# THE USE OF THE SEISMIC CONE AND CONE PRESSUREMETER FOR CONTROL OF GROUND MODIFICATION IN SILTS AND SANDS

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## ABSTRACT

Ground improvement contractors are commonly required to meet a performance criterion in terms of a minimum achieved SPT N-value or cone tip resistance. Where silts and silty sands are encountered, the assessment of compliance with such a performance specification frequently becomes contentious. This paper describes the results of seismic cone penetration tests and cone pressuremeter tests carried out at a site in the silts and sands of the Fraser River Delta before and after ground improvement. The effect of the ground modification on tip resistance, pore pressure response, shear wave velocity, and the characteristics of the pressuremeter curves will be compared and discussed. Observations of the implications of the results for the specification and control of ground improvement are made.

Kewords: ground improvement, liquefaction, pressuremeter, siesmic piezo-cone

## INTRODUCTION

In the sands and silts of the Fraser River delta, potentially large ground movements may occur due to pore pressure generation, liquefaction and pore pressure redistribution during and after seismic shaking. The potential for large ground movements can be reduced in the near-surface materials by vibratory compaction of granular deposits and reinforcement of silts and clays. This paper presents the results of seismic piezo-cone and full-displacement pressuremeter testing in sands and silts typical of the Fraser Delta which have been improved by vibro-replacement (stone columns). These results are used to illustrate important issues in the use of penetration testing for quality control and quality assurance of ground improvement and to examine the potential benefits of the use of the cone pressuremeter for this purpose.

Soil conditions in the Fraser River Delta typically consist of generally fine-grained overbank, floodplain and intertidal clayey silts overlying Fraser River sands, which in turn overlie marine foreslope deposits, consisting of loose to compact silty sands interbedded with soft to firm grey clayey silt (1). The deep sands and silts are of prodelta, marine and glaciomarine origin and in places exceed 200m in thickness. Fraser River Sand is a fine uniform sand. Based on its depositional history, it can be expected to contain zones with variable amounts of fines and lenses of silt.

## LIQUEFACTION ASSESSMENT

The conventional approach to liquefaction assessment in the Lower Mainland of British Columbia is based on in situ testing. This paper will address the use of piezo-cone penetration testing (CPTU) and shear wave velocity measurement. For critical facilities, undisturbed sampling is attempted and the samples are subjected to cyclic triaxial or cyclic simple shear tests.

### Based on CPTU Testing

Figure 1 shows the chart recommended by the US National Committee on Earthquake Engineering Research (NCEER)(2) for use in the Seed Simplified Method approach to liquefaction assessment. The chart includes a boundary (a resistance curve) between combinations of Cyclic Stress Ratio (CSR) and normalized penetration resistance, $q_{c1N}$, which are likely to result in liquefaction from those for which liquefaction is unlikely. The normalized values refer to the measured penetration resistance corrected to a consistent stress level. The recommended equation is:

$$q_{c1N} = (q_c/p_a)*(p_a/\sigma_v')^{0.5}$$

where $\sigma_v'$ is the vertical effective overburden stress and $p_a$ is one atmosphere (100 kPa). Disturbed samples for determinations of fines content (percent passing the #200 sieve) are obtained either by SPT



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testing or off solid flight augers.

For an increasing presence of fines, the tip resistance at a given density decreases. This may be because of an increase in compressibility of the sands or because the decreased permeability results in only partial drainage, i.e. the generation of excess pore pressures during penetration. The liquefaction resistance of a soil at a given density may also be affected by the presence of fines. These two phenomena are recognized in the liquefaction resistance chart by setting reduced resistance curves for elevated fines contents. NCEER recommends that CPT criteria should not be used for assessment of liquefaction resistance for soils with apparent fines contents greater than about 30 %. Above this level liquefaction assessment should be based on other approaches such as the "Chinese Criterion"(4).

**Based on Shear Wave Velocity Measurement**

Shear wave velocity, $V_s$, is also used as an indicator of liquefaction susceptibility. Research has indicated that the shear wave velocity is a function of the void ratio, the effective stresses in the direction of propagation and of particle motion during the passage of a shear wave, the stress history and the age of the deposit. Again, the measured value of $V_s$ should be corrected to a consistent stress level to allow valid comparison between sites. The normalized shear wave velocity is given by the expression:

$$(V_s)_1 = V_s\,(p_a/\sigma_v')^{0.25}$$

where $p_a$ and $\sigma_v'$ are as before. Based on observation of sites at which liquefaction has been observed, the relationship shown in Figure 2 has been adopted to permit liquefaction assessment of sands.

It can be seen that variations in fines content do not have a large effect on the boundary between resistance curves. However, there is little information on the variation of $V_s$ in soils with very high silt contents.



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## QUALITY CONTROL OF GROUND IMPROVEMENT

Cohesionless soils are densified most effectively by vibratory means. For in place densification of loose sands in the soils of the Fraser Delta, the most common methods of ground improvement are Deep Dynamic Compaction (DDC) and Vibro-replacement (stone-columns). In the former, compactive energy is applied to the ground by successive blows of a large mass dropped by a crane in a controlled pattern. In the latter, a vibrating rod is inserted into the ground and coupling between the vibrator and the surrounding ground results in the soil being vibrated into a denser packing. Stone is introduced into the hole which improves coupling between the probe and the soil and allows probes to be placed at larger spacings than if densification was by vibration alone. The stone columns provide an additional benefit by acting as zones of higher permeability for dissipation of any pore pressures created by seismic shaking. The degree of densification achieved depends on the level of energy applied and the pattern and sequencing of its application.

As the proportion of fines in the soil increases, the effectiveness of vibratory compaction becomes lower. Increasing fines content reduces the permeability of the soil being treated. This restricts drainage and makes it more difficult to force the soil particles into a denser packing. When high pore pressures are generated or liquefaction occurs in the soil adjacent to the soil being vibrated, the transmission of additional vibration to the surrounding soil is severely attenuated. The radius of influence of the process is thus greatly reduced and the procedures followed must be adjusted. The spacing of the probe or drop locations must be reduced and the treatment must be sequenced to allow time for dissipation of excess pore pressures before further compactive effort is applied. The presence of increased fines content also affects the assessment of the degree of improvement achieved. It is generally recognized that the level of improvement achievable by vibration in silts and clays is difficult to assess and other forms of improvement are more appropriate. In these soils, improvement of the resistance of the soil to seismic



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shaking can be achieved by considering the reinforcing action provided by the presence of stone columns.

Specifications for ground improvement are typically written in terms of the achievement of a required performance. For non-seismic design, the required performance may be a maximum allowable settlement at working load and this may be assessed by the performance of a load test at the completion of the contract. Pressuremeter testing has commonly been used for the assessment of improvement by DDC. Indeed, Debats et al. (5) argue that the pressuremeter used in accordance with the Menard rules, is the optimum method for assessment of ground improvement, particularly in soils with fines, as the results are more sensitive to stress history than are the results of CPTU testing and shear wave velocity measurements. However, for improvement against liquefaction, there is little guidance as to the relationship between the results of the static pressuremeter test and the response of the soil to cyclic loading. Cyclic pressuremeter testing may offer some insight but this development is still in the research phase.

For design against liquefaction, the required performance is often a minimum value of $(q_c)_{1N}$ based on Figure 1. With the increased use of $V_s$ for liquefaction assessment, a threshold $V_{s1}$ could be specified based on Figure 2.

The remainder of this paper presents and discusses results of CPTU testing, shear wave velocity measurements and full-displacement pressuremeter testing before and after vibro-replacement at a Fraser Delta site.



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## CASE HISTORY

The site in question was situated in the Fraser River Delta and was to be developed with a 12 storey tower surrounded by a 4 storey parkade. The soil conditions consisted of fill at the surface over soft clayey silt to about 3 m below ground. The clayey silt graded into sandy silt to silty sand and at about 6 to 7 m, medium dense sand was encountered. Below about 12.5 m depth, increasingly frequent silt lenses occurred with depth. The recommended foundation treatment consisted of placement of fill to act as a working platform followed by ground improvement to create a zone of improved soil below and around the foundations of the structure to limit the potential for large ground movements due to liquefaction of the sands and cohesionless silts, and to improve the resistance to cyclic loading of the surficial silts and clays around the piles. The surficial silts were not removed.

The contractor elected to carry out vibro-replacement using a triangular grid with stone columns spaced at 3 m centres. The ground improvement was to achieve a $q_{c1N}$ value of 10 MPa in clean sand. Reduced criteria for sands with elevated fines content were 8 MPa in sands with between 15 and 25% fines and 5 MPa for 24% to 35% fines. The testing was to be carried out at the centroid of the triangles of stone columns.

### In Situ Testing

The field work reported in this paper was carried out separately from the contract in situ testing and was designed to investigate whether a Seismic Cone Pressuremeter (SCPM) would provide additional information for quality control of vibro-replacement over the more standard cone penetration testing. The ground improvement work was already under way when the research was initiated and so the "before" data were obtained in an area just off site which had not experienced the stripping and grade fill placement which was undertaken prior to ground treatment on the site proper. The "after" testing was carried out



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about 15 metres away in a zone where vibro-replacement had been carried out to 10 m below original grade. The testing at each location consisted of a seismic piezo-cone sounding (SCPT) using a standard 35.7 mm cone followed by a 74 mm diameter full-displacement pressuremeter (FDPM) test in the same hole. The FDPM testing was carried out by pushing the UBC Self-Boring Pressuremeter (SBPM) behind a conical tip of the same diameter as the SBPM. The pressuremeter expansion test is thus not strictly comparable to a cone pressuremeter test as considerable time elapsed between the SCPT sounding and the pressuremeter test. However, as the same procedure was used before and after improvement, the results should be comparable. The equipment and procedures followed for the seismic CPT testing are as described in Robertson et al.(5). Hammer blows on the ends of a beam supporting the truck were used to generate shear waves.

The UBC SBPM is 74 mm in diameter and the expansion section has a length to diameter ratio of about 6. It is a monocell probe with displacement of the membrane measured using six strain arms located at mid-height of the expanding section. The tests were carried out by inflating the membrane at a constant rate to 3% strain, holding the pressure constant for 5 minutes, and then carrying out unload-reload loops before increasing the pressure further. In some cases additional unload-reload loops were carried out at higher strain levels prior to unloading.

**Results**

*Effect of Ground Improvement on Cone Penetration Test Results*

Figure 3 shows an overlay of the before and after CPTU logs. The "after" tests were carried out about 3 months after vibro-replacement. The effect of the ground treatment in the sand below about 6 m is readily apparent with the tip resistance having increased by up to 117%. The friction value has also increased and the pore pressure response in the upper sand has become more strongly negative indicating a more strongly dilating sand. The negative pore pressure response could be interpreted to mean that there is elevated silt content in the zone between about 4.5 m and 6 m below ground but the level of improvement achieved suggests that the soil is reasonably clean.

The level of improvement in the clayey silt from 1 to 3 m, indicated by comparison of $q_c$ values before and after treatment, is inconclusive but there appears to have been an increase in friction values. Figure 4 shows the cone profile at an enlarged scale to allow comparison of the effect of the ground treatment on the soft silt. There has been an increase in the tip resistance and an apparent doubling of sleeve friction suggesting that the treatment has been effective in increasing the strength of the silt but the difference in readings is close to the resolution of the instrument. The pore pressure response before treatment indicated rapid variation in the dilation characteristics of the soil, likely a result of interbedding of silts, sands and silty sands. The post-treatment response is more consistently positive suggesting that one effect of the ground treatment has been to mix the layers although this may reflect site variability.

*Effect of Ground Improvement on Shear Wave Velocity*

Figure 5 shows the values of $V_s$ measured before and after vibro-replacement. Again, there is a clear increase in $V_s$ in the sands but the increase in the silts is less clear-cut. This may be because clayey silts require a much longer time interval than the sands to recover from the effects of the remoulding



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experienced during ground treatment.

*Effect of Ground Improvement on Pressuremeter Curves*

Figures 6 and 7 present the results of PM tests before and after ground treatment in the sands and clayey silts, respectively. It proved impossible to push the pressuremeter unit deeper than 5.5 m, about 1.2 m into the densified sand and at this depth it was not possible to inflate the pressuremeter past a cavity strain of about 3% due to the limitations of the pressure system. The measured lift-off pressure has increased from about 140 to 220 kPa - an increase in effective lateral stress from about 70 to 170 kPa or an increase of about 142%. The slope of the initial part of the expansion curve during the initial phase of expansion is much steeper after improvement (7 MPa versus 4 MPa) and the slope of the unload-reload loops has increased from an equivalent shear modulus of about 33 MPa to 44 MPa.

In the silts, the lift-off pressures have increased. There was no pore pressure measurement adjacent to the membrane so the proportion of the lift-off pressure made up of pore pressure is unknown. There has also been an increase in the maximum pressure attained and the distance between the expansion curve and the contraction curve. This distance varies with shear strength in SBPM tests (7) and is assumed to be an indicator of shear strength in these tests. It appears that there has been an increase in shear strength due to the vibro-replacement. The unload-reload stiffnesses have also increased from 1.1 and 1.4 MPa to 1.8 and 2.0 MPa.



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**DISCUSSION**

All methods of assessment are indicating considerable improvement in the sands. The CPTU and the FDPM are indicating improvement in the clayey silts but the shear wave velocity does not show any conclusive improvement.

If the sole performance criterion is based on the cyclic resistance curves in Figure 1, then satisfactory performance has been achieved in the sands as the tip resistances now plot to the right of the Resistance Curves for the design CSR. The changes in the cyclic resistance of the clayey silts after improvement are unknown although the undrained shear strength appears to have increased. This is indicated by both the CPTU and the FDPM. The FDPM also indicates an increase in stiffness of the clayey silt and the interpretation of the CPTU indicates an increased level of OCR. The differences in measured CPTU values are, however, close to the resolution of the instrument and so must be interpreted with caution.

Use of Figure 1 alone ignores the effect of stress-strain history on the soil being analyzed. Ground improvement changes the density, but also the stress regime and the stress history of the deposit. Interpretation of in situ testing results should also consider stress level and stress history effects. By measuring the degree of improvement by three different tests in the same hole, further insight can be gained concerning the effects of the ground improvement.

For example, chamber test data (8, 9) have indicated that the CPT tip resistance is a function of both density and stress level, with the lateral stress being dominant. For example, the relationship between Dr, $\sigma_h'$ and $q_c$ for chamber tests on unaged Ticino Sand is given by (10) to be :

$$q_c = 248\, \sigma_h'^{0.55} \exp[2.38 D_r]$$

This relationship is commonly used to represent the relationship between $D_r$ and $q_c$ for moderately



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compressible sands when interpreting CPTU data in normally consolidated unaged sands.

$V_s$ has also been found to vary with density (or void ratio) and stress level. Chillarige et al. (11) give the following relationship for $V_s$ in Fraser River Sand based on a laboratory test program:

$$V_s = (295-143e)(\sigma_v'/p_a)^{0.26}(K_o)^{0.125}$$

where e is void ratio, $p_a$ is as before, and $K_o$ is the ratio of horizontal to lateral effective stress. As $K_o^{0.125}$ varies from 0.89 to 1.1 for $0.4<K_o<3.0$, $K_o$ has little effect on $V_s$. Again, aging effects are not considered.

Based on these equations, $V_s$ should depend on $\sigma_v'$ and $\sigma_h'$ to the power 0.125 and $q_c$ on $\sigma_h'^{0.55}$. Manipulation of these equations using representative values of $e_{max}$, $e_{min}$ and $K_o$ allows exploration of the likely effects of densification on tip resistance and $V_s$. Aging effects known to be important in the assessment of ground improvement have not been considered.

Field testing indicated that the initial $q_c$ and $V_s$ values at a depth of about 8.5 m were about 11 MPa and 175 m/s respectively and became about 20 MPa and about 200 m/s after ground improvement. Using conventional interpretation procedures based on tip resistance (i.e. ignoring $K_o$), this would represent an increase in Dr from about 70% to 98%. It can be shown, however, that the after treatment values of tip resistance and $V_s$ can also be attained by an increase in Ko from 0.45 to 1.4 and no increase in $D_r$.

The FDPM test carried out at about 5 m depth suggests that the lateral stress increased by about 1.4 times after ground improvement and so much of the increase in observed tip resistance is likely due to increased stress level. Again, it should be noted that the important issue of aging of the sand has not been included. In fact, both $q_c$ and $V_s$ have been observed to decrease in sands when measured soon after ground treatment and to then show an increase with time after treatment (12). This aspect of the response of soils to densification is poorly understood and requires further research.

The above discussion suggests that both the density and the stress regime has been changed by ground treatment. For design of foundations to be supported in or on the improved ground, the stress deformation characteristics under both static and cyclic loading conditions will govern the anticipated soil-structure interaction. It therefore makes more sense to write a ground improvement technical specification in terms of achieved stiffness and strength with due consideration of the required performance of the proposed structure. Jamiolkowski and Pasqualini (13) have indicated that the degree of overconsolidation has much more effect on the stiffness of the soil than any increase in density. Neither the CPTU nor $V_s$ measurement give reliable stiffness information for foundation design, because the effect of the ambient lateral stress on the former cannot be assessed and the latter allows calculation of only a small strain stiffness. The stiffness at larger strain levels will be considerably affected by the stress-strain history imparted by the densification method used. The pressuremeter expansion curve provides a measured load-deformation curve for the treated soil and, as noted by Debats (5), foundation design using the results of Menard pressuremeter testing has proved effective on sites which have been improved. Methods of the stress-strain behaviour of improved ground under cyclic loading are less well -developed.

## CONCLUSION

Liquefaction assessment, the need for ground improvement and the quality control and assurance of the ground treatment are conventionally based on the interpretation of penetration testing. More recently shear wave velocities have also been used.

For design against liquefaction, the amount and type of fines have an effect on both the parameters measured, such as penetration resistance, and on the susceptibility of the soils to contract under cyclic



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loading and to generate excess pore pressure. The combined effects have been incorporated into the Cyclic Resistance Curves used for liquefaction assessment but the effects are different and should be considered separately. Fines also have an effect on the degree of improvement attainable by vibratory methods of densification and on the ability of in situ testing to detect such improvement..

The importance of considering the effects of both increases in density and of lateral stress when interpreting in situ test results for the assessment of ground improvement has been illustrated. The additional information provided by a combination of tests and, in particular, the Cone Pressuremeter is likely to improve our understanding of the changes in soil behaviour achieved by ground treatment. Consideration should be given to writing technical specifications for ground treatment in terms of the desired improvement in stress-deformation behaviour of the soil and the method of quality control selected should provide an assessment of such behaviour. Again, the Cone Pressuremeter or other combinations of penetration testing and pressuremeter testing should prove beneficial.

Further research is required into the assessment of the behaviour under cyclic loading of fine grained soils and particularly silts which fail the Chinese Criterion of liquefaction assessment. Although vibro-replacement appears to be capable of increasing the strength and stiffness of such soils as indicated by the results of FDPM testing and CPTU testing, the degree of improvement attained and its influence on the cyclic resistance of silts requires further research.

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**REFERENCES**

(1) Armstrong, J.E. (1981). *Post-Vashon Wisconsinan glaciation, Fraser Lowland, British Columbia.* Geological Survey of Canada, Bulletin 322, 34 p.

(2) National Committee on Earthquake Engineering Research (1997). Workshop on Liquefaction Resistance.

(3) Seed, H.B. and Idriss, I.M. (1971). "Simplified procedure for evaluating soil liquefaction potential." *Journal of Soil Mechanics and Foundations Division*, ASCE, **97**(9), 1249-1273

(4) Wang, W. (1979). "Some findings in Soil Liquefaction." *Water Conservancy and Hydroelectric Power Scientific Research*, Beijing, China.

(5) Debats, J-M.,M., Frank, R.A., Gambin, M.P., and Savasta, P.A.(1998). "The Menard pressuremeter for quality control of soil densification." *Geotechnical Site Characterization*, Robertson and Mayne (eds), A.A. Balkema, Rotterdam.

(6) Robertson, P.K., Campanella, R.G., Gillespie, D. and Rice, A.. (1986). "Seismic CPT to measure in-situ shear wave velocity." *Journal of Geotechnical Engineering*, ASCE, **112**:791-804.

(7) Wroth, C.P. (1984). "Interpretation of in-situ tests." Rankine Lecture, British Geotechnical Society, U.K..

(8) Houlsby, G.T., and Hitchman,R. (1988). "Calibration chamber tests of a cone penetrometer in sands." *Geotechnique*, London, U.K. 38(1), 39-44.

(9) Bellotti, R., Crippa, V., Pedroni, S., Baldi, G., Fretti, C., Ostricati, D., Ghionna, V., Jamiolkowski, M. and Pasqualini, E. (1985). "Laboratory validation of in-situ tests." *Italian Geotech. Assoc. (AGI) Jubilee Vol., Proceedings of 11th International Conference on Soil Mechanics and Foundation Engineering*, San Francisco, California. A.A.



BACK

Balkema..

(10) Baldi, G., Bellotti, R., Ghionna, V.N., Jamiolkowski, M. and Pasqualini, E. (1986). "Interpretation of CPT's and CPTU's Second Part: Drained Penetration of Sands." *Proceedings of 4th International Geotechnical Seminar on Field Instrumentation and In Situ Measurements*, Nan Yang Technical Institute, Singapore.

(11) Chillarige, et al. (1997). *Canadian Geotechnical Journal*, Vol.

(12) Schmertmann, J.H. (1991). "The mechanical aging of soils." 25th Karl Terzaghi Lecture, *Journal of Geotechnical Engineering*, ASCE, **117**(9):1288 - 1330.

(13) Jamiolkowski, M., and Pasqualini, E. (1992). ""Compaction of granular soils - remarks on quality control." *Grouting, Soil Improvement and Geosynthetics*. Borden, R.H., Holtz, R.D. and Juran, I. (Editors), ASCE Geotechnical Special Publication No. 30, 1488 pp.

**KEY TO TABLES AND FIGURES**

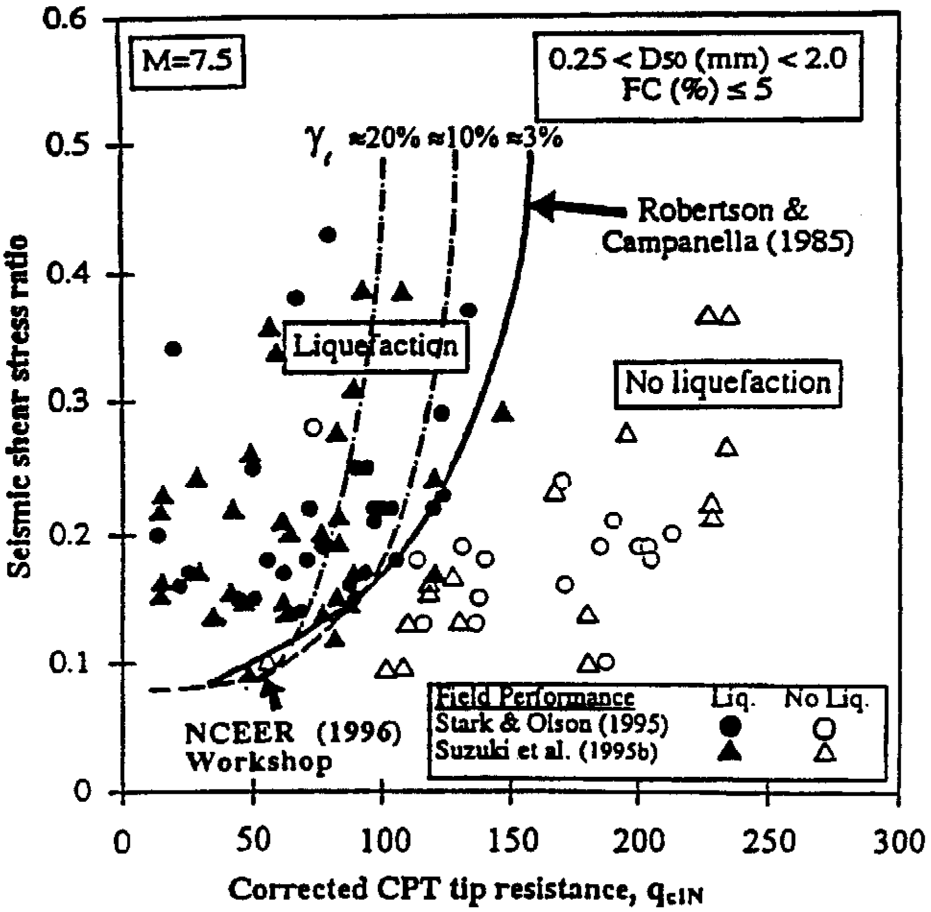


Figure 1: NCEER Workshop Recommended Curve for Calculation of Cyclic Resistance from CPT Data

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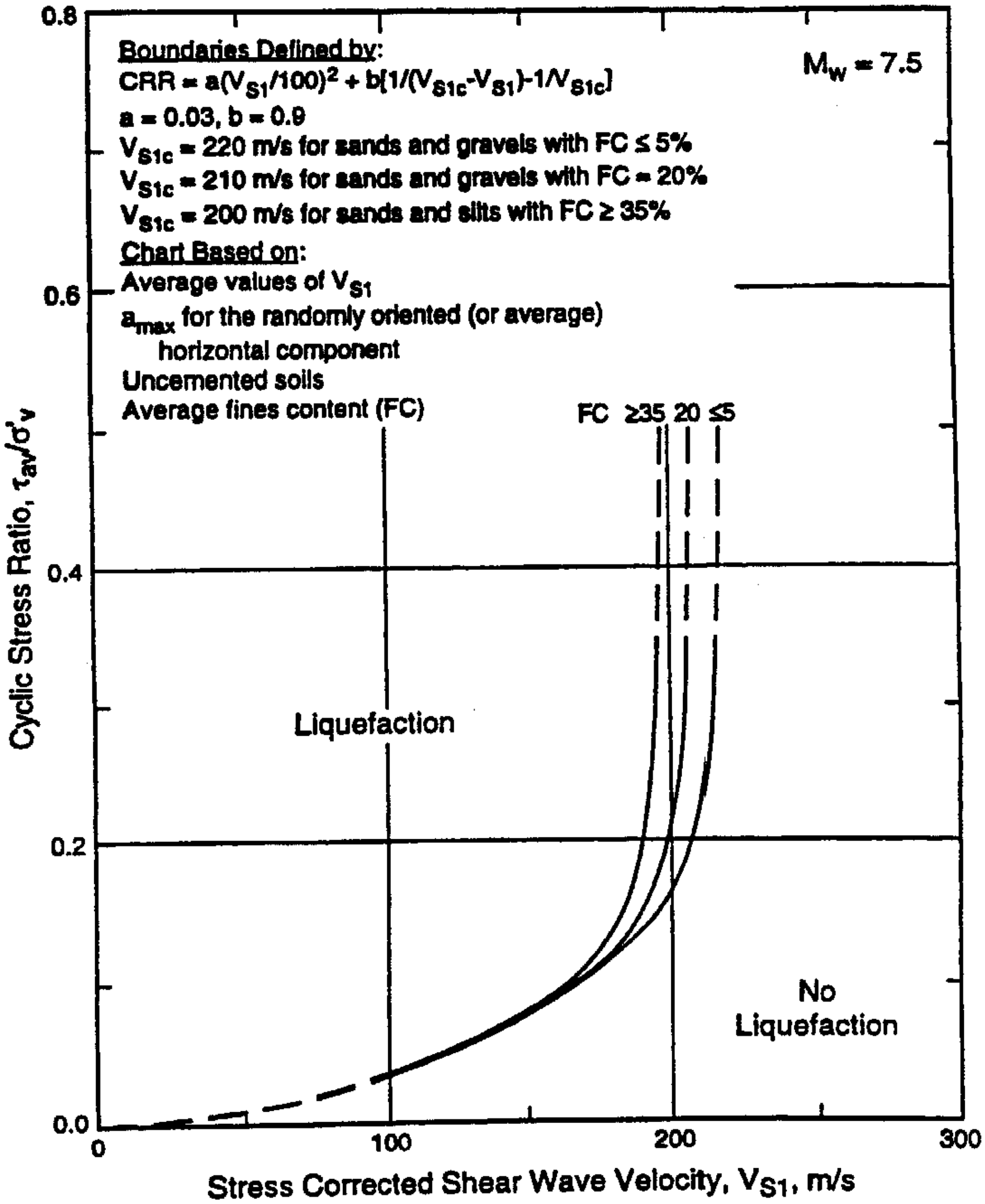


Figure 2: Curves Recommended by NCEER Workshop for Calculation of Cyclic Resistance from Shear Wave Velocity Data

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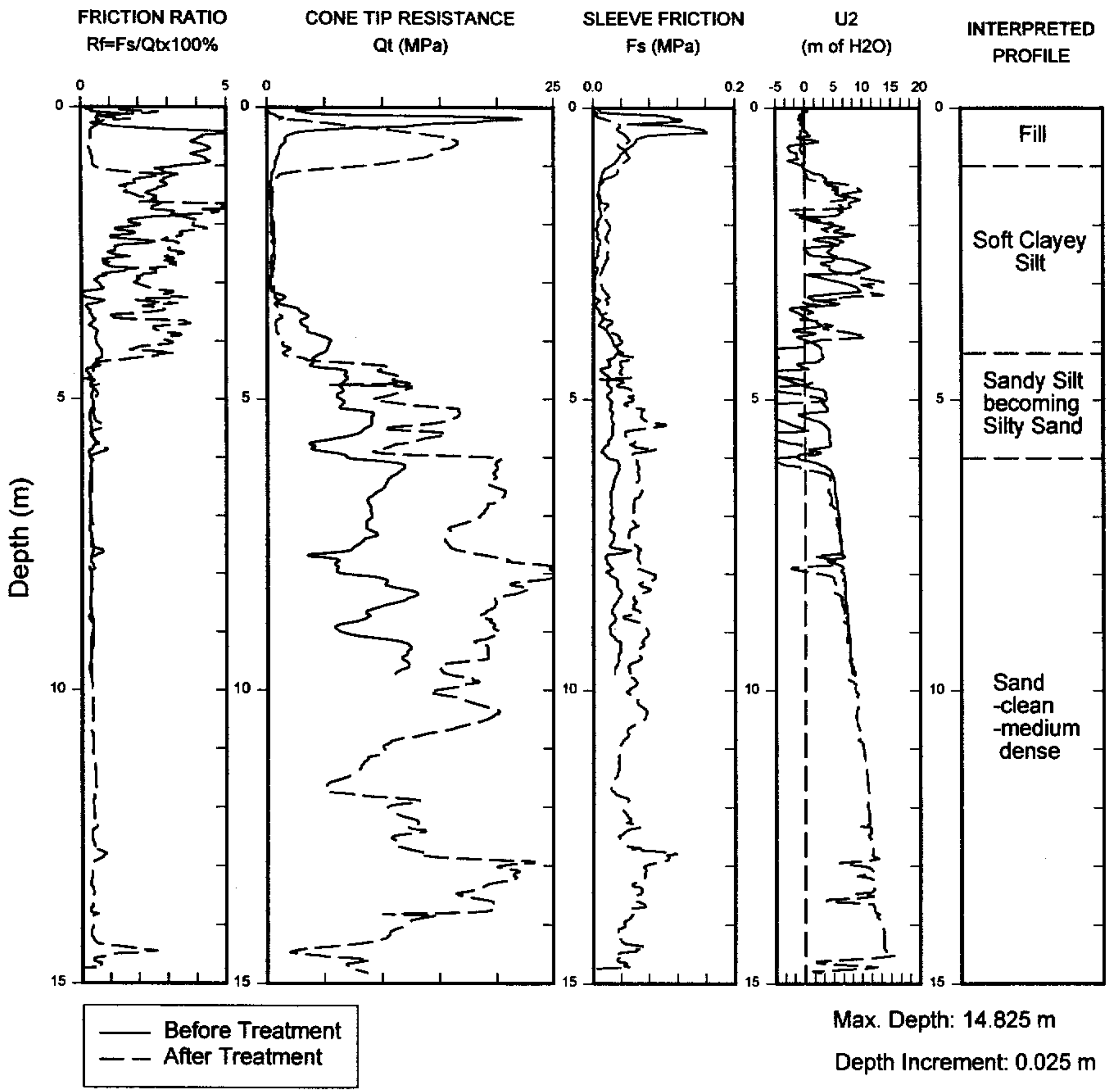


Figure 3: CPTU Profiles Before and After Vibro-Replacement

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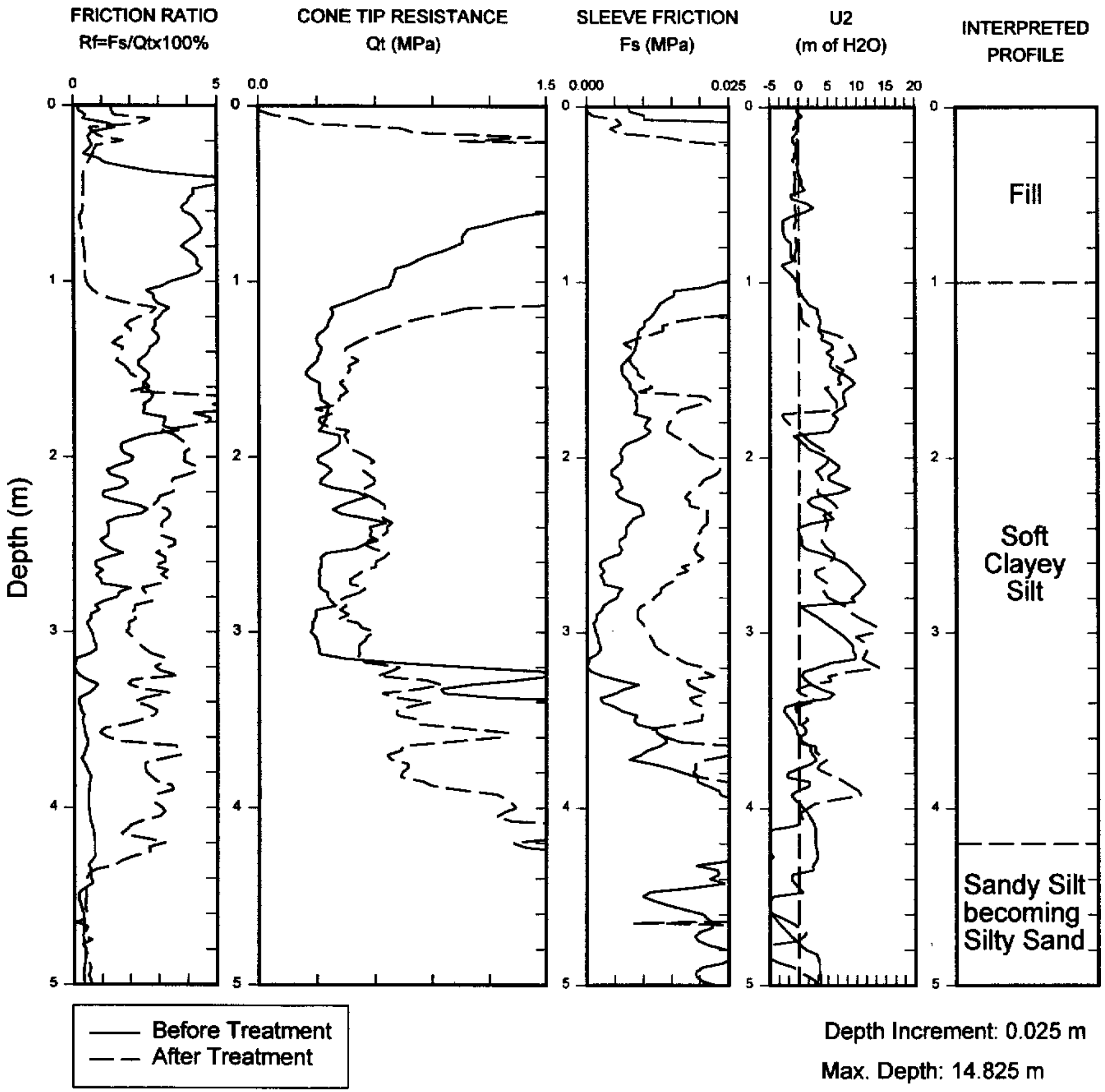


Figure 4: CPTU Profiles Before and After Vibro-Replacement (Upper 5m at Expanded Scale)

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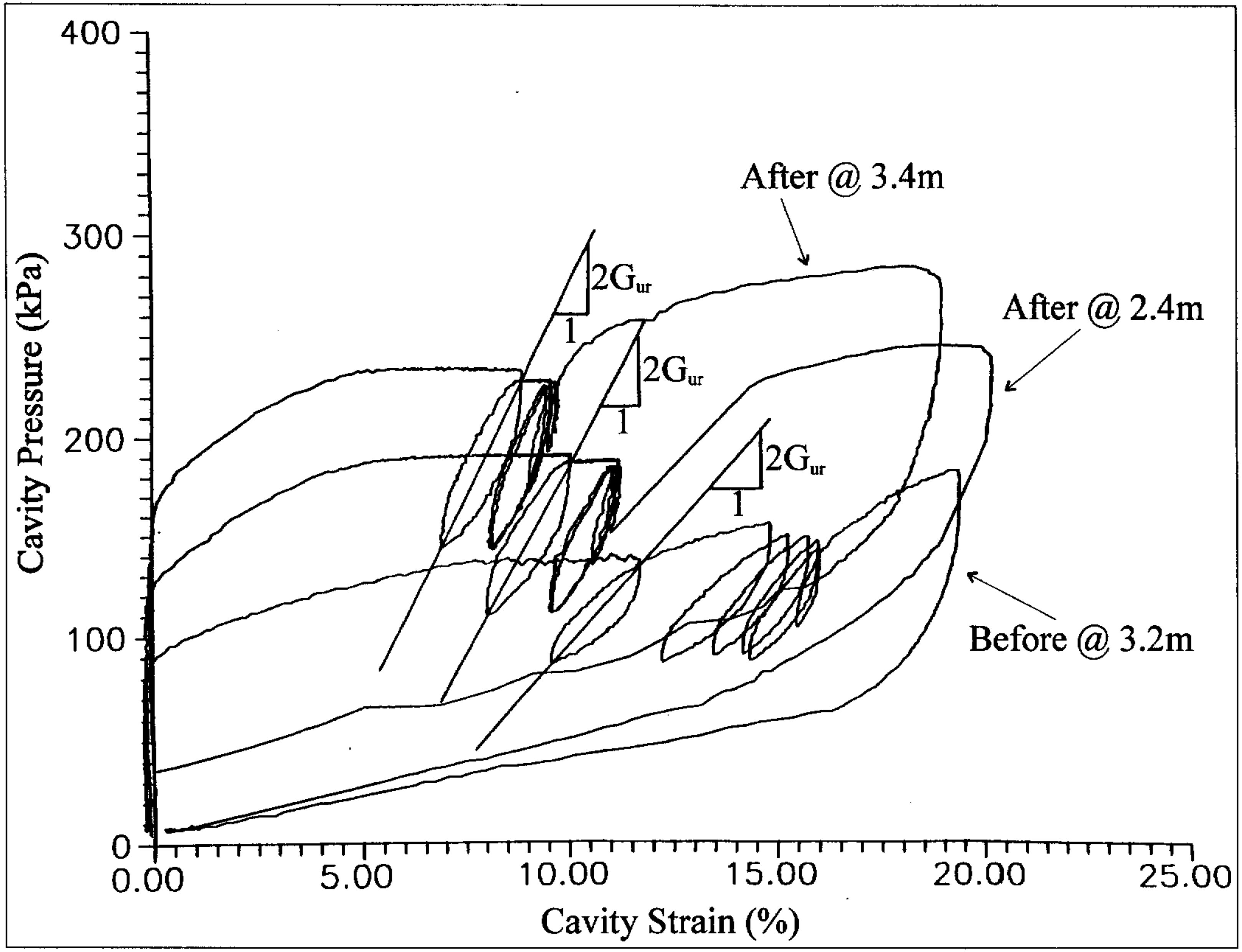


Figure 7: Pre- and Post-Densification Pressuremeter Tests in Clayey Silts

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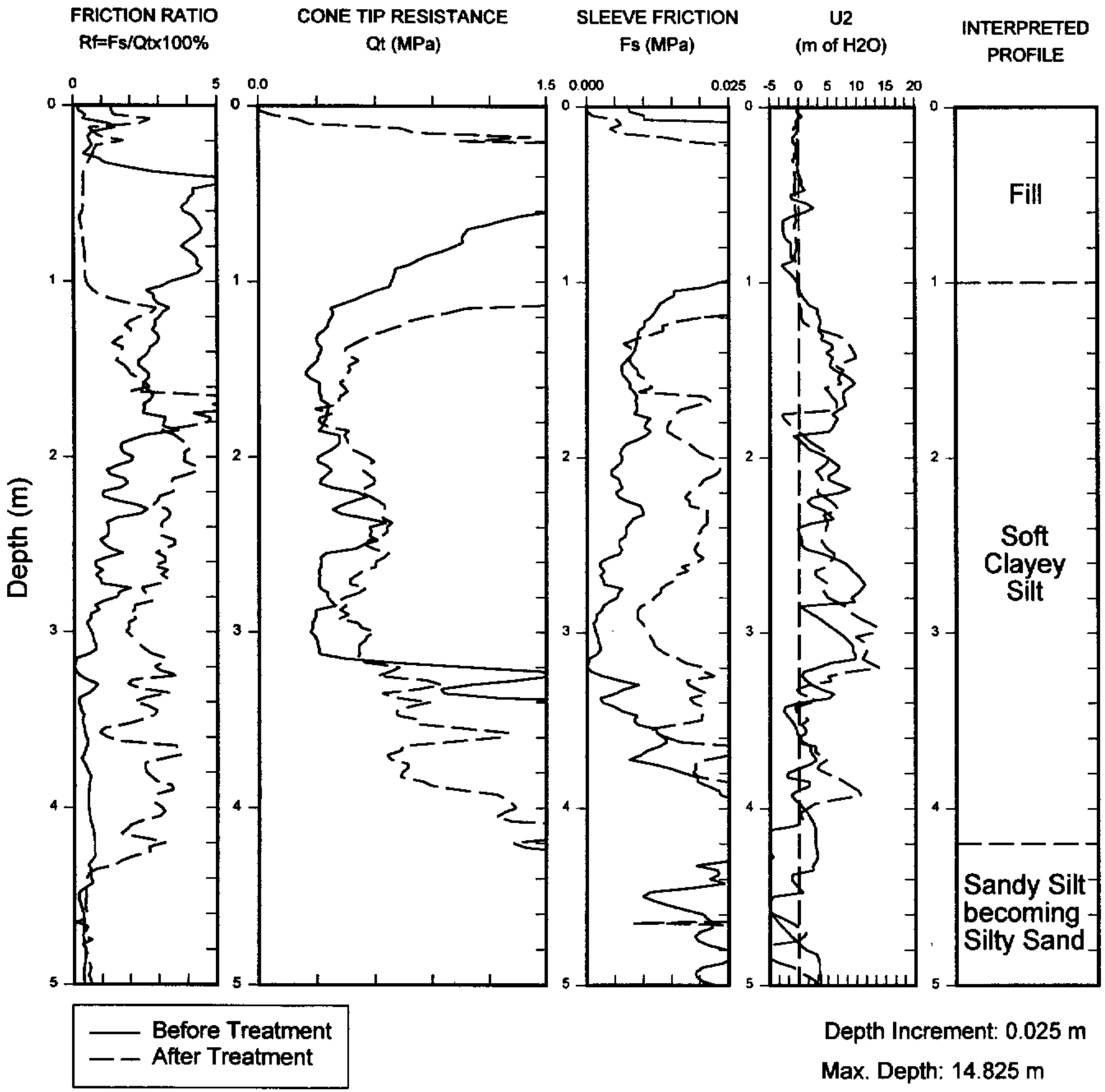


Figure 4: CPTU Profiles Before and After Vibro-Replacement (Upper 5m at Expanded Scale)

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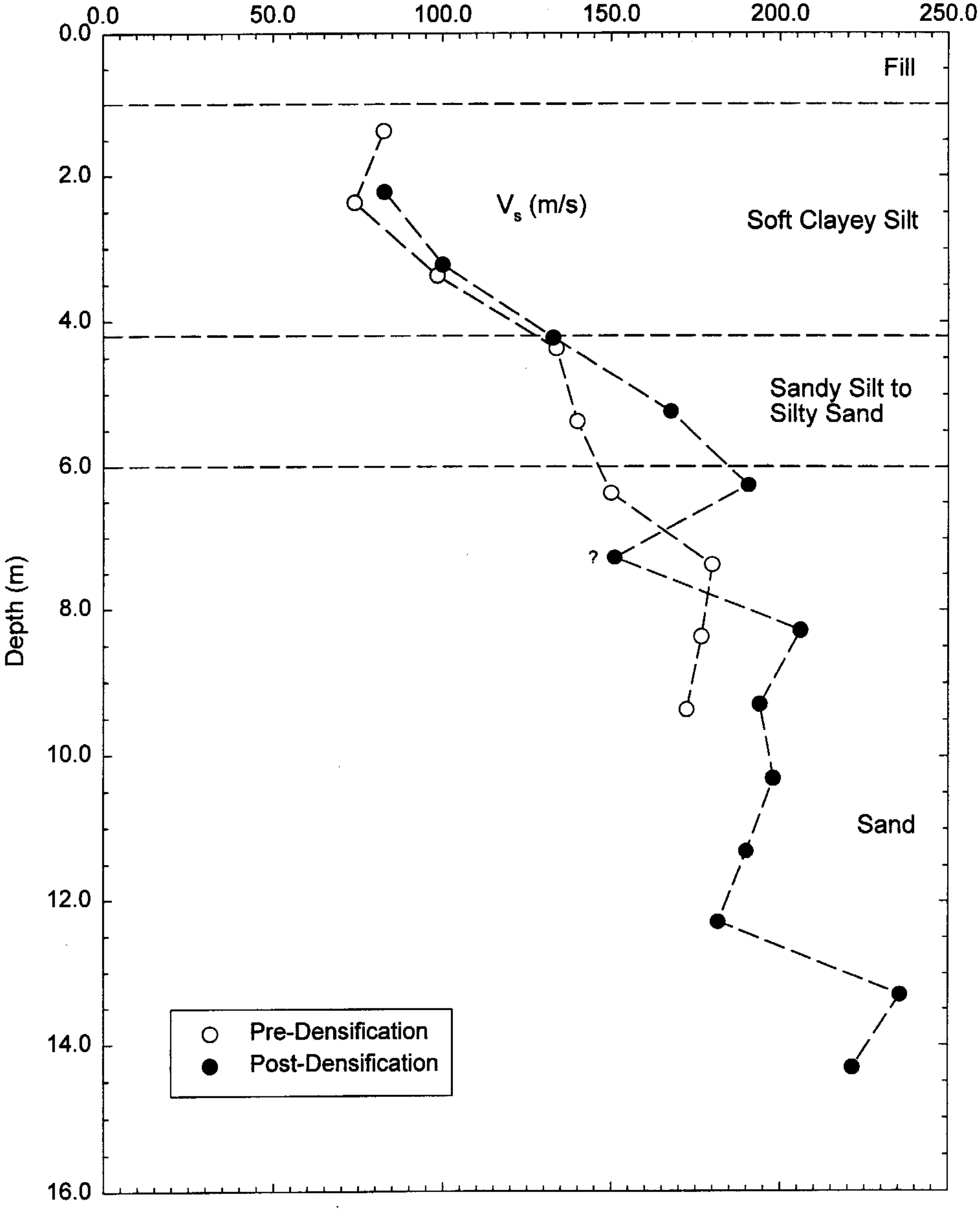


Figure 5: Comparison of $V_S$ Measurements Before and After Vibro-Replacement

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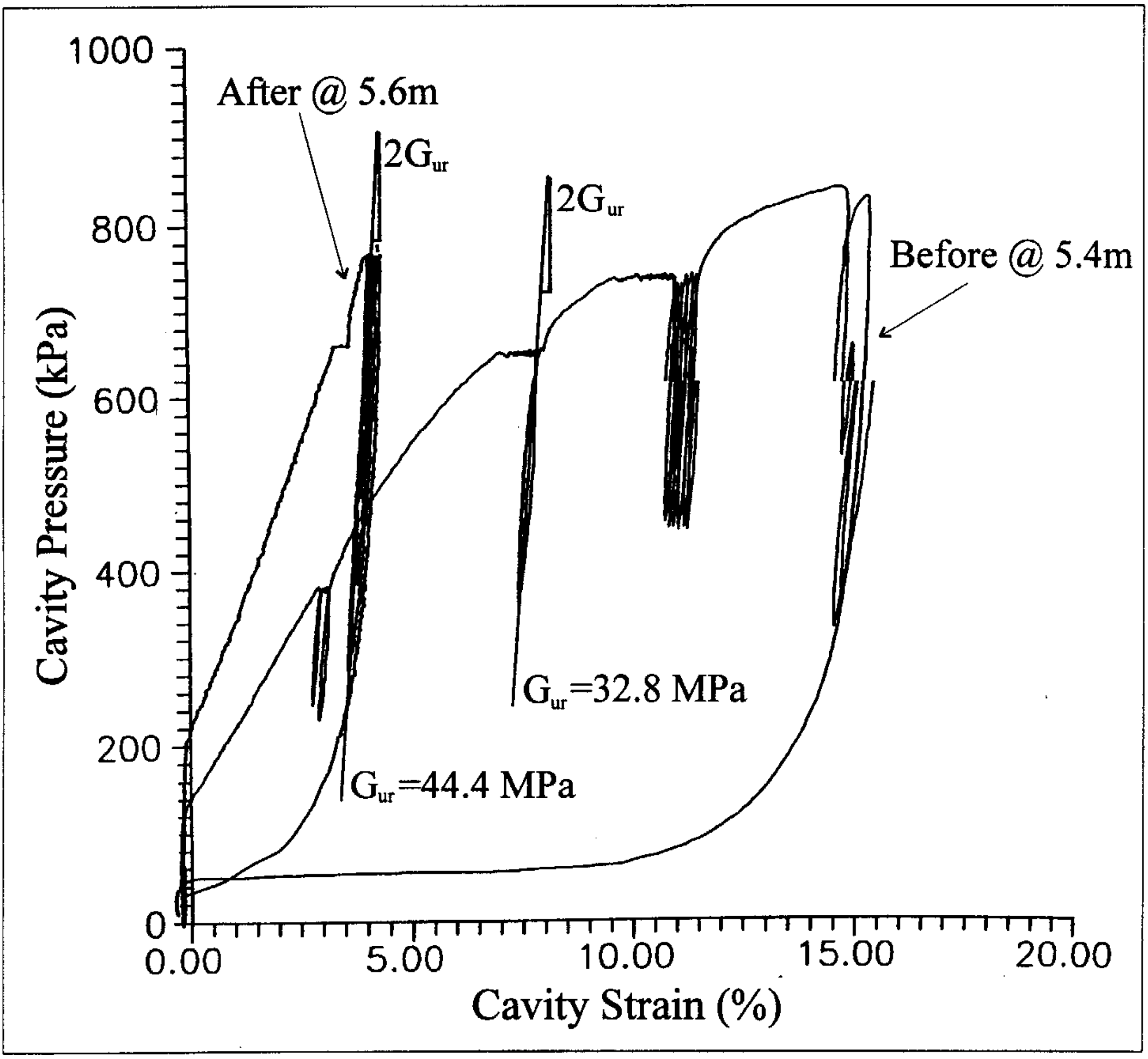


Figure 6: Pre- and Post-Densification Pressuremeter Test in Sand

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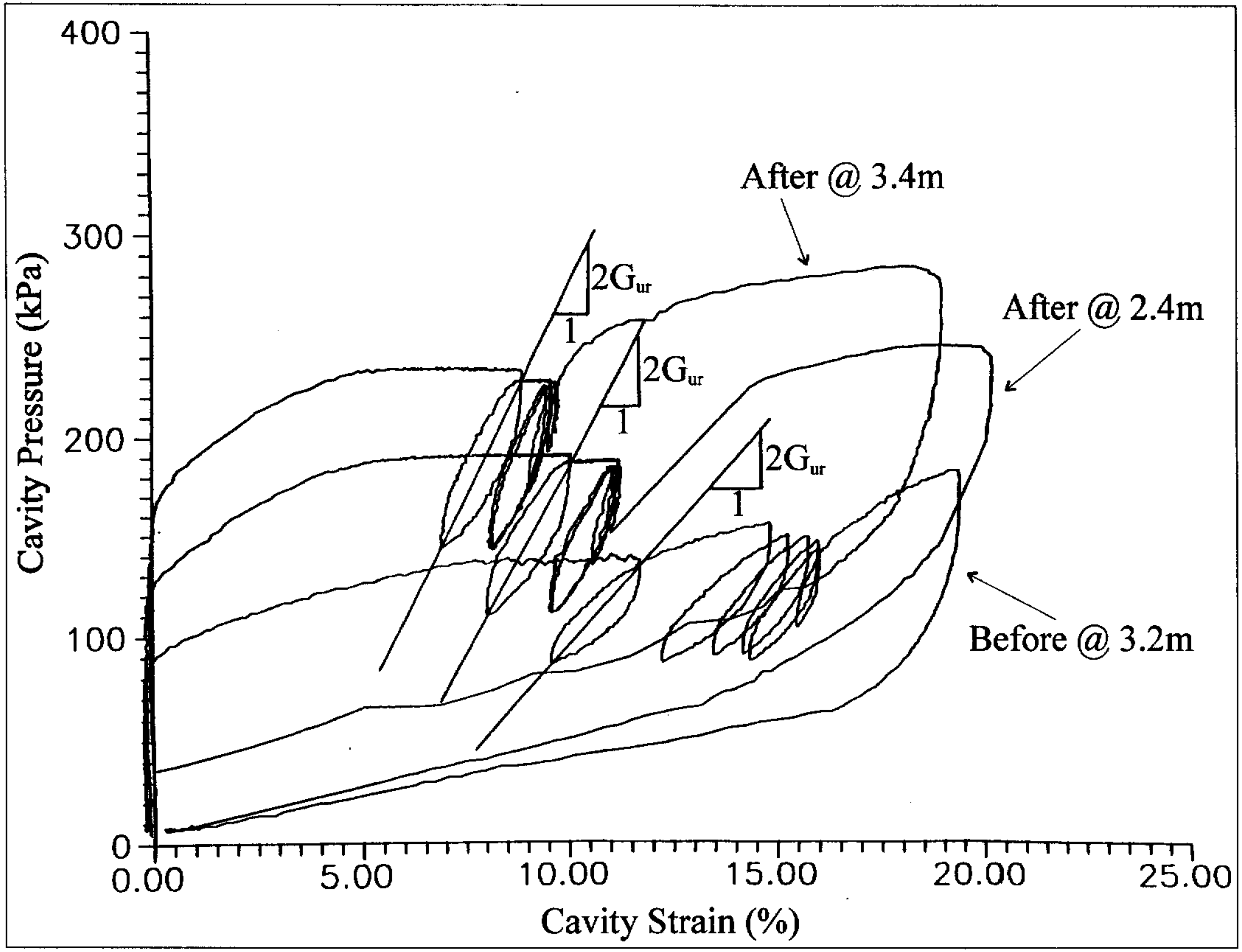


Figure 7: Pre- and Post-Densification Pressuremeter Tests in Clayey Silts

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"Zone #2=Organic material Zone #8 =Fine sand
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"Zone #4=Silty clay Zone #10=Gravelly sand
"Zone #5=Clayey silt Zone #11=Very stiff fine grained *
"Zone #6=Silty sand Zone #12=Sand to clayey sand *
" * Overconsolidated and/or cemented
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"
"---| INPUT FILE: C:\EXEPACK\52BETA\UBC\data\PIZZA1.CPD |--------

| " Depth " (meter) | Qcr (bars) | Qt (avg) (bars) | Bq (ratio) | Rf (%) | Uo (meter) | U2 (meter) | Gamma (kN/m^3) | CS(avg) (kPa) | EOS(avg) (kPa) | Rf Zone (zone #) | Bq Zone (zone #) | Spt N (blow/ft) | Spt N1 (blow/ft) | State (e-units) | Ic index | FC (%) | Dr (%) | Phi (degree) | CSR (Qc) (ratio) | CSR (Bq) (ratio) | FL (ratio) | Q(Norm) (ratio) | F(Norm) (%) | Depth (meter) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3.000 | 9E9 | 2.756 | 0.193 | 0.553 | 2.000 | 6.290 | 18.860 | 56.975 | 37.355 | 1 | 3 | 0 | 0 | 0.132 | 2.663 | 58.093 | 9E9 | 9E9 | 9E9 | 9E9 | 9E9 | 5.852 | 0.698 | 3.000 |
| 3.100 | 9E9 | 3.050 | 0.283 | 0.688 | 2.100 | 9.188 | 18.860 | 58.861 | 38.260 | 1 | 3 | 0 | 0 | 0.123 | 2.729 | 60.885 | 9E9 | 9E9 | 9E9 | 9E9 | 9E9 | 6.434 | 0.853 | 3.100 |
| 3.200 | 9E9 | 9.228 | 0.029 | 0.043 | 2.200 | 4.735 | 18.860 | 60.747 | 39.165 | 1 | 5 | 1 | 2 | 0.207 | 1.686 | 16.675 | 9E9 | 9E9 | 9E9 | 9E9 | 9E9 | 22.011 | 0.046 | 3.200 |
| 3.300 | 50.191 | 12.280 | -0.002 | 0.499 | 2.300 | 2.033 | 18.860 | 62.633 | 40.070 | 6 | 6 | 2 | 3 | -0.012 | 1.910 | 26.181 | 6 | 35 | 0.041 | 0.283 | 0.145 | 29.083 | 0.526 | 3.300 |
| 3.400 | 50.267 | 16.391 | -0.001 | 0.230 | 2.400 | 2.225 | 18.860 | 64.519 | 40.975 | 7 | 6 | 2 | 3 | 0.025 | 1.576 | 11.985 | 17 | 37 | 0.041 | 0.284 | 0.145 | 38.428 | 0.240 | 3.400 |
| 3.500 | 60.400 | 28.725 | -0.015 | 0.282 | 2.500 | -1.665 | 18.860 | 66.405 | 41.880 | 7 | 7 | 4 | 6 | -0.039 | 1.415 | 5.146 | 38 | 39 | 0.066 | 0.285 | 0.231 | 67.003 | 0.289 | 3.500 |
| 3.600 | 80.608 | 33.518 | -0.008 | 0.391 | 2.600 | 0.035 | 19.650 | 68.331 | 42.825 | 7 | 8 | 5 | 8 | -0.077 | 1.483 | 8.051 | 44 | 39 | 0.085 | 0.285 | 0.299 | 76.673 | 0.399 | 3.600 |
| 3.700 | 60.501 | 29.341 | -0.001 | 0.343 | 2.700 | 2.352 | 18.860 | 70.256 | 43.769 | 7 | 7 | 5 | 8 | -0.052 | 1.493 | 8.480 | 38 | 39 | 0.085 | 0.286 | 0.298 | 65.431 | 0.352 | 3.700 |
| 3.800 | 80.716 | 34.465 | -0.010 | 0.455 | 2.800 | -0.505 | 19.650 | 72.182 | 44.714 | 7 | 8 | 6 | 9 | -0.088 | 1.546 | 10.704 | 44 | 39 | 0.096 | 0.286 | 0.336 | 75.465 | 0.465 | 3.800 |
| 3.900 | 80.737 | 42.897 | -0.006 | 0.511 | 2.900 | 0.488 | 19.650 | 74.147 | 45.698 | 8 | 8 | 7 | 11 | -0.114 | 1.531 | 10.082 | 52 | 41 | 0.118 | 0.286 | 0.411 | 92.249 | 0.520 | 3.900 |
| 4.000 | 80.747 | 53.811 | -0.005 | 0.498 | 3.000 | 0.413 | 19.650 | 76.112 | 46.682 | 8 | 8 | 9 | 14 | -0.130 | 1.460 | 7.052 | 60 | 41 | 0.150 | 0.286 | 0.524 | 113.641 | 0.505 | 4.000 |
| 4.100 | 80.747 | 52.660 | -0.001 | 0.590 | 3.100 | 2.430 | 19.650 | 78.077 | 47.666 | 8 | 8 | 9 | 14 | -0.141 | 1.547 | 10.752 | 59 | 41 | 0.150 | 0.286 | 0.524 | 108.840 | 0.599 | 4.100 |
| 4.200 | 80.738 | 48.846 | -0.001 | 0.708 | 3.200 | 2.858 | 19.650 | 80.042 | 48.650 | 8 | 8 | 8 | 12 | -0.147 | 1.655 | 15.325 | 56 | 41 | 0.128 | 0.286 | 0.449 | 98.759 | 0.720 | 4.200 |
| 4.300 | 80.720 | 40.667 | -0.001 | 0.639 | 3.300 | 2.882 | 19.650 | 82.007 | 49.634 | 7 | 8 | 7 | 11 | -0.120 | 1.668 | 15.917 | 48 | 41 | 0.118 | 0.286 | 0.411 | 80.281 | 0.653 | 4.300 |
| 4.400 | 80.694 | 38.419 | -0.009 | 0.600 | 3.400 | -0.155 | 19.650 | 83.972 | 50.618 | 7 | 8 | 6 | 9 | -0.109 | 1.663 | 15.672 | 45 | 39 | 0.096 | 0.286 | 0.336 | 74.243 | 0.613 | 4.400 |
| 4.500 | 80.660 | 60.200 | -0.009 | 0.215 | 3.500 | -2.155 | 19.650 | 85.937 | 51.602 | 8 | 8 | 9 | 14 | -0.063 | 1.134 | 0.000 | 62 | 41 | 0.150 | 0.286 | 0.525 | 114.998 | 0.218 | 4.500 |
| 4.600 | 80.619 | 68.270 | -0.012 | 0.269 | 3.600 | -4.715 | 19.650 | 87.902 | 52.586 | 8 | 8 | 10 | 15 | -0.091 | 1.172 | 0.000 | 67 | 43 | 0.161 | 0.285 | 0.564 | 128.155 | 0.273 | 4.600 |
| 4.700 | 80.571 | 67.004 | -0.009 | 0.312 | 3.700 | -2.320 | 19.650 | 89.867 | 53.570 | 8 | 8 | 10 | 15 | -0.099 | 1.241 | 0.000 | 66 | 41 | 0.161 | 0.285 | 0.564 | 123.402 | 0.316 | 4.700 |
| 4.800 | 80.517 | 63.946 | -0.004 | 0.359 | 3.800 | 1.055 | 19.650 | 91.831 | 54.554 | 8 | 8 | 10 | 15 | -0.105 | 1.319 | 1.102 | 64 | 41 | 0.161 | 0.285 | 0.565 | 115.533 | 0.365 | 4.800 |
| 4.900 | 80.458 | 63.048 | -0.001 | 0.353 | 3.900 | 3.467 | 19.650 | 93.796 | 55.538 | 8 | 8 | 10 | 15 | -0.100 | 1.324 | 1.285 | 63 | 41 | 0.161 | 0.284 | 0.566 | 111.834 | 0.358 | 4.900 |
| 5.000 | 80.393 | 62.846 | -0.001 | 0.345 | 4.000 | 3.625 | 19.650 | 95.761 | 56.522 | 8 | 8 | 10 | 15 | -0.097 | 1.322 | 1.213 | 62 | 41 | 0.161 | 0.284 | 0.566 | 109.495 | 0.351 | 5.000 |
| 5.100 | 81.340 | 64.864 | -0.001 | 0.382 | 4.100 | 3.270 | 19.650 | 97.726 | 57.506 | 8 | 8 | 10 | 15 | -0.106 | 1.357 | 2.700 | 63 | 41 | 0.161 | 0.284 | 0.567 | 111.097 | 0.388 | 5.100 |
| 5.200 | 102.916 | 76.775 | -0.001 | 0.320 | 4.200 | 3.173 | 19.650 | 99.691 | 58.490 | 8 | 9 | 12 | 18 | -0.105 | 1.239 | 0.000 | 69 | 43 | 0.193 | 0.283 | 0.683 | 129.558 | 0.325 | 5.200 |
| 5.300 | 104.143 | 91.227 | -0.005 | 0.282 | 4.300 | -0.393 | 19.650 | 101.656 | 59.474 | 9 | 9 | 14 | 20 | -0.109 | 1.138 | 0.000 | 76 | 43 | 0.215 | 0.283 | 0.761 | 151.682 | 0.285 | 5.300 |
| 5.400 | 105.357 | 90.514 | -0.002 | 0.300 | 4.400 | 2.497 | 19.650 | 103.621 | 60.458 | 9 | 9 | 14 | 20 | -0.111 | 1.170 | 0.000 | 75 | 43 | 0.215 | 0.282 | 0.762 | 148.001 | 0.303 | 5.400 |
| 5.500 | 106.556 | 86.168 | -0.001 | 0.314 | 4.500 | 3.860 | 19.650 | 105.586 | 61.442 | 9 | 9 | 13 | 18 | -0.109 | 1.210 | 0.000 | 73 | 43 | 0.193 | 0.282 | 0.687 | 138.526 | 0.318 | 5.500 |
| 5.600 | 107.692 | 77.620 | -0.000 | 0.348 | 4.600 | 4.220 | 19.650 | 107.551 | 62.426 | 8 | 9 | 12 | 17 | -0.107 | 1.289 | 0.000 | 68 | 41 | 0.183 | 0.281 | 0.650 | 122.618 | 0.353 | 5.600 |
| 5.700 | 87.049 | 55.238 | -0.001 | 0.410 | 4.700 | 4.225 | 19.650 | 109.516 | 63.410 | 8 | 8 | 9 | 12 | -0.089 | 1.469 | 7.462 | 55 | 41 | 0.128 | 0.280 | 0.458 | 85.386 | 0.419 | 5.700 |
| 5.800 | 87.933 | 38.959 | -0.002 | 0.484 | 4.800 | 4.037 | 19.650 | 111.481 | 64.393 | 7 | 8 | 7 | 10 | -0.070 | 1.654 | 15.321 | 41 | 39 | 0.107 | 0.280 | 0.382 | 58.771 | 0.498 | 5.800 |
| 5.900 | 88.804 | 47.394 | -0.008 | 0.272 | 4.900 | 0.955 | 19.650 | 113.446 | 65.377 | 8 | 8 | 7 | 9 | -0.041 | 1.386 | 3.917 | 48 | 39 | 0.096 | 0.279 | 0.344 | 70.757 | 0.278 | 5.900 |
| 6.000 | 89.663 | 69.324 | -0.009 | 0.278 | 5.000 | -1.080 | 19.650 | 115.411 | 66.361 | 8 | 8 | 11 | 15 | -0.074 | 1.260 | 0.000 | 63 | 41 | 0.161 | 0.278 | 0.578 | 102.725 | 0.283 | 6.000 |
| 6.100 | 113.138 | 106.569 | -0.003 | 0.330 | 5.100 | 1.722 | 19.650 | 117.376 | 67.345 | 9 | 9 | 16 | 21 | -0.124 | 1.192 | 0.000 | 79 | 43 | 0.226 | 0.278 | 0.813 | 156.499 | 0.333 | 6.100 |
| 6.200 | 114.183 | 117.909 | -0.001 | 0.305 | 5.200 | 4.030 | 19.650 | 119.341 | 68.329 | 9 | 9 | 18 | 23 | -0.125 | 1.134 | 0.000 | 82 | 43 | 0.247 | 0.277 | 0.893 | 170.813 | 0.308 | 6.200 |
| 6.300 | 115.214 | 111.470 | -0.001 | 0.298 | 5.300 | 4.690 | 19.650 | 121.306 | 69.313 | 9 | 9 | 17 | 22 | -0.117 | 1.146 | 0.000 | 80 | 43 | 0.237 | 0.276 | 0.856 | 159.069 | 0.301 | 6.300 |
| 6.400 | 116.230 | 104.899 | -0.000 | 0.281 | 5.400 | 5.063 | 19.650 | 123.271 | 70.297 | 9 | 9 | 16 | 20 | -0.105 | 1.146 | 0.000 | 77 | 43 | 0.215 | 0.276 | 0.780 | 147.468 | 0.284 | 6.400 |
| 6.500 | 117.233 | 101.918 | -0.000 | 0.271 | 5.500 | 5.120 | 19.650 | 125.236 | 71.281 | 9 | 9 | 15 | 19 | -0.099 | 1.146 | 0.000 | 76 | 43 | 0.204 | 0.275 | 0.742 | 141.223 | 0.274 | 6.500 |
| 6.600 | 118.223 | 96.130 | -0.000 | 0.266 | 5.600 | 5.217 | 19.650 | 127.201 | 72.265 | 9 | 9 | 14 | 17 | -0.091 | 1.164 | 0.000 | 73 | 43 | 0.183 | 0.274 | 0.666 | 131.263 | 0.270 | 6.600 |
| 6.700 | 119.200 | 89.188 | -0.000 | 0.273 | 5.700 | 5.400 | 19.650 | 129.166 | 73.249 | 9 | 9 | 14 | 17 | -0.085 | 1.204 | 0.000 | 70 | 41 | 0.183 | 0.273 | 0.667 | 119.996 | 0.277 | 6.700 |
| 6.800 | 120.163 | 87.817 | -0.000 | 0.281 | 5.800 | 5.568 | 19.650 | 131.131 | 74.233 | 9 | 9 | 13 | 16 | -0.085 | 1.224 | 0.000 | 69 | 41 | 0.172 | 0.273 | 0.630 | 116.532 | 0.286 | 6.800 |
| 6.900 | 121.114 | 89.671 | -0.000 | 0.284 | 5.900 | 5.675 | 19.650 | 133.096 | 75.217 | 9 | 9 | 14 | 17 | -0.087 | 1.225 | 0.000 | 70 | 41 | 0.183 | 0.272 | 0.671 | 117.447 | 0.288 | 6.900 |
| 7.000 | 122.052 | 90.580 | -0.000 | 0.287 | 6.000 | 5.878 | 19.650 | 135.061 | 76.201 | 9 | 9 | 14 | 17 | -0.087 | 1.230 | 0.000 | 70 | 41 | 0.183 | 0.271 | 0.673 | 117.097 | 0.291 | 7.000 |
| 7.100 | 122.978 | 87.480 | -0.000 | 0.287 | 6.100 | 5.998 | 19.650 | 137.026 | 77.185 | 9 | 9 | 13 | 15 | -0.083 | 1.247 | 0.000 | 68 | 41 | 0.161 | 0.270 | 0.595 | 111.562 | 0.292 | 7.100 |
| 7.200 | 123.892 | 86.383 | -0.000 | 0.271 | 6.200 | 6.040 | 19.650 | 138.991 | 78.169 | 9 | 9 | 13 | 15 | -0.076 | 1.234 | 0.000 | 67 | 41 | 0.161 | 0.270 | 0.597 | 108.730 | 0.275 | 7.200 |
| 7.300 | 124.793 | 92.578 | -0.000 | 0.290 | 6.300 | 6.040 | 19.650 | 140.956 | 79.153 | 9 | 9 | 14 | 16 | -0.087 | 1.240 | 0.000 | 70 | 41 | 0.172 | 0.269 | 0.639 | 115.180 | 0.295 | 7.300 |
| 7.400 | 125.684 | 87.694 | -0.000 | 0.324 | 6.400 | 6.050 | 19.650 | 142.921 | 80.137 | 9 | 9 | 14 | 16 | -0.090 | 1.304 | 0.450 | 68 | 41 | 0.172 | 0.268 | 0.641 | 107.646 | 0.330 | 7.400 |
| 7.500 | 126.562 | 79.467 | -0.000 | 0.309 | 6.500 | 6.220 | 19.650 | 144.886 | 81.121 | 9 | 9 | 12 | 14 | -0.077 | 1.323 | 1.282 | 63 | 41 | 0.150 | 0.267 | 0.562 | 96.175 | 0.315 | 7.500 |
| 7.600 | 127.429 | 71.606 | -0.000 | 0.576 | 6.600 | 6.275 | 19.650 | 146.851 | 82.105 | 8 | 9 | 12 | 14 | -0.117 | 1.607 | 13.290 | 59 | 41 | 0.150 | 0.266 | 0.564 | 85.423 | 0.588 | 7.600 |
| 7.700 | 102.628 | 43.344 | -0.000 | 0.525 | 6.700 | 6.583 | 19.650 | 148.816 | 83.089 | 8 | 8 | 8 | 9 | -0.063 | 1.738 | 18.872 | 39 | 37 | 0.096 | 0.265 | 0.362 | 50.375 | 0.544 | 7.700 |
| 7.800 | 103.304 | 60.550 | -0.004 | 0.311 | 6.800 | 4.333 | 19.650 | 150.781 | 84.073 | 8 | 8 | 10 | 11 | -0.051 | 1.434 | 5.978 | 52 | 39 | 0.118 | 0.265 | 0.445 | 70.227 | 0.319 | 7.800 |
| 7.900 | 103.972 | 60.376 | -0.001 | 0.410 | 6.900 | 6.430 | 19.650 | 152.746 | 85.057 | 8 | 8 | 10 | 11 | -0.071 | 1.538 | 10.385 | 52 | 39 | 0.118 | 0.264 | 0.446 | 69.187 | 0.420 | 7.900 |
| 8.000 | 104.631 | 64.744 | -0.001 | 0.317 | 7.000 | 6.570 | 19.650 | 154.711 | 86.041 | 8 | 8 | 10 | 11 | -0.056 | 1.426 | 5.634 | 54 | 39 | 0.118 | 0.263 | 0.447 | 73.449 | 0.325 | 8.000 |
| 8.100 | 131.602 | 99.040 | -0.000 | 0.317 | 7.100 | 6.767 | 19.650 | 156.676 | 87.025 | 9 | 9 | 15 | 16 | -0.092 | 1.282 | 0.000 | 70 | 41 | 0.172 | 0.262 | 0.655 | 112.006 | 0.322 | 8.100 |
| 8.200 | 132.405 | 103.764 | -0.000 | 0.325 | 7.200 | 6.948 | 19.650 | 158.641 | 88.009 | 9 | 9 | 16 | 17 | -0.097 | 1.280 | 0.000 | 72 | 41 | 0.183 | 0.261 | 0.699 | 116.098 | 0.330 | 8.200 |
| 8.300 | 133.198 | 121.934 | -0.000 | 0.310 | 7.300 | 6.935 | 19.650 | 160.606 | 88.993 | 9 | 9 | 19 | 20 | -0.106 | 1.213 | 0.000 | 78 | 43 | 0.215 | 0.260 | 0.826 | 135.209 | 0.314 | 8.300 |
| 8.400 | 133.981 | 126.817 | -0.000 | 0.300 | 7.400 | 6.985 | 19.650 | 162.571 | 89.977 | 9 | 9 | 19 | 20 | -0.106 | 1.190 | 0.000 | 79 | 43 | 0.215 | 0.259 | 0.828 | 139.136 | 0.304 | 8.400 |
| 8.500 | 134.754 | 113.908 | -0.000 | 0.292 | 7.500 | 7.040 | 19.650 | 164.536 | 90.961 | 9 | 9 | 18 | 19 | -0.093 | 1.219 | 0.000 | 75 | 41 | 0.204 | 0.259 | 0.789 | 123.418 | 0.296 | 8.500 |
| 8.600 | 135.499 | 95.109 | -0.000 | 0.293 | 7.600 | 7.227 | 19.650 | 166.501 | 91.945 | 9 | 9 | 15 | 15 | -0.077 | 1.285 | 0.000 | 68 | 41 | 0.161 | 0.258 | 0.624 | 101.630 | 0.298 | 8.600 |
| 8.700 | 136.207 | 86.947 | -0.000 | 0.315 | 7.700 | 7.370 | 19.650 | 168.466 | 92.929 | 9 | 9 | 14 | 14 | -0.074 | 1.347 | 2.271 | 64 | 41 | 0.150 | 0.257 | 0.584 | 91.750 | 0.321 | 8.700 |
| 8.800 | 136.904 | 82.836 | -0.001 | 0.371 | 7.800 | 7.320 | 19.650 | 170.431 | 93.913 | 8 | 9 | 13 | 13 | -0.082 | 1.427 | 5.662 | 62 | 41 | 0.139 | 0.256 | 0.544 | 86.390 | 0.378 | 8.800 |
| 8.900 | 110.073 | 62.778 | -0.001 | 0.387 | 7.900 | 7.407 | 19.650 | 172.396 | 94.897 | 8 | 8 | 10 | 10 | -0.060 | 1.543 | 10.585 | 51 | 39 | 0.107 | 0.255 | 0.419 | 64.337 | 0.398 | 8.900 |
| 9.000 | 110.615 | 63.106 | -0.001 | 0.374 | 8.000 | 7.568 | 19.650 | 174.361 | 95.881 | 8 | 8 | 10 | 10 | -0.057 | 1.532 | 10.128 | 51 | 39 | 0.107 | 0.254 | 0.420 | 63.998 | 0.385 | 9.000 |
| 9.100 | 138.936 | 86.118 | -0.000 | 0.330 | 8.100 | 7.692 | 19.650 | 176.326 | 96.865 | 9 | 9 | 14 | 14 | -0.073 | 1.381 | 3.735 | 63 | 41 | 0.150 | 0.253 | 0.592 | 87.085 | 0.337 | 9.100 |

"Output file from CPTINT - Version 5.2
"==================================
"INPUT FILE: C:\EXEPACK\52BETA\UBC\data\PIZZA3.CPD
"----------This File Name: PIZZA3A.DOC
"
"Licensed to: UBC IN-SITU Testing Research
" Address: For BETA Testing & Evaluation
" City: www.civil.ubc.ca/home/in-situ
"
"Interpreter Name: CAMPANELLA
"
"File Number: PIZZA3 Date: 02-21-91 11:30
"Operator: RGC,MLD,KJR Location: WSTMSTR&COONEY, Richmond, BC
"Cone Type: HOG3wSTDpp&seis

# VIBRO-REPLACEMENT AREA

"

"SUMMARY SHEET
"'a' for calculating Qt: 0.800
"Value for Water Table (in m): 1.000
"Valid Zone Classification based on: Bq
"Missing unit weight to start depth: 18.860
"Define Zone 6 for Sand Parameters? YES
"Sand Compressibility for calc Dr: Moderate
"Method for Friction Angle: Robertson & Campanella
"Silty sand correction for CSR (Qc)? NO
"EQ magnitudes for CSR (Qc): 7.500
"'a max/g' value for calc CSR (Eq): 0.300
"Graph used for calculating rd: Fraser Delta
"FL value used for calculating Qcr: 1.200000
"Vertical Flow Gradient, i (- up): +0.000
"Constant Volume Friction Angle: 33.000
"CPT to SPT N60 Conversion: Jeffries & Davies
"

"Soil Behavior Type Zone Numbers
"For Rf Zone & Bq Zone Classification
"------------------------------------
"Zone #1=Sensitive fine grained Zone #7 =Sand with some Silt
"Zone #2=Organic material Zone #8 =Fine sand
"Zone #3=Clay Zone #9 =Sand
"Zone #4=Silty clay Zone #10=Gravelly sand
"Zone #5=Clayey silt Zone #11=Very stiff fine grained *
"Zone #6=Silty sand Zone #12=Sand to clayey sand *
" * Overconsolidated and/or cemented
"
"NOTE: For soil classification, Rf values > 8 are assumed to be 8.
" Note: 9E9 means Out Of Range

"---| INPUT FILE: C:\EXEPACK\52BETA\UBC\data\PIZZA3.CPD |------------------------------

| " Depth " (meter) | Qcr (bars) | Qt (avg) (bars) | Bq (ratio) | Rf (%) | Uo (meter) | U2 (meter) | Gamma (kN/m^3) | OS (avg) (kPa) | EOS (avg) (kPa) | Rf Zone (zone #) | Bq Zone (zone #) | Spt N (blow/ft) | Spt N1 (blow/ft) | State (e-units) | Ic index | FC (%) | Dr (%) | Phi (degree) | CSR (Qc) (ratio) | CSR (Eq) (ratio) | FL (ratio) | Q (Norm) (ratio) | F (Norm) (%) | Depth (meter) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4.000 | 50.704 | 13.014 | -0.002 | 3.002 | 3.000 | 2.765 | 18.860 | 75.129 | 45.699 | 4 | 6 | 3 | 5 | -0.166 | 2.666 | 58.229 | 6 | 35 | 0.057 | 0.289 | 0.199 | 26.834 | 3.186 | 4.000 |
| 4.100 | 50.720 | 15.591 | -0.028 | 2.250 | 3.100 | -1.112 | 18.860 | 77.015 | 46.604 | 5 | 6 | 3 | 5 | -0.150 | 2.480 | 50.360 | 12 | 35 | 0.057 | 0.289 | 0.198 | 31.801 | 2.367 | 4.100 |
| 4.200 | 50.729 | 15.278 | -0.061 | 2.433 | 3.200 | -5.813 | 18.860 | 78.901 | 47.509 | 5 | 6 | 3 | 5 | -0.159 | 2.520 | 52.024 | 11 | 35 | 0.057 | 0.289 | 0.198 | 30.498 | 2.566 | 4.200 |
| 4.300 | 60.879 | 27.968 | -0.032 | 1.876 | 3.300 | -5.600 | 18.860 | 80.787 | 48.414 | 6 | 7 | 6 | 9 | -0.190 | 2.244 | 40.321 | 34 | 39 | 0.096 | 0.289 | 0.332 | 56.099 | 1.932 | 4.300 |
| 4.400 | 101.443 | 78.180 | -0.014 | 0.491 | 3.400 | -8.042 | 19.650 | 82.713 | 49.359 | 8 | 9 | 12 | 18 | -0.158 | 1.363 | 2.962 | 74 | 43 | 0.193 | 0.289 | 0.669 | 156.716 | 0.496 | 4.400 |
| 4.500 | 101.393 | 99.550 | -0.012 | 0.397 | 3.500 | -8.173 | 19.650 | 84.678 | 50.343 | 9 | 9 | 15 | 23 | -0.160 | 1.208 | 0.000 | 83 | 45 | 0.247 | 0.289 | 0.857 | 196.062 | 0.400 | 4.500 |
| 4.600 | 101.333 | 110.377 | -0.008 | 0.415 | 3.600 | -4.885 | 19.650 | 86.643 | 51.327 | 9 | 9 | 17 | 26 | -0.171 | 1.209 | 0.000 | 86 | 45 | 0.285 | 0.288 | 0.988 | 213.360 | 0.418 | 4.600 |
| 4.700 | 101.265 | 114.600 | -0.003 | 0.302 | 3.700 | 0.265 | 19.650 | 88.608 | 52.311 | 9 | 9 | 17 | 26 | -0.145 | 1.061 | 0.000 | 87 | 45 | 0.285 | 0.288 | 0.989 | 217.383 | 0.305 | 4.700 |
| 4.800 | 101.190 | 106.044 | -0.008 | 0.397 | 3.800 | -4.400 | 19.650 | 90.573 | 53.295 | 9 | 9 | 16 | 24 | -0.160 | 1.208 | 0.000 | 84 | 45 | 0.260 | 0.288 | 0.904 | 197.277 | 0.400 | 4.800 |
| 4.900 | 101.108 | 113.804 | -0.005 | 0.524 | 3.900 | -2.352 | 19.650 | 92.538 | 54.279 | 9 | 9 | 18 | 27 | -0.188 | 1.327 | 1.446 | 86 | 45 | 0.297 | 0.287 | 1.035 | 207.961 | 0.529 | 4.900 |
| 5.000 | 101.018 | 96.537 | -0.002 | 0.562 | 4.000 | 2.507 | 19.650 | 94.503 | 55.263 | 8 | 9 | 16 | 24 | -0.178 | 1.405 | 4.725 | 79 | 43 | 0.260 | 0.287 | 0.906 | 172.977 | 0.568 | 5.000 |
| 5.100 | 100.923 | 121.259 | -0.008 | 0.400 | 4.100 | -5.510 | 19.650 | 96.468 | 56.247 | 9 | 9 | 19 | 29 | -0.168 | 1.191 | 0.000 | 88 | 45 | 0.324 | 0.286 | 1.131 | 213.870 | 0.403 | 5.100 |
| 5.200 | 101.722 | 164.962 | -0.007 | 0.415 | 4.200 | -7.552 | 19.650 | 98.433 | 57.231 | 9 | 9 | 25 | 37 | -0.196 | 1.143 | 0.000 | 99 | 45 | 0.646 | 0.286 | 2.260 | 286.521 | 0.418 | 5.200 |
| 5.300 | 102.957 | 164.835 | -0.006 | 0.413 | 4.300 | -5.887 | 19.650 | 100.398 | 58.215 | 9 | 9 | 25 | 37 | -0.194 | 1.144 | 0.000 | 99 | 45 | 0.646 | 0.285 | 2.264 | 281.425 | 0.416 | 5.300 |
| 5.400 | 104.178 | 150.324 | -0.005 | 0.552 | 4.400 | -3.387 | 19.650 | 102.363 | 59.199 | 9 | 9 | 24 | 35 | -0.210 | 1.312 | 0.791 | 95 | 45 | 0.503 | 0.285 | 1.767 | 252.202 | 0.556 | 5.400 |
| 5.500 | 105.387 | 110.261 | -0.004 | 0.720 | 4.500 | -0.450 | 19.650 | 104.328 | 60.183 | 8 | 9 | 19 | 27 | -0.204 | 1.513 | 9.323 | 83 | 43 | 0.297 | 0.284 | 1.047 | 181.478 | 0.727 | 5.500 |
| 5.600 | 106.582 | 148.774 | -0.006 | 0.307 | 4.600 | -5.013 | 19.650 | 106.293 | 61.167 | 9 | 9 | 22 | 31 | -0.156 | 1.038 | 0.000 | 94 | 45 | 0.358 | 0.283 | 1.263 | 241.490 | 0.309 | 5.600 |
| 5.700 | 107.765 | 134.287 | -0.007 | 0.401 | 4.700 | -4.852 | 19.650 | 108.257 | 62.151 | 9 | 9 | 21 | 29 | -0.168 | 1.192 | 0.000 | 90 | 45 | 0.324 | 0.283 | 1.145 | 214.326 | 0.404 | 5.700 |
| 5.800 | 108.935 | 111.788 | -0.005 | 0.508 | 4.800 | -1.002 | 19.650 | 110.222 | 63.135 | 9 | 9 | 18 | 25 | -0.170 | 1.353 | 2.521 | 82 | 43 | 0.272 | 0.282 | 0.965 | 175.317 | 0.513 | 5.800 |
| 5.900 | 110.082 | 96.279 | -0.003 | 0.783 | 4.900 | 1.885 | 19.650 | 112.187 | 64.119 | 8 | 9 | 17 | 23 | -0.193 | 1.599 | 12.983 | 76 | 43 | 0.247 | 0.281 | 0.879 | 148.409 | 0.793 | 5.900 |
| 6.000 | 111.162 | 170.184 | -0.004 | 0.320 | 5.000 | -2.200 | 19.650 | 114.152 | 65.103 | 9 | 9 | 25 | 34 | -0.165 | 1.040 | 0.000 | 98 | 45 | 0.431 | 0.281 | 1.537 | 259.656 | 0.322 | 6.000 |
| 6.100 | 112.228 | 199.692 | -0.005 | 0.311 | 5.100 | -4.378 | 19.650 | 116.117 | 66.087 | 9 | 9 | 29 | 39 | -0.176 | 0.992 | 0.000 | 104 | 45 | 0.788 | 0.280 | 2.815 | 300.410 | 0.313 | 6.100 |
| 6.200 | 113.280 | 199.522 | -0.003 | 0.320 | 5.200 | -0.028 | 19.650 | 118.082 | 67.071 | 9 | 9 | 29 | 38 | -0.176 | 1.009 | 0.000 | 103 | 45 | 0.717 | 0.279 | 2.567 | 295.720 | 0.322 | 6.200 |
| 6.300 | 114.317 | 197.649 | -0.001 | 0.323 | 5.300 | 3.622 | 19.650 | 120.047 | 68.055 | 9 | 9 | 29 | 38 | -0.175 | 1.020 | 0.000 | 103 | 45 | 0.717 | 0.279 | 2.574 | 288.663 | 0.325 | 6.300 |
| 6.400 | 115.340 | 195.236 | -0.001 | 0.326 | 5.400 | 4.388 | 19.650 | 122.012 | 69.039 | 9 | 9 | 29 | 37 | -0.174 | 1.031 | 0.000 | 102 | 45 | 0.646 | 0.278 | 2.324 | 281.026 | 0.328 | 6.400 |
| 6.500 | 116.349 | 195.196 | -0.000 | 0.321 | 5.500 | 4.500 | 19.650 | 123.977 | 70.023 | 9 | 9 | 29 | 37 | -0.171 | 1.026 | 0.000 | 101 | 45 | 0.646 | 0.277 | 2.330 | 276.991 | 0.323 | 6.500 |
| 6.600 | 117.345 | 205.973 | -0.001 | 0.329 | 5.600 | 4.100 | 19.650 | 125.942 | 71.007 | 9 | 9 | 30 | 38 | -0.177 | 1.029 | 0.000 | 103 | 45 | 0.717 | 0.276 | 2.595 | 288.302 | 0.331 | 6.600 |
| 6.700 | 118.327 | 204.499 | -0.001 | 0.305 | 5.700 | 4.550 | 19.650 | 127.907 | 71.991 | 9 | 9 | 30 | 37 | -0.168 | 0.998 | 0.000 | 103 | 45 | 0.646 | 0.276 | 2.343 | 282.287 | 0.307 | 6.700 |
| 6.800 | 119.296 | 195.737 | -0.001 | 0.295 | 5.800 | 4.537 | 19.650 | 129.872 | 72.975 | 9 | 9 | 29 | 36 | -0.161 | 0.997 | 0.000 | 101 | 45 | 0.574 | 0.275 | 2.090 | 266.446 | 0.297 | 6.800 |
| 6.900 | 120.253 | 189.984 | -0.000 | 0.299 | 5.900 | 5.173 | 19.650 | 131.837 | 73.959 | 9 | 9 | 28 | 34 | -0.158 | 1.014 | 0.000 | 99 | 45 | 0.431 | 0.274 | 1.575 | 255.097 | 0.301 | 6.900 |
| 7.000 | 121.197 | 185.767 | -0.000 | 0.304 | 6.000 | 5.465 | 19.650 | 133.802 | 74.943 | 9 | 9 | 27 | 33 | -0.156 | 1.030 | 0.000 | 98 | 45 | 0.403 | 0.273 | 1.476 | 246.094 | 0.306 | 7.000 |
| 7.100 | 122.128 | 177.059 | -0.000 | 0.319 | 6.100 | 5.565 | 19.650 | 135.767 | 75.926 | 9 | 9 | 26 | 31 | -0.155 | 1.069 | 0.000 | 96 | 45 | 0.358 | 0.272 | 1.315 | 231.410 | 0.322 | 7.100 |
| 7.200 | 123.047 | 161.570 | -0.000 | 0.363 | 6.200 | 5.730 | 19.650 | 137.732 | 76.910 | 9 | 9 | 25 | 30 | -0.157 | 1.155 | 0.000 | 92 | 45 | 0.338 | 0.271 | 1.245 | 208.284 | 0.366 | 7.200 |
| 7.300 | 123.954 | 157.822 | -0.000 | 0.324 | 6.300 | 5.985 | 19.650 | 139.697 | 77.895 | 9 | 9 | 24 | 28 | -0.144 | 1.114 | 0.000 | 91 | 45 | 0.310 | 0.271 | 1.144 | 200.817 | 0.327 | 7.300 |
| 7.400 | 124.850 | 154.205 | -0.000 | 0.338 | 6.400 | 6.220 | 19.650 | 141.662 | 78.878 | 9 | 9 | 23 | 27 | -0.144 | 1.142 | 0.000 | 90 | 43 | 0.297 | 0.270 | 1.102 | 193.700 | 0.341 | 7.400 |
| 7.500 | 125.734 | 156.388 | -0.000 | 0.374 | 6.500 | 6.378 | 19.650 | 143.627 | 79.862 | 9 | 9 | 24 | 28 | -0.153 | 1.188 | 0.000 | 90 | 43 | 0.310 | 0.269 | 1.152 | 194.023 | 0.378 | 7.500 |
| 7.600 | 126.606 | 163.740 | -0.000 | 0.395 | 6.600 | 6.350 | 19.650 | 145.592 | 80.846 | 9 | 9 | 25 | 28 | -0.161 | 1.203 | 0.000 | 92 | 45 | 0.310 | 0.268 | 1.155 | 200.731 | 0.399 | 7.600 |
| 7.700 | 127.467 | 187.818 | -0.002 | 0.337 | 6.700 | 3.707 | 19.650 | 147.557 | 81.830 | 9 | 9 | 28 | 32 | -0.158 | 1.097 | 0.000 | 97 | 45 | 0.378 | 0.267 | 1.415 | 227.717 | 0.339 | 7.700 |
| 7.800 | 128.317 | 211.729 | -0.001 | 0.306 | 6.800 | 4.940 | 19.650 | 149.522 | 82.814 | 9 | 9 | 31 | 35 | -0.159 | 1.025 | 0.000 | 101 | 45 | 0.503 | 0.266 | 1.887 | 253.862 | 0.308 | 7.800 |
| 7.900 | 155.018 | 245.687 | -0.003 | 0.252 | 6.900 | 0.122 | 20.440 | 151.527 | 83.838 | 10 | 10 | 35 | 39 | -0.155 | 0.902 | 0.000 | 106 | 45 | 0.788 | 0.265 | 2.970 | 291.243 | 0.254 | 7.900 |
| 8.000 | 156.073 | 250.756 | -0.002 | 0.318 | 7.000 | 1.692 | 20.440 | 153.571 | 84.901 | 10 | 10 | 37 | 41 | -0.175 | 1.008 | 0.000 | 107 | 45 | 0.931 | 0.264 | 3.521 | 293.542 | 0.320 | 8.000 |
| 8.100 | 157.114 | 243.352 | -0.001 | 0.351 | 7.100 | 4.943 | 20.440 | 155.615 | 85.964 | 10 | 10 | 36 | 39 | -0.180 | 1.066 | 0.000 | 106 | 45 | 0.788 | 0.264 | 2.992 | 281.276 | 0.353 | 8.100 |
| 8.200 | 158.142 | 215.405 | -0.001 | 0.315 | 7.200 | 5.373 | 20.440 | 157.659 | 87.027 | 10 | 10 | 32 | 34 | -0.159 | 1.047 | 0.000 | 101 | 45 | 0.431 | 0.263 | 1.643 | 245.704 | 0.317 | 8.200 |
| 8.300 | 159.157 | 225.087 | -0.001 | 0.346 | 7.300 | 5.210 | 20.440 | 159.703 | 88.090 | 10 | 10 | 34 | 36 | -0.170 | 1.083 | 0.000 | 102 | 45 | 0.574 | 0.262 | 2.195 | 253.707 | 0.348 | 8.300 |
| 8.400 | 133.442 | 205.729 | -0.001 | 0.294 | 7.400 | 6.207 | 19.650 | 161.707 | 89.114 | 9 | 9 | 30 | 32 | -0.147 | 1.034 | 0.000 | 98 | 45 | 0.378 | 0.261 | 1.451 | 229.047 | 0.296 | 8.400 |
| 8.500 | 134.218 | 198.603 | -0.001 | 0.297 | 7.500 | 6.392 | 19.650 | 163.672 | 90.097 | 9 | 9 | 30 | 31 | -0.144 | 1.052 | 0.000 | 97 | 45 | 0.358 | 0.260 | 1.378 | 218.615 | 0.299 | 8.500 |
| 8.600 | 134.985 | 195.952 | -0.000 | 0.293 | 7.600 | 6.703 | 19.650 | 165.637 | 91.081 | 9 | 9 | 29 | 30 | -0.141 | 1.053 | 0.000 | 96 | 45 | 0.338 | 0.259 | 1.305 | 213.320 | 0.295 | 8.600 |
| 8.700 | 135.735 | 187.320 | -0.000 | 0.316 | 7.700 | 6.867 | 19.650 | 167.602 | 92.065 | 9 | 9 | 28 | 29 | -0.142 | 1.102 | 0.000 | 94 | 45 | 0.324 | 0.258 | 1.255 | 201.643 | 0.319 | 8.700 |
| 8.800 | 136.435 | 190.872 | -0.000 | 0.264 | 7.800 | 6.990 | 19.650 | 169.567 | 93.049 | 9 | 9 | 28 | 29 | -0.128 | 1.023 | 0.000 | 94 | 45 | 0.324 | 0.257 | 1.259 | 203.307 | 0.267 | 8.800 |
| 8.900 | 137.125 | 196.638 | -0.000 | 0.363 | 7.900 | 7.395 | 19.650 | 171.532 | 94.033 | 9 | 9 | 30 | 30 | -0.156 | 1.156 | 0.000 | 95 | 45 | 0.338 | 0.256 | 1.319 | 207.290 | 0.366 | 8.900 |
| 9.000 | 137.806 | 200.301 | -0.000 | 0.384 | 8.000 | 7.545 | 19.650 | 173.497 | 95.017 | 9 | 9 | 31 | 31 | -0.162 | 1.180 | 0.000 | 96 | 45 | 0.358 | 0.255 | 1.402 | 208.978 | 0.387 | 9.000 |
| 9.100 | 138.476 | 195.072 | -0.000 | 0.385 | 8.100 | 7.350 | 19.650 | 175.462 | 96.001 | 9 | 9 | 30 | 30 | -0.159 | 1.191 | 0.000 | 95 | 45 | 0.338 | 0.254 | 1.328 | 201.369 | 0.388 | 9.100 |
| 9.200 | 139.137 | 183.443 | -0.000 | 0.383 | 8.200 | 7.432 | 19.650 | 177.427 | 96.985 | 9 | 9 | 28 | 28 | -0.152 | 1.208 | 0.000 | 92 | 43 | 0.310 | 0.254 | 1.222 | 187.316 | 0.387 | 9.200 |
| 9.300 | 139.789 | 191.374 | -0.000 | 0.342 | 8.300 | 7.738 | 19.650 | 179.392 | 97.969 | 9 | 9 | 29 | 29 | -0.145 | 1.148 | 0.000 | 93 | 43 | 0.324 | 0.253 | 1.282 | 193.510 | 0.345 | 9.300 |
| 9.400 | 140.431 | 191.569 | -0.000 | 0.334 | 8.400 | 7.814 | 19.650 | 181.357 | 98.953 | 9 | 9 | 29 | 28 | -0.143 | 1.140 | 0.000 | 93 | 43 | 0.310 | 0.252 | 1.230 | 191.763 | 0.337 | 9.400 |
| 9.500 | 141.064 | 173.016 | -0.000 | 0.349 | 8.500 | 7.830 | 19.650 | 183.322 | 99.937 | 9 | 9 | 27 | 26 | -0.136 | 1.190 | 0.000 | 89 | 43 | 0.285 | 0.251 | 1.135 | 171.290 | 0.352 | 9.500 |
| 9.600 | 141.689 | 149.721 | -0.000 | 0.341 | 8.600 | 8.330 | 19.650 | 185.287 | 100.921 | 9 | 9 | 23 | 22 | -0.121 | 1.227 | 0.000 | 83 | 43 | 0.237 | 0.250 | 0.946 | 146.518 | 0.345 | 9.600 |
| 9.700 | 142.304 | 154.742 | -0.000 | 0.329 | 8.700 | 8.625 | 19.650 | 187.252 | 101.905 | 9 | 9 | 24 | 23 | -0.120 | 1.204 | 0.000 | 84 | 43 | 0.247 | 0.249 | 0.993 | 150.011 | 0.333 | 9.700 |
| 9.800 | 142.911 | 176.960 | -0.000 | 0.324 | 8.800 | 8.273 | 19.650 | 189.217 | 102.889 | 9 | 9 | 27 | 26 | -0.129 | 1.161 | 0.000 | 89 | 43 | 0.285 | 0.248 | 1.147 | 170.151 | 0.327 | 9.800 |
| 9.900 | 143.509 | 173.460 | -0.000 | 0.343 | 8.900 | 8.672 | 19.650 | 191.182 | 103.873 | 9 | 9 | 27 | 25 | -0.132 | 1.193 | 0.000 | 88 | 43 | 0.272 | 0.247 | 1.101 | 165.151 | 0.346 | 9.900 |