M_{DMT}/q_c RATIO IN SANDS DEPENDS ON STRESS HISTORY AND METHOD OF COMPACTION

Part A of DMT D-2 showed that one could establish a useable site-specific correlation between the CPT cylindrical electric tip q_c and the dilatometer constrained modulus M. We now have further data that shows even greater diversity possible in this correlation. Figure 3C-1 shows the correlation curves from the previous D-2, p. 2-1, and in addition the correlation curve we obtained from a washed, very fine tailings sand after compaction by a vibratory roller. The figure also includes an average point from the large calibration test chamber work on NC, clean, medium, quartz sand by ENEL in Italy. It seems even clearer now that a single correlation in all sands does not exist. As suggested subsequently, different treatments of the same sand will likely produce different correlations. If desired, the engineer must establish the M/q_c ratio on a site-specific and probably treatment-specific basis. The engineer cannot at present use CPT work only and thereby eliminate

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more expensive dilatometer or other testing to get insitu modulus information.

A closer examination of the data in Figure 3C-1 gives a preliminary indication of possibly important information regarding the engineering performance of treated sands. The upper point came from the static, normally consolidated, pluvially deposited sands in the Italian ENEL Chamber tests. The upper field data curve came from 16 correlation pts. in a predominately sand layer in which a contractor used compaction grouting to improve the CPT q_c values in this layer. The next lower curve resulted from 14 correlation points in sand wherein the sand was first densified by dynamic compaction (dropping a 36 ton weight 105 ft). The lowest field curve came from 17 correlation pts. in a fine, quartz tailings sand after compaction using a vibratory roller on the surface. Judging by this preliminary evidence we tentatively conclude that the greater the vibration component in the sand densification process, the greater the resulting ratio of M_{DMT}/q_c. Our reasoning for this follows below:

Chamber placement by pluvial deposition does not involve mechanical vibrations, other than perhaps those in the general environment of the Chamber and those due to the bouncing of the grains during deposition. Compaction grouting represents a quasi-static method for densification with perhaps minor vibrations associated with the pumping machinery and grout pipe insertion. In this case the sand also experienced some vibrations from overhead (above 10 m) dynamic compaction. Dynamic compaction of course induces shock waves and the associated decaying vibrations after each blow. Vibratory rolling compaction involves thousands of cycles of continuous vibration.

Perhaps vibrations induce a accumulative prestressing effect, but one which acts over only a relatively small subsequent shear strain. Then the subsequent CPT cone penetration produces large shear and volume strains (approx. 15%) which tend to destroy this effect while the DMT produces significantly smaller strains (approx. 5%) which leave at least some of the vibration-prestress effect measureable in the DMT modulus determination.

Now consider the enclosed Figure 3C-2 (ref. Figs. 26, 27) which present some liquefaction test results of interest to the above discussion. The figures came from a recent Japanese publication (noted above [Fig. 26]), but others have reported similar findings. This figure shows that the normalized cyclic shear stress ratio required to induce liquefaction at constant unit weight or relative density increases with the amount of vibration accompanying the preparation of the sample -- air pluviated (no vibrations) to wet tamping (decaying transient impact vibrations) to preparation by continuous vibrations. The development of liquefaction results from the accumulative strain effects of very low strain cyclic loading. The behavior presented in these Figs. thus supports the concept that vibrations stiffen a sand's

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structure and increase its subsequent static and cyclic modulus at low levels of strain. It seems likely that the CPT would more extensively destroy this stiffening change in structure and not measure its effect while the DMT does not as greatly destroy the change in structure and at least partially measures its effect. The above explanation would in part account for the pattern of the different correlations shown in Fig. 3C-1.

3D - SPEEDING UP THE CALCULATION OF K_o AND OCR IN SANDS

Item B. in DMT D-1 described a new calculation procedure for ϕ_{ps}, K_o and OCR in sands. As described on p. 1-1 of D-1, the method involves a double iteration for K_o and ϕ. This procedure has proven quite time consuming, especially on the HP 41CV. We have since discovered by trial that the value of ϕ calculated has proven relatively insensitive to K_o and one can obtain essentially the same results without iterating for K_o. This has considerably shortened the time required without sacrificing significant accuracy in the results. We have now modified all our programs accordingly. Dr. Gupta has included this modification in the enclosed BASIC language program.

You should have already received[1] a cover p. titled "INDEX TO....(revised July 83) plus 14 pp. showing by highlighting the modifications in the HP 41CV program to eliminate the unneeded iteration for K_o. If you have not already done so, we again suggest you also modify your HP 41CV program and magnetic storage cards to take advantage of the shorter calculation times.

3E - GRAPH FOR ESTIMATING ϕ_{ps} AT ANY STRESS LEVEL FROM ϕ_{ops}

Section B. in DMT D-2, together with analysis p. 2-3, described the method we now use to present ϕ_{ps} normalized to a certain stress level. When using this information you likely will want to know ϕ_{ps} or ϕ_{ax} (triaxial test peak ϕ) at some other stress level. To make these determinations more convenient we have included herein a graph Figure 3E to convert the normalized ϕ_{ops} to ϕ_{ps} at any σ_{ff}' stress level between 0.2 and 5 bar. The equation noted in the last paragraph of Section B. in DMT D-2 allows a quick estimate of the equivalent axisymmetric ϕ_{ax} from the plane strain ϕ_{ps} as determined above. Figure 3E includes an example of converting ϕ_{ops} to ϕ_{ps} to ϕ_{ax}.

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[1] If not, let GPE know and we will mail to you postpaid.

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3F - COMPACTED SAND ALERT

The present method for calculating ϕ_{ps}, K_o, and OCR in sands requires knowing the total static "P" thrust acting at a point just above the friction reducer above the DMT blade. We normally measure this thrust at the ground surface and, in accord with the suggestions by Schmertmann, assume that the pushrod/sand friction above this point is negligible and we take it = 0. Experience to date indicates that this assumption produces reasonable results for the common situation of having natural sand deposits no deeper than 15 m. below the ground surface. However, this assumption of negligible rod/soil friction may introduce significant error for the special case of testing in compacted sands.

Engineers can sometimes check the above assumption by comparing the total thrust to advance the DMT blade with a parallel q_c profile from a CPT sounding. Often the CPT will show a deep layer with a very low value of q_c. If the dilatometer thrust also reduces to a very low value when reaching that layer then one has some evidence suggesting a negligible rod/soil friction.

We have observed in layers with high lateral stresses that the soil above the friction reducer appears to close elastically around the reducer and again make significant stress contact with the rods above the reducer and thereby produce significant rod friction. This will likely occur in soils deliberately compacted by processes such as dynamic compaction, the various types of rolling compaction, displacement piles, compaction grouting, and possibly even vibro-flotation or a large static surcharge. In these circumstances the DMT user needs to be alert to the significant rod friction possibility and the consequent possible errors in the present computer programs for ϕ_{ps}, K_o and OCR that assume negligible rod friction.

Ideally one should obtain P by a load cell just above the DM blade. Researchers at the UBC (Vancouver) are developing such a load cell. In the absence of this ideal the user can perhaps somehow estimate the parasitic soil/rod friction and subtract it from the total thrust to make a more accurate estimate of the net thrust P reaching to just above the friction reducer. Note that if one uses a too-large P then ϕ_{ps} will compute too high, and values of K_o and OCR will compute too low.

3G - VERY LOOSE SAND ALERT, PUSHED AND DRIVEN DMTS

Since DMT D-2 we had the opportunity to perform parallel DMT and CPT soundings in a very loose mine tailings sand backfill before any compaction treatment. These gave mechanical q_c values in the range of 2 to 19 bar with

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an average mechanical q_c = 9 bar, in a layer 2.8 m thick and with a calculated vertical effective stress of about 0.30 bar. When entering the correlations established for normally consolidated clean, uniform quartz sands, this translates to an average relative density of about 15%. From the results of vibratory rolling from the surface, we know that this sand has great sensitivity to compaction by vibration. It seemed that the results obtained from the DMTs depended significantly on the method of insertion, and seemingly even on the vibrations associated with the quasi-static method of insertion using the motorized GMB hydraulic system on a CPT truck. We also used hammer-driven insertion with a hand-lifted, 40 lb hammer dropping about 12".

Figure 3G-1 presents the detailed results from parallel (1 to 2m apart) Dutch mechanical CPT and hand CPT soundings, and two DMT soundings -- one pushed and one driven. Part (a) shows the comparative, uncorrected A and B readings for driving vs. pushing. Again, as first explained in item C. of DMT D-1, we have evidence that driving reduces both the A and B readings in very loose sand. Part (b) again shows that driving the DM also produces lower (therefore conservative) M values than when pushing the DM into sensitive soils.

But, note the similarity of data and results around the 2 and 3m depths in Fig. 3G-1. The q_c summary at the right side of Fig. 3G-1, and particularly for the handcone, shows especially weak sand layers at the 2 and 3m depths. These layers have a D_r = only 0% according to the aforementioned correlations. They appear so sensitive that even hydraulic pushing may introduce enough vibrational disturbance (or possibly only displacement disturbance in extremely loose sands) to exceed some "critical" level and compact/collapse/densify the sand structure to almost the same degree as the driving vibrations. The writer has inserted the near-vertical line in Fig. 3G-1(b) to indicate a possible trend for M vs. depth had it proved possible to insert the blades without vibration.

We think that this experience may indicate that even when using the CPT quasi-static insertion method in very loose sands that significant vibrations may reach the dilatometer blade and cause unwanted compaction and a distortion of the DMT results. We therefore want to alert potential users of the DMT in very loose sands that to get proper and consistent results may require a blade insertion technique that does not permit vibrations to travel down the rods and reach the blade. At the least, efforts should be made to minimize such vibrations to the extent practical. Users of the DMT need to recognize that DMT results may appear erratic in what otherwise appears to be a more uniform soil due to an erratic occurrence of critical and non-critical behavior with respect to insertion compaction around the blade. The higher, non-critical A and B data will likely prove less disturbed and produce more accurate results.

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3H - ADAPTOR SLOT CAN CUT CABLE

We have discovered a minor, easily corrected problem with the upper, slotted adaptor that fits on the CPT pushrods to allow the DM cable to exit from the rods. On some of these adaptors the machining to make the slot has left a sharp inside and outside edge which can cut the cable in the event of an accidental tug on the cable. Check your adaptors. If needed, have a machinist round these edges or do it yourself with suitable metal files and avoid a possible problem in the field.

3I - 2E REVISITED -- CONFERENCE PROCEEDINGS AVAILABLE

We have received word from Mobile Augers Research Ltd. that they now have the Proceedings of their Conference available for purchase and distribution. GPE has received their copies and we congratulate Mobile Augers on a nice job and we recommend purchase as a "must" for all users of the DMT. You can order a copy for $50 Canadian from the form again included herein (p. 3-13).

John H. Schmertmann
Editor

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TABLE 3B-1 - SUMMARY OF DMT PREDICTONS IN "PEAT" SOILS

Site No.	LOCATION INVESTIGATOR DATE (ref.)	INFO. re: Peat	ave. I_D	DMT predicted	Actual Observed	Notes
1.	Miami Schmertmann Jan 84 S&C report	$\overline{w}$ = 670%, very fibrous, 0.83 ignition loss, surface to 4′ with GWT at 0.5′	0.8 (dessicated) 0.2 NC	s_u = 0.70 b at surface to 0.01b at 3 ft depth	surface bearing failure at backfigured s_u = 0.075 b	s_{uvane} = 0.24 b
				settlement = 52 mm, OC crust	settlement = 43 mm in 1 day	2x2 ft plate on surface, after 1 day
2.	Victoria County, Ont., Canada Hayes Jun 82 Conf. Proc*	fibrous and amorphous	0.15	s_u = 0.08 b	s_{uvane} = 0.15 b but experience shows have to use 1/2 s_{uvane} for embankments	
				settlement = 260-340 mm	projected 30 yr. settlements = 250-300 mm	existing road embankment
3.	do. (Emily Creek)		0.25			
4.	Petersborough, Ont., Canada Hayes Sep 83 S.I.S. report	org. silt/peat/ marl layer, 11-25′ depth, below WT, ave. w = 150% pt ave. w = 80% other	0.15	settlement = 262 mm, of which 90% in layer	approx. 200 mm at end of primary, project 270 mm in 30 yrs.	building, 2000 psf area load increase,

abbrev. S&C = Schmertmann & Crapps
S.I.S. = Site Investigations Services, Ltd.
* = 1st Int. Dilatometer Conf., Edmonton
Canada, Feb 83, by: Mobile Augers Research Ltd.
(see p. 3-13)

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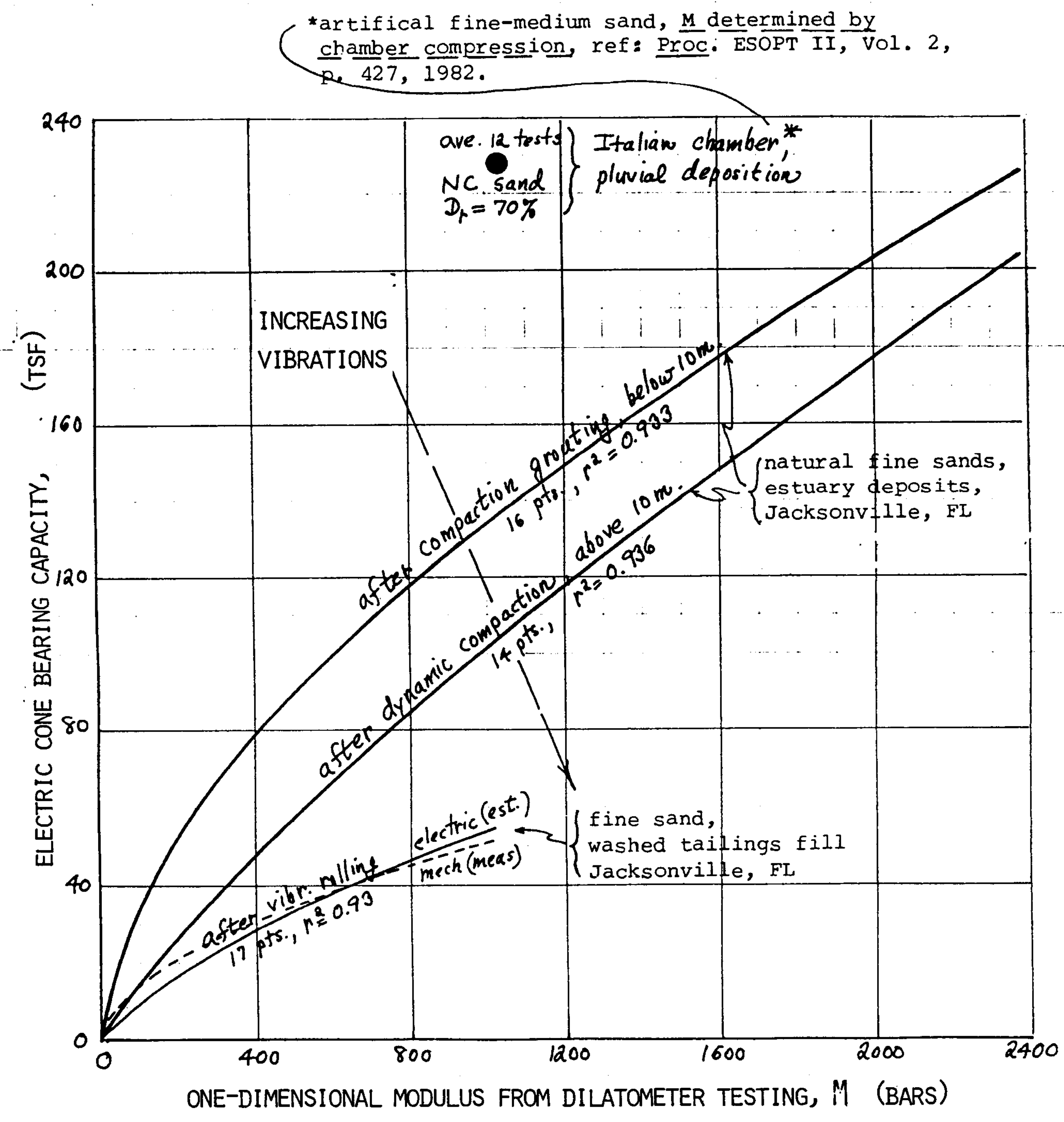

Figure 3C-1 - DATA SUGGESTING THAT M_{DMT}/q_c RATIO DEPENDS ON THE VIBRATIONS ASSOCIATED WITH THE COMPACTION OF A SAND

(increasing vibration increases M/q_c ratio)

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Taken from: Soils and Foundations (Japan)
Vol. 23, No. 3, Sep 83
by: Tatsuoka et. al.

undrained torsional shear test on Toyoura sand with a constant shear distortion rate (1%/min) and with a constant shear stress amplitude. The number of loading cycle for the data is 12. As can be seen from these figures the major shear strains were induced in the range between A and B or between C and D. In these ranges, the excess pore pressure is decreasing. Corresponding to larger shear strain at higher portions caused by larger τ/σ'_v values, positive dilatancy or. a decrease in excess pore pressure at higher portions may be larger than at lower portions. These may result in the water migration from lower portions to higher portions which results in loosening the top portion of sample. This mechanism was called "a kind of pumping action" by Casagrande (1976). The data shown in Fig. 25 seems to show that the effects of pumping action are not noticeable for DA less than at least 12% but become significant for larger DA values due to repetitions of pumping action. Of course, more detailed researches will be necessary to clarify this mechanism. The water migration of this kind may be easier to occur in a slower test. Therefore, it can be said that the deformation shown in Fig. 24 for tests with f=0.01 Hz is not more uniform than that for the test results presented in the paper for which f was 0.5 Hz if the aforementioned mechanism is true.

Professor Vaid recommended another sample preparation method in which densification is achieved by vibrations with the loading cap being on the sand surface with a small seating load. It was pointed out further that the resistance to liquefaction of Ottawa sand sample prepared by the method described above (Fig. 22) is larger than that of Toyoura sand or Sengenyama sand prepared by the air pluviation method (Fig. 14) for identical values of relative density. It was suggested that such differences in resistance to liquefaction were caused by the different nonuniformity of deformation and the resistances of Toyoura sand and Sengenyama sand presented in the paper were underestimated

FIGURE 3C-2

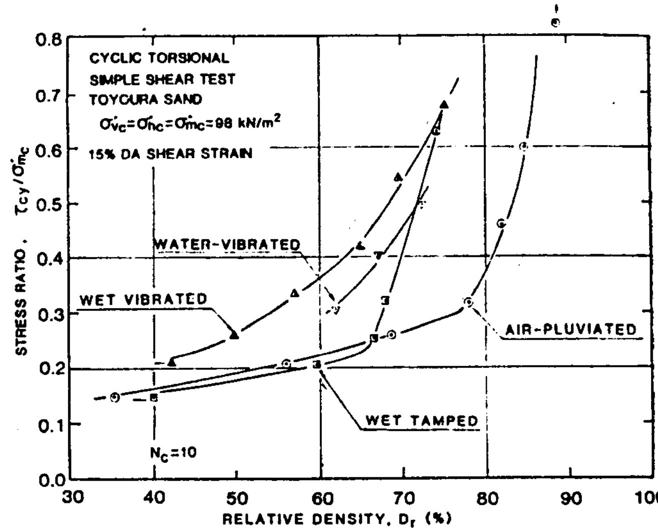

Fig. 26. Resistance to liquefaction of Toyoura sand prepared by various methods

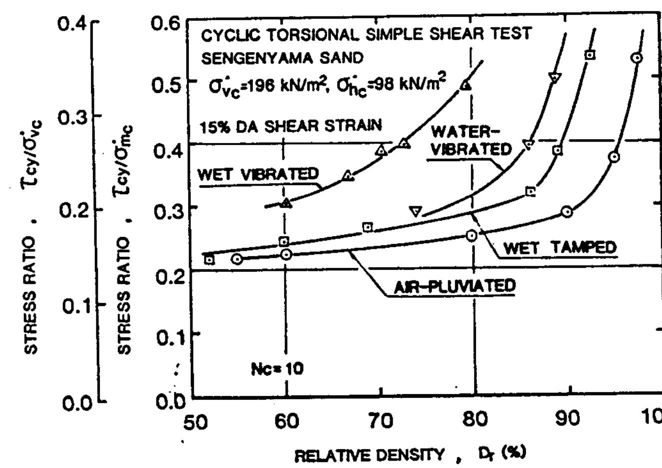

Fig. 27. Resistance to liquefaction of Sengenyama sand prepared by various methods

such difference in resistance compared at identical values of relative density can be possible among different kinds of sand samples prepared by the same sample preparation methods even in the case where the test results are free from the effects of nonuniform deformation. Beyond this point, it seems unreasonable to the present authors to compare the test results of samples prepared by the different sample preparation methods. Shown in Figs. 26 and 27 are the test results on samples prepared by the different sample preparation methods (Tatsuoka et al. 1982). In all the methods employed, the ribs of the loading cap were digged into the

Problem: determining ϕ_{ps} and ϕ_{ax} from DMT ϕ_{ops} Work by: JHS date: 25 Jan 84

Check by: date:

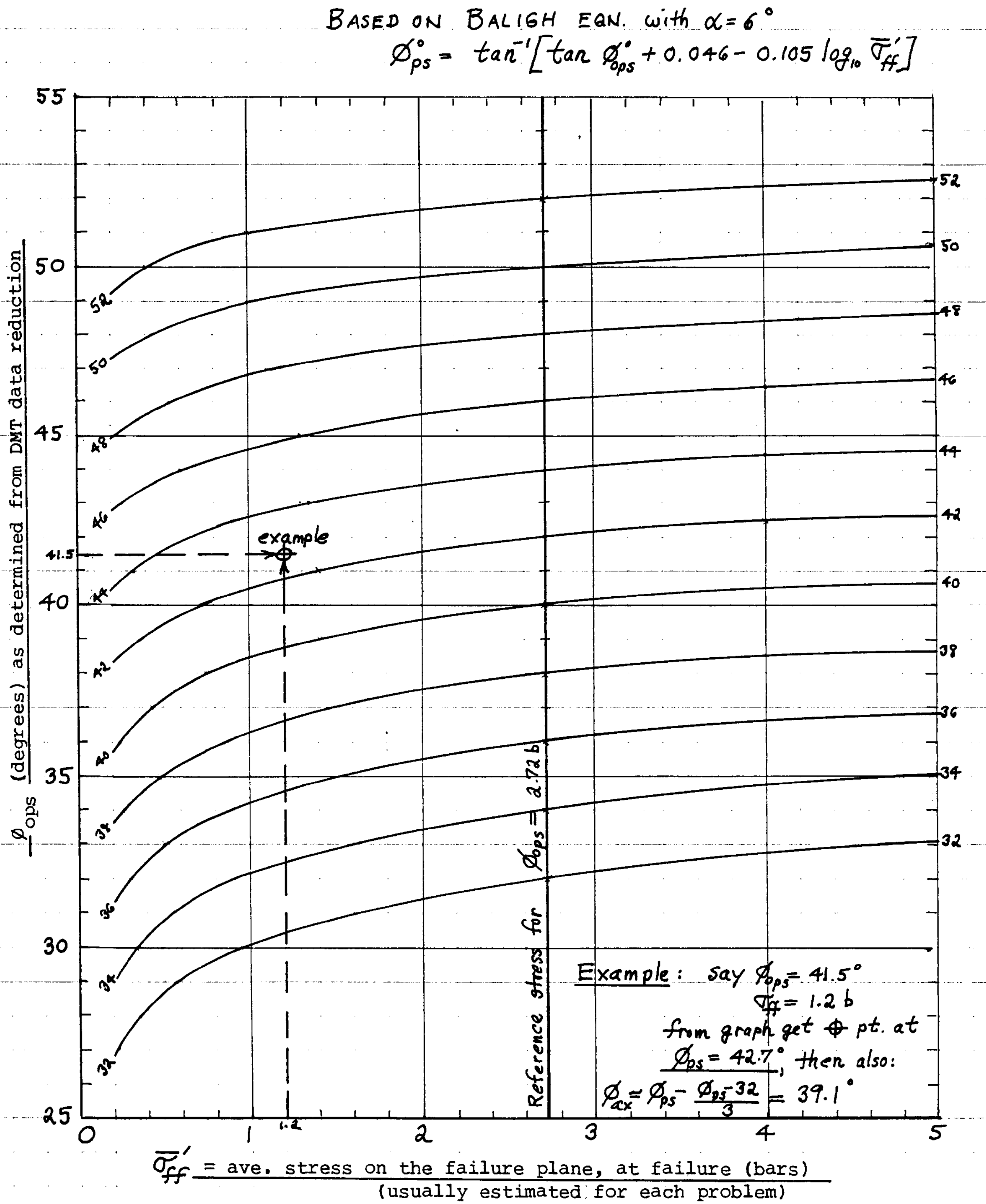

FIGURE 3E - GRAPH FOR THE RAPID ESTIMATION OF FRICTION ANGLES IN SAND, FROM THE DMT OUTPUT, APPLICABLE TO THE STRESS LEVEL IN YOUR PROBLEM

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SCHMERTMANN & CRAPPS, INC. Job No. ______

Problem: POSSIBLE EFFECT OF PUSHING VIBRATIONS IN VERY LOOSE SAND

Work by: JHS date: 26 Jan 84

Check by: ______ date: ______

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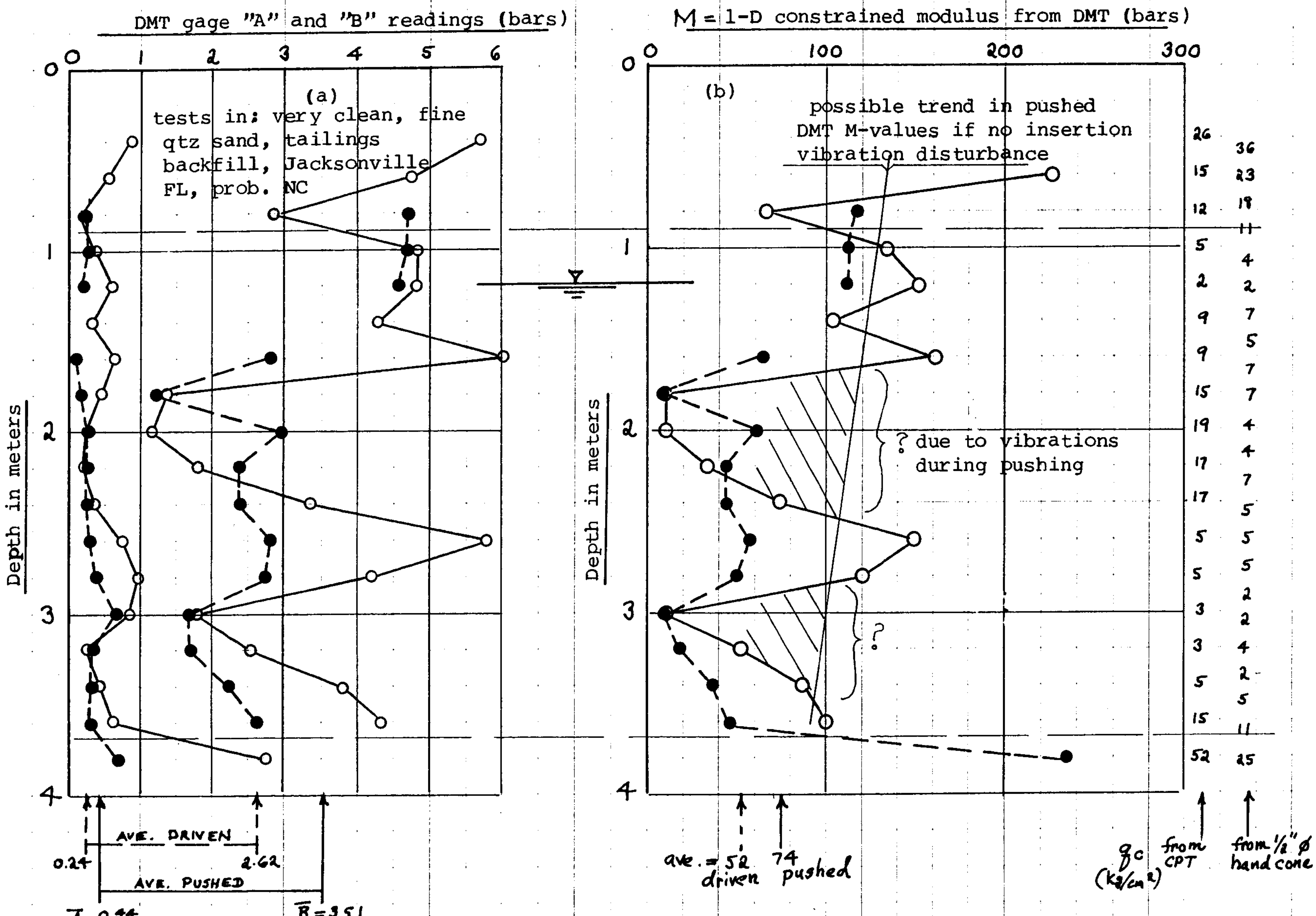
FIGURE 3G-1 - DIFFERENCES IN DMT RESULTS FROM PUSHING WITH CPT HYDRAULIC MACHINERY VS. DRIVING 8-21, 40lb-12in BLOWS/20cm TO INSERT DM



Note: Ave. of 14 OCRs, pushed tests from 0.9 - 3.7m, = 1.00 using calculation methods given in DMT D-1, item B. Ave. K_o = 0.49, ϕ_{ops} = 28.0°

DMT D-2

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MOBILE NEWS

Volume 1, #3

Dr. John H. Schmertmann

FIRST INTERNATIONAL CONFERENCE ON THE FLAT DILATOMETER

Mobile Augers & Research Ltd. sponsored a technical conference on the Flat Dilatometer, February 4, 1983.

The featured speaker, Dr. John H. Schmertmann, a very much respected and renowned practising engineer, presented a state of the art paper on this exciting new insitu testing device.

The event was attended by over sixty engineers, drawn from California, Washington, Ontario, Quebec and Saskatchewan as well as the local area.

Flat Dilatometer case histories in eastern Canada were provided by Mr. John A. Hayes, P. Eng., president, Site Investigation Services Ltd., Peterborough, Ontario. Mr. Hayes' examples were highway construction across organic swamp lands and high rise buildings on glacial materials.

C.N. Rail, Canada's largest rail system is in the process of upgrading and twin tracking western Canadian lines to haul grain to tide water. Mr. John Mekechuk, P. Eng., senior geotechnical engineer, provided flat

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PROCEEDINGS

FIRST INTERNATIONAL CONFERENCE ON THE

FLAT DILATOMETER

CONTENTS

1. *SCHMERTMANN, Dr. J. H., (1983):* PAST, PRESENT AND FUTURE OF THE FLAT DILATOMETER.
   Dr. Schmertmann: provides history of the instrument since inception in 1974, discusses Marchetti's (The Inventor) philosophy on insitu measurement, and gives insight into the instruments geotechnical significance.

2. *HAYES, J. A., (1983):* CASE HISTORIES INVOLVING THE FLAT DILATOMETER.
   Mr. Hayes: provides hands on experiences with the instrument, results from three specific sites and description of the test procedures.

3. *MEKECHUK, John, (1983):* FLAT DILATOMETER USE ON C.N. RAIL LINES.
   Mr. Mekechuk: provides data from four CN rail test sites, 3 from the Skeena subdivision, British Columbia and one from the Fort Frances subdivision, Ontario, Canada.

4. *BURGESS, N., (1983):* USE OF THE FLAT DILATOMETER IN THE BEAUFORT SEA.
   Mr. Burgess: provides data related to design of foundations for offshore artificial and caisson retained islands in Canada's arctic ocean.

5. *CAMPANELLA, Dr. R. G., (1983):* CURRENT RESEARCH AND DEVELOPMENT OF THE FLAT DILATOMETER.
   Dr. Campanella and Mr. Peter Robertson: provide information related to geotechnical research on the instrument's performance and developments to expand its capability.

— The conference concluded with some quite lively discussion . . . which is provided as part of the proceedings package.

— copies of the proceedings are available @ $50.00 each from:

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APPENDIX 3A

LISTING OF HAYWARD BAKER MICROSOFT BASIC PROGRAM FOR DATA REDUCTION FROM THE DMT, WITH OUTPUT EXAMPLE (but no instruction manual and DMT location deleted)

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