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Utilization of XBP in Predicting Mine Impact Burial

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14. ABSTRACT This report evaluates the possibility of using the Expendable Bottom Penetrometer (XBP) to predict mine impact burial. The XBP data collected at four different locations was processed and analyzed. Noise-contaminated XBP signals were analyzed and successfully filtered. Routines used for denoising are documented. XBP-derived parameters were compared with the data on full-scale cylinder impact burial. A modified version of the IMPACT28 burial prediction program was used in conjunction with XBP- and STING (Sea Terminal Impact Naval Gage)-derived shear strength of the sediments. Results showed the XBP-derived shear strength yielded more accurate predictions on percent volume burial of cylinders whereas, STING-derived shear strength correlated better with cylinder height exposed and final pitch. Conclusions on utilization of XBP and STING probes are drawn.					
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UTILIZATION OF XBP IN PREDICTING MINE IMPACT BURIAL

Introduction

The primary objective of this study was to evaluate the applicability and usefulness of the Expendable Bottom Penetrometer (XBP)-derived data to predicting the Mine Countermeasures (MCM) Doctrinal Mine Burial Bottom Category. Amount of burial on impact currently represents the main contributing factor to the overall category determination. A number of parameters derived from the XBP record have been evaluated for potential correlation with amount of burial of large cylinders. Additionally, the newly developed model (Aubeny, 2005) of inferring the undrained shear strength from the XBP deceleration profiles has been implemented. The data reported herein was collected as part of the Mine Burial Project at the Naval Research Laboratory (NRL) as well as a similar effort undertaken by the FWG (Forschungsanstalt der Bundeswehr für Wasserschall und Geophysik, Kiel, Germany). This study utilized data from the following cruises: in the vicinity of Cocodrie, LA in 2002 (referred to as "P02"), in the COMINEWARCOM training area off the coast of Corpus Christi, TX ("G06"), in East Bay, LA in 2003 ("P03"), and in the Baltic (near Kiel, Germany) in 2003 ("SS"). Experimental data from STING (Sea Terminal Impact Naval Gauge) was also evaluated for applicability in mine burial category prediction. Burial predictions made using XBP and STING profiles as input were compared with those made using the lab measured vane shear strength. The model burial predictions were done using a modified version of the IMPACT28 software.

Data collection, processing

The list of available data sources is presented in Table 1. This list does not include two other cruises: East Bay / Garden Is., 2004 and North Sea, 2004. XBP, STING, gravity core, or the cylinder burial data has not been processed at the time of writing of this report. The results of analysis on these sets of data will be available at a later stage and upon completion of all the diagnostic testing. Table 1 lists the cruise locations and the number of probe drops (or deployments consisting of several drops, as in the case of STING probe) performed, as well as the available cylinder drop data. Here, the FWG cylinders did not have the internal instrumentation that allowed recording the fall trajectory, as was the case in other cruises listed, where the NRL

instrumented cylinder was used. The SS cruise, thus, did not provide information on the dynamics of the cylinder on impact with the sediment. This lack of cylinder dynamics data prevented the authors exercising the modified IMPACT28 model for predictions of the impact burial based on the XBP and STING derived values of the shear strength of the sediment (the details of this method are presented below).

XBP data processing

The XBP data presented in this report was processed from “raw” binary files saved using the XBP supplied software. These files (extension “p1b”) contain high frequency data, otherwise inaccessible using standard XBP procedures. Matlab™ routines were written to extract the data and all relevant constants from the “raw” files for further enhanced processing outside the standard XBP-provided package. It was also found that several XBP deployments had been contaminated with complex and variable noise structure, rendering the signals unusable by the standard XBP software.

Denoising contaminated XBP signals

The noise contaminated files, alluded to above, included the following deployments:

- G06, Corpus Christi, May 2002 (2 files):
 - ♦ 15my0921.p1b
 - ♦ 15my0923.p1b
- P02, Cocodrie, January 2002 (5 files)
 - ♦ 08ja0752.p1b
 - ♦ 08ja0823.p1b
 - ♦ 08ja1235.p1b
 - ♦ 09ja0754.p1b
 - ♦ 09ja1056.p1b

Several filtering techniques were attempted to eliminate the effects of the noise and recover the signal. This task was completed successfully with the results and detailed description of the processes and tools used presented in Appendix A (File: “NAVO_XBP_denoising_Appendix_A”).

Maps of the areas tested are shown in Fig. 1 - Fig. 11. The cylinder drops are grouped at some cruises by location and proximity to the available gravity core and STING and XBP drop locations.

Analysis

The analysis presented here included several methods of predicting the amount of impact burial of large cylinders from field-deployed probes, including XBP and STING. First, XBP-derived parameters, describing the deceleration history of the probe impacting the sediment were compared with those of the large instrumented cylinder. As a separate but important effort, qualitative comparison of the XBP- and STING-predicted undrained shear strength with that from lab-processed miniature vane test results is presented. Then, similar analysis is done using STING data of deployments with variable size foot (25, 35, 50, and 70 mm). Lastly, cylinder burial predictions are done using experimentally-derived averaged dynamic parameters of a generic large cylinder, and estimates of sediment density and sediment shear strength as derived from XBP and STING drops.

Direct correlations between XBP-derived parameters and measured cylinder burial

The following XBP-derived parameters were examined:

- A_{max} – maximum deceleration of the probe recorded during penetration
- D/S_{max} , where $D = \int A ds$ is an integral of the deceleration vs. penetration distance, normalized by the maximum penetration recorded (S_{max}). This parameter distinguishes between the “hard”-sediment response where A_{max} is large and S_{max} is small, as opposed to the soft sediment response, where the A_{max} is small and S_{max} is large.
- S_{max} – maximum penetration achieved by probe

Fig. 12 - Fig. 20 show results of these correlations. Best-fit curves are given in several cases where the correlation is most probable, e.g. percent volume buried vs. D/S_{max} (Fig. 12), vs. A_{max} (Fig. 15), and vs. S_{max} (Fig. 18). Most of these correlation attempts yielded no beneficial conclusions, as the data seemed to be only weakly correlated. Data

given in Fig. 15 appears to have most degree of correlation of all cases tested, however, tremendous natural variability of the actual experimental cylinder position in water before impact produces a tremendous amount of variability, hardly matched by the XBP-derived parameters.

Derivation of undrained shear strength from XBP

Fig. 21 -- Fig. 30 give comparison of the undrained shear strength values derived from the XBP data using C. Aubeny's routine with these of the lab-measured vane tests. These vane tests are represented by the site averages with standard deviations shown as error bars. Two charts are given for each set of data, one zoomed on the XBP drop, the other on the entire depth of interest. An assumption is needed on the law of change of the XBP-determined shear strength in order to estimate it to the depth relevant to the cylinder burial predictions. One could extrapolate (linear) the middle portion of the XBP (after C. Aubeny), without the top or the bottom 5 cm, to the depth of interest, of about 2 to 5 m. Alternatively, and recognizing the fact that the entire penetration depth of a small tool like the XBP penetrometer is very small, one could assume constant shear strength with depth. This second technique will underestimate the actual strength, and the first method will likely overestimate it. It was decided to use the constant with depth assumption, judging that amount of error in this type of procedure is smaller than in the other.

Derivation of undrained shear strength from STING

Similar analysis was performed on the STING data and is shown in Fig. 31 - Fig. 44. Here, the results of the 70 mm foot seem to fit the lab vane data the best, and the 25 mm foot results fit the worst. In selecting values of shear strength from STING data for analysis of the next section, the undrained shear strength was approximated for each group of drops (of the same foot diameter) using a bi-linear approach: one segment for a linear-with-depth shear strength increase until the end of STING drop data, and then extending the last (maximum) value of the shear strength constant with depth, as to not to grossly overestimate the sediment strength beyond depth of STING penetration.

Burial predictions using modified IMPACT28 and derived shear strength

Fig. 45 – Fig. 50 show the results of the calculation, performed in the following fashion. A generic cylinder was considered, taking an averaged (NRL cylinder data) geometry, mass and mass offset, together with the averaged dynamics of this cylinder during the impact on mud. An average sediment density was assumed to be the same for all tests (563 kg/m³ submerged). It has been shown that the density values play only minor role in prediction using IMPACT28-type models. The sediment only portion of the IMPACT28 model was then run, using the shear strength predictions derived from either XBP or STING, as described above.

A quantitative analysis in the quality of predictions done using XBP- and STING-derived shear strength was performed. A series of statistical parameters were evaluated, describing the relative quality of predicted versus measured percent volume buried, maximum cylinder height protruding, and final pitch. These parameters were defined as follows:

$$\frac{\sum (VE_p - VE_m)^2}{n} \cdot \frac{1}{100^2},$$

$$\frac{\sum (HE_p - HE_m)^2}{n} \cdot \frac{1}{d^2},$$

$$\frac{\sum (\theta_p - \theta_m)^2}{n} \cdot \frac{1}{(\pi/4)^2},$$

where VE – is percent volume exposed, HE – is the maximum cylinder height exposed, θ – is final pitch, and “ p ” stands for predicted and “ m ” – for measured. d – is the cylinder diameter. The results of these calculations are given in Table 3. It can be observed that the XBP-derived predictions produce better correlations with measured data than STING-based for the cylinder volume exposed. The opposite trend is true for predictions of height exposed and pitch. It should be noted that pitch predictions were not very accurate in both cases, as they are apparently more sensitive to the accurate knowledge of orientation at impact.

Discussion, conclusions, and recommendations for future work

Analyses of the predictions done show that the volume buried and the height exposed are predicted much better than the values of the pitch. In fact most pitch

predictions are confined to a very narrow band, showing virtual lack of correlation between predicted and actually measured data.

STING – derived shear strength appear to produce better results on the overall burial predictions than those that were derived from XBP. The 70 mm STING foot matched the lab measured vane shear strength the best and is recommended when using STING, utilizing the provided software. STING analysis procedure could be adjusted in the future to assure similar prediction quality of the undrained shear strength from variously sized feet.

Direct correlation between the XBP-derived parameters that describe the probe dynamics in the sediment and the experimentally measured cylinder burial parameters (volume buried, maximum height exposed, final pitch) showed lack of strong dependencies. Questionably best match was achieved in plotting the percent volume buried as a function of D/S_{max} .

Statistical comparisons of the quality of IMPACT28 predictions where the shear strength data was inferred from STING and XBP data are somewhat inconclusive. STING-based results predicted the cylinder height exposed better than the XBP-based, while the opposite trend was observed in predicting percent volume buried. Pitch predictions were marginally better for STING-based data, but both performed rather inaccurately.

Qualitative comparisons of XBP-derived parameters and cylinder volume buried based on surface plots are presented in Fig. 51 - Fig. 53. Krigging technique was used in generating these surfaces. Among the parameters plotted, A_{max} , and to the lesser extent S_{max} , showed some visual correlation with cylinder burial data. Notably, there were no XBP tests performed in the West and North-West parts of the testing area due to presence of gravel and other harder materials on the bottom. Some of the Krigging results, therefore, show diverging lines as a result of this lack of data on grid points.

Several items are recommended for further research.

- Data derived from STING records could be analyzed in parameterized fashion, similar to the XBP presented here. Possible correlations between cylinder volume buried, maximum height protruding, final pitch, etc. and STING maximum penetration, peak deceleration, D/S_{max} and other parameters could be tested.

- Quantitative analysis of correlations of surface plots for XBP- and cylinder-derived parameters is warranted. Additionally, surface plots could be computed for the STING-derived parameters, using the similar approach.

Finally, natural variability in the large cylinder dynamics in the water column before the cylinder arrives at the bottom is quite large. Thus accurate burial predictions are not likely to be possible as the precise state of a cylinder on contact with the sediment will not be known accurately in the field during the MCM operations. It appears that these techniques should be used with great caution. The data acquired through any of the techniques presented here should be regarded as estimates only.

References

Aubeny, C. (2005) Private communications, Texas A&M University, Department of Civil Engineering, College Station, TX77843-3136

Tables

Table 1 List of available data sources

Location/set	ID	XBP	STING deployments	STING foot, mm	Su (core)	Mine burial
Baltic	SS	58	30	35, 70	processed	100*
Cocodrie, LA, Jan 2002*	P02	6	15	25, 35, 50	processed	11
Corpus Christi, TX, May 2002	G06	33	12	25, 35	processed	10
East Bay, LA, July 2003	P03	8	15	25, 35, 70	processed	37
East Bay, Garden Isle, LA May 2004	P04	14	-	-	-	55

Note: Each STING deployment consists of several (2 to 5) individual drops

* - cylinder dropped in partially restricted configuration, with winch line attached

Table 2 IMPACT28 input parameter statistics, based on the experimental data from large cylinder deployments (cruises: P02, G06, P03, and P04)

	Mass, kg	Apparent Mass in water, kg	Overall Length, m	Maximum Diameter, m	Length of Taper, m	Minimum Taper Diameter, m	Distance CM to CG, m	Vz', m/s	Vx', m/s	Theta, deg	Theta rate, rad/s
MEAN	1066	531	2.372	0.533	0	0.533	0.078	3.66	-1.05	66.1	0.091
STD	16	15	0.043	0.000	0	0.000	0.038	0.80	0.86	20.5	0.380

Table 3 Comparison of the STING- and XBP-derived shear strength analysis with experimental data

	% volume exposed: measured - predicted	Height Protruding: measured - predicted	pitch: measured - predicted
STING	0.021	0.140	0.143
XBP	0.011	0.209	0.147

Figures

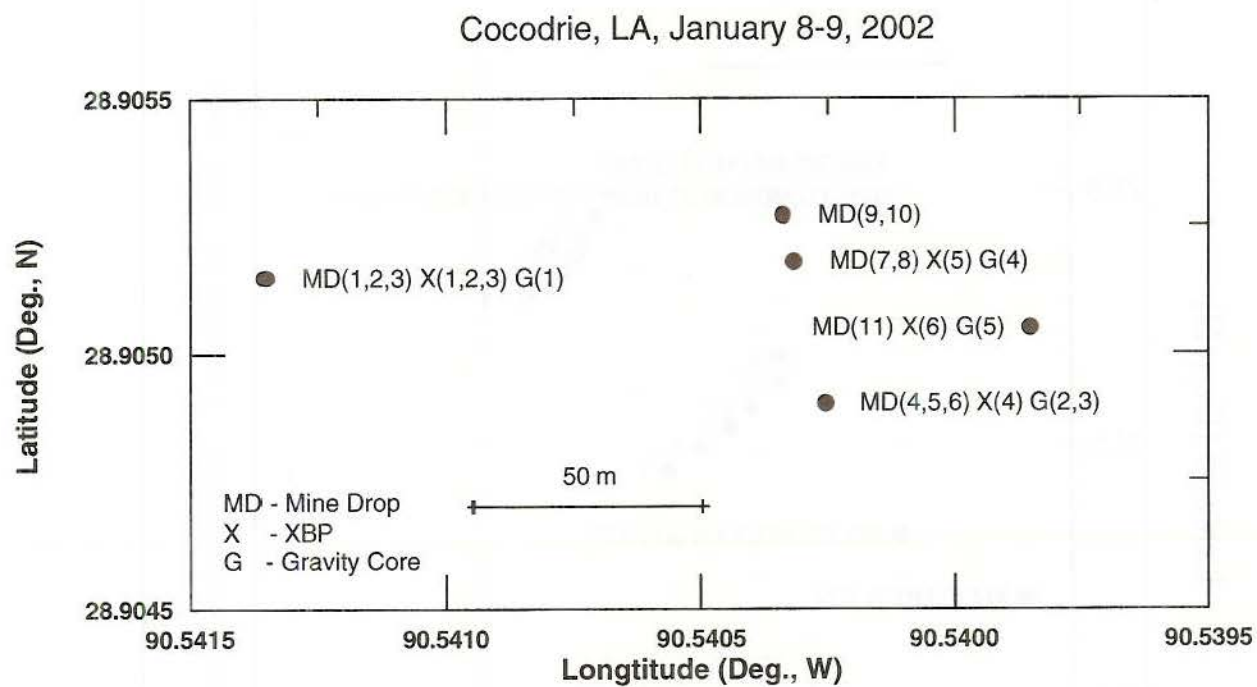


Fig. 1 Deployment locations for P02 cruise (Cocodrie, LA, 2002)

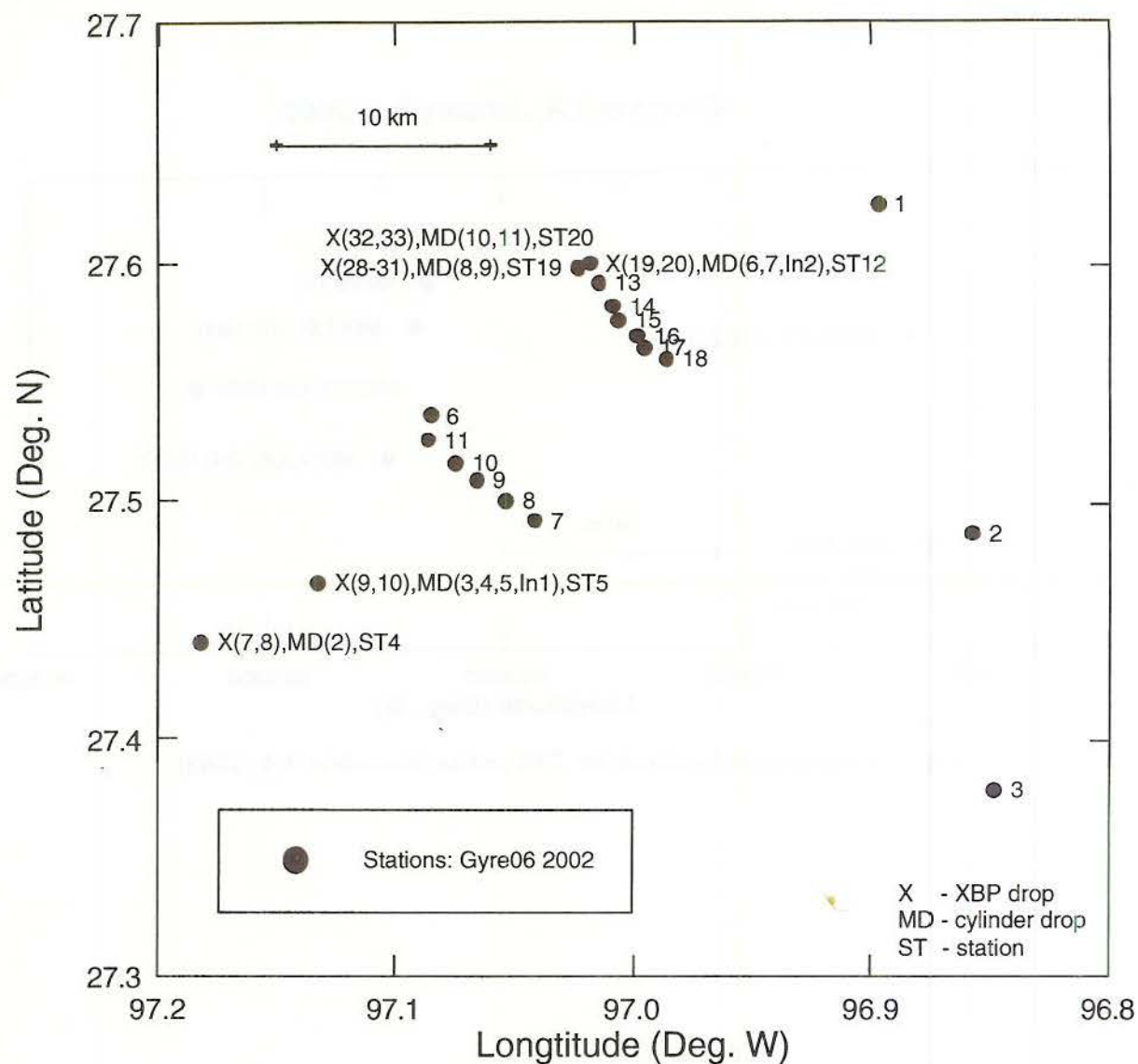


Fig. 2 Deployment locations for G06 cruise (Corpus Christi, TX, 2002)



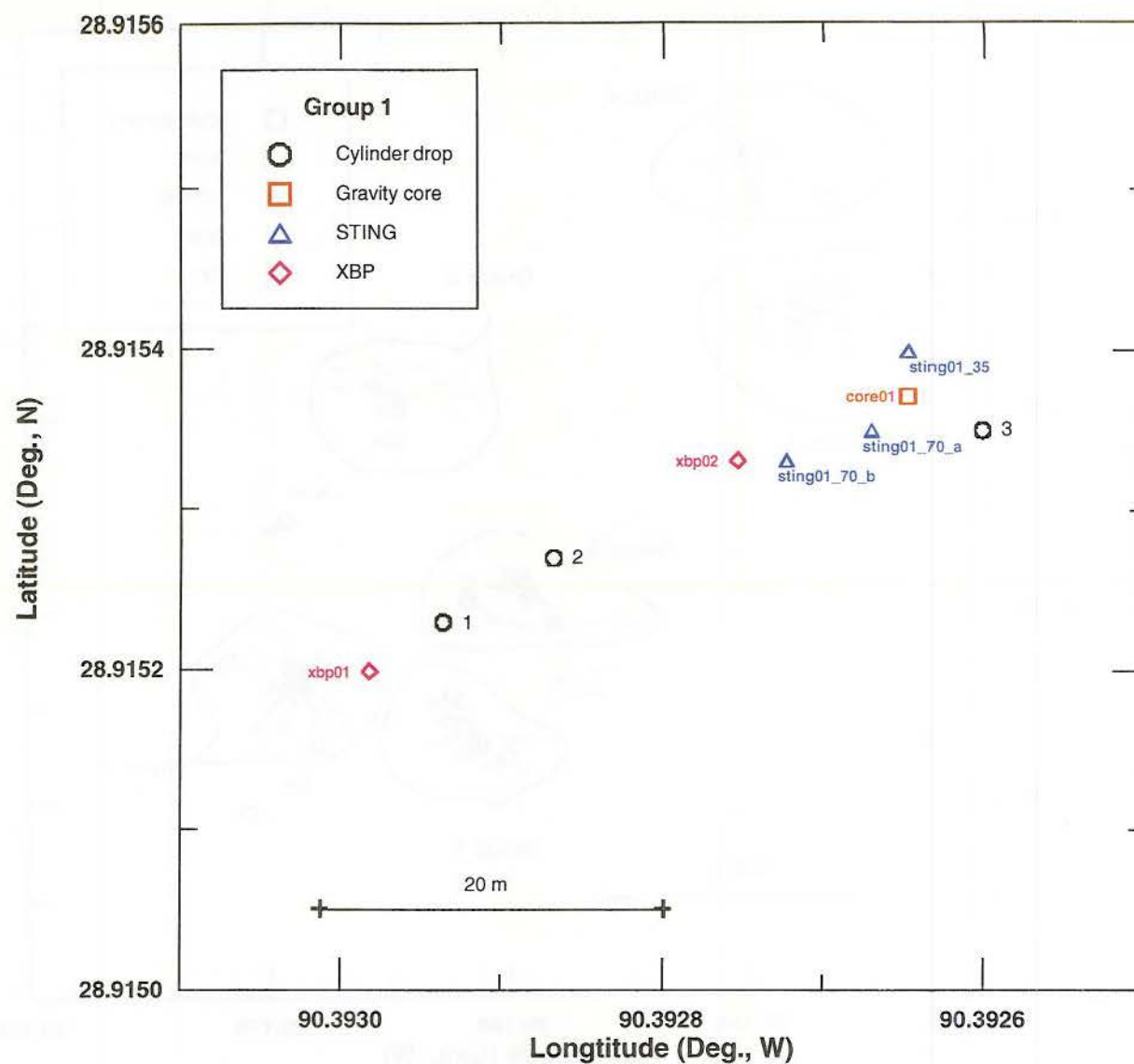


Fig. 4 Deployment locations for P04 cruise (East Bay / Garden Island, LA, 2004). Group 1

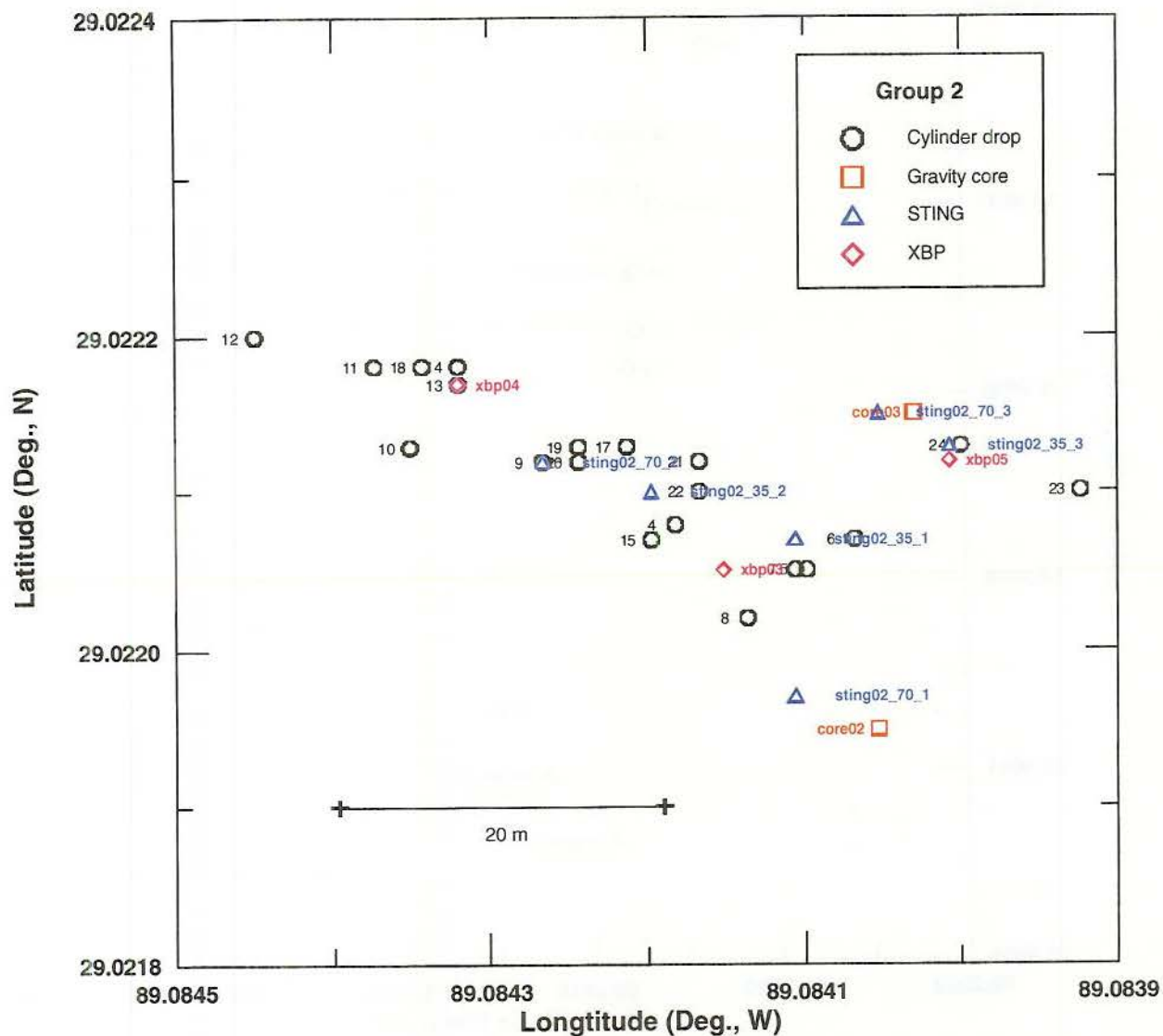


Fig. 5 Deployment locations for P04 cruise (East Bay / Garden Island, LA, 2004). Group 2

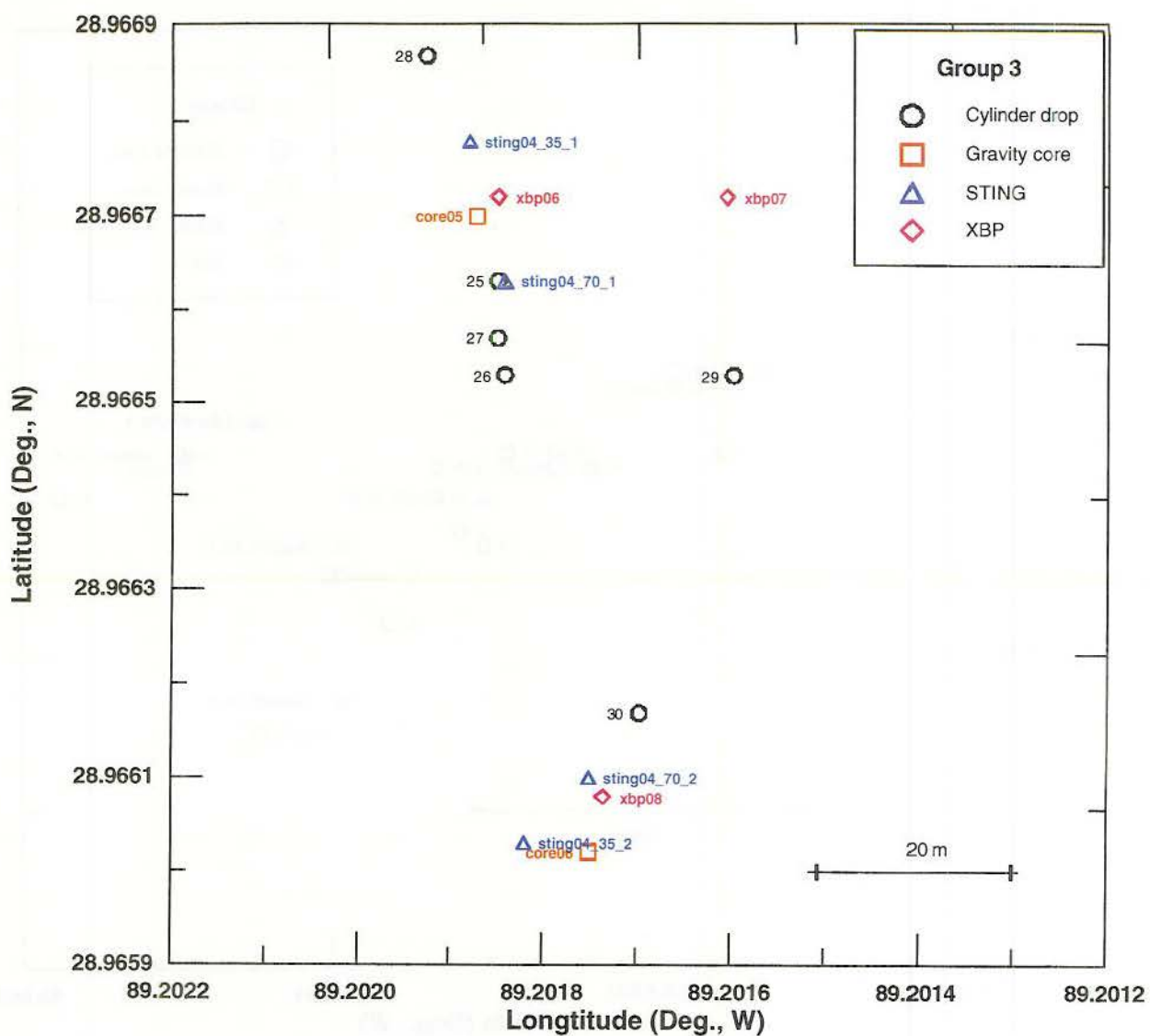


Fig. 6 Deployment locations for P04 cruise (East Bay / Garden Island, LA, 2004). Group 3

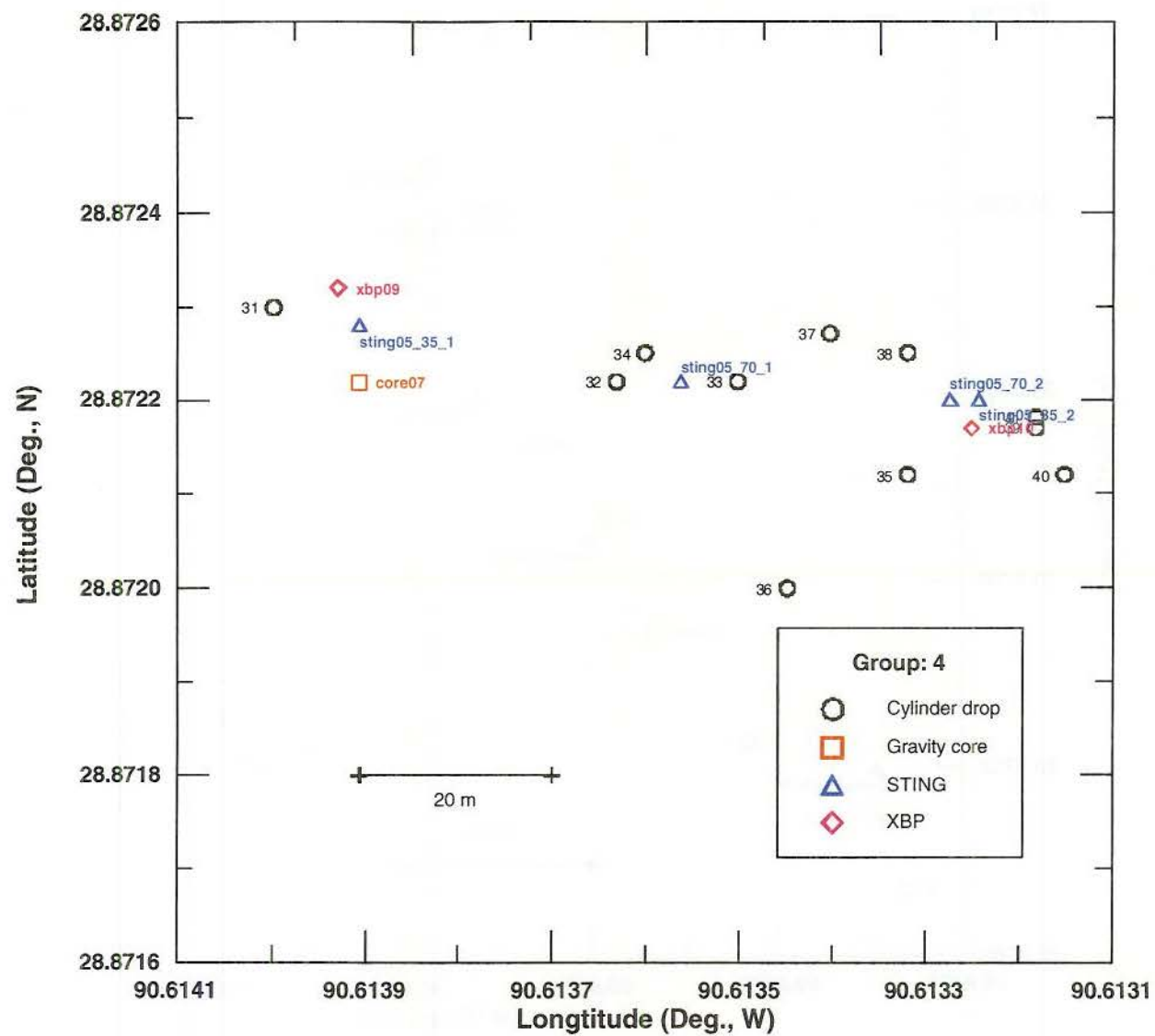


Fig. 7 Deployment locations for P04 cruise (East Bay / Garden Island, LA, 2004). Group 4

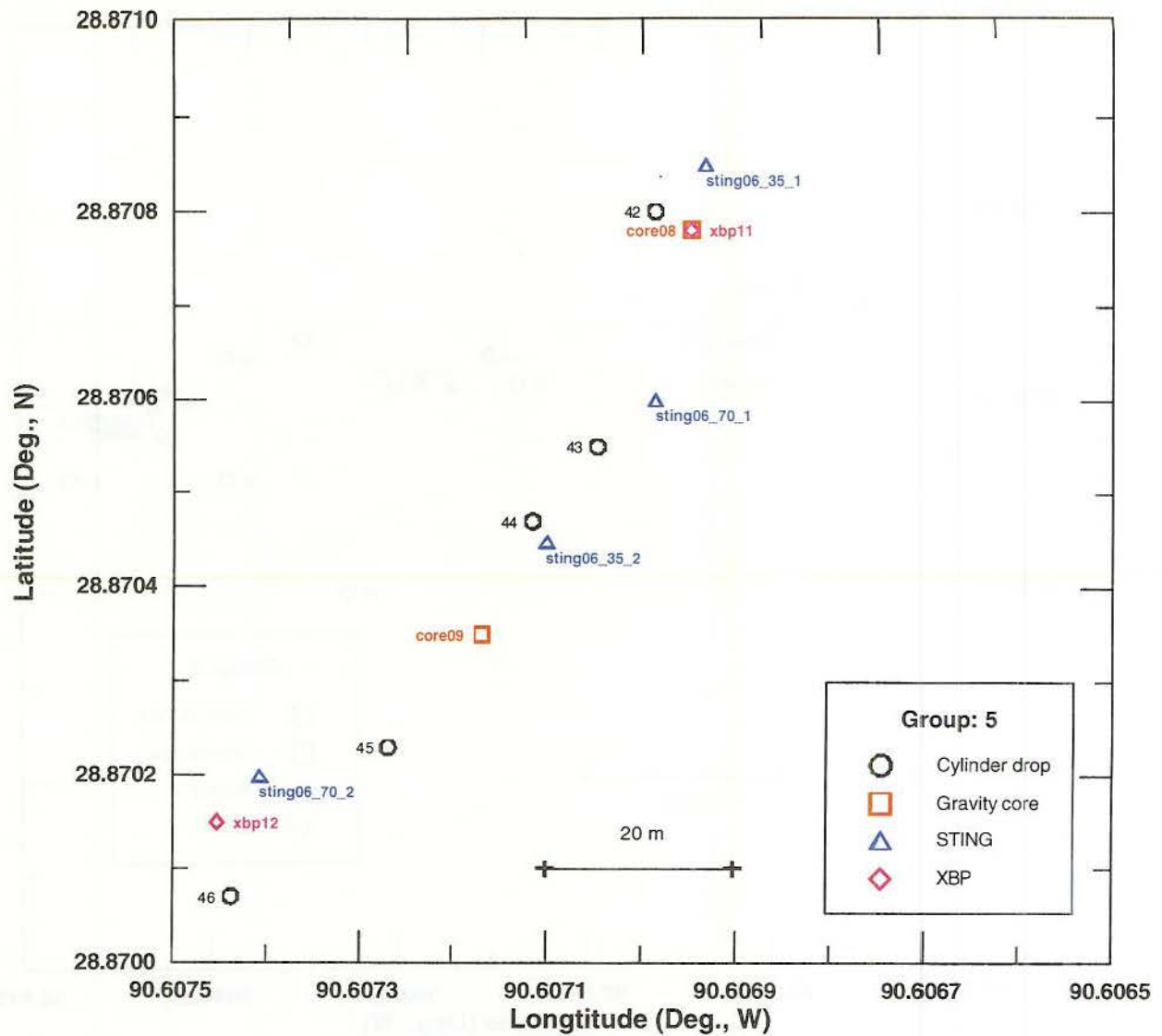


Fig. 8 Deployment locations for P04 cruise (East Bay / Garden Island, LA, 2004). Group 5

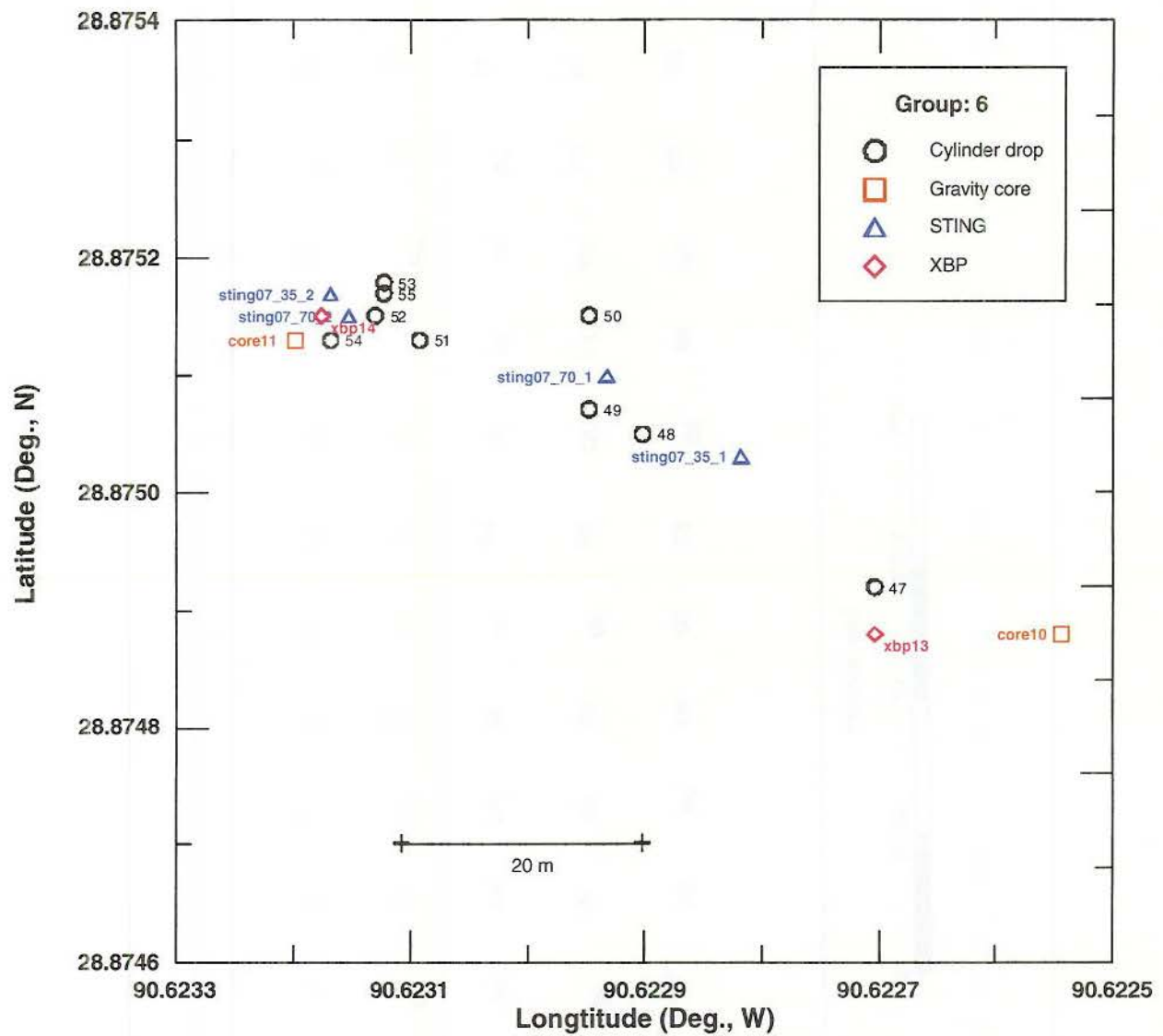


Fig. 9 Deployment locations for P04 cruise (East Bay / Garden Island, LA, 2004). Group 6

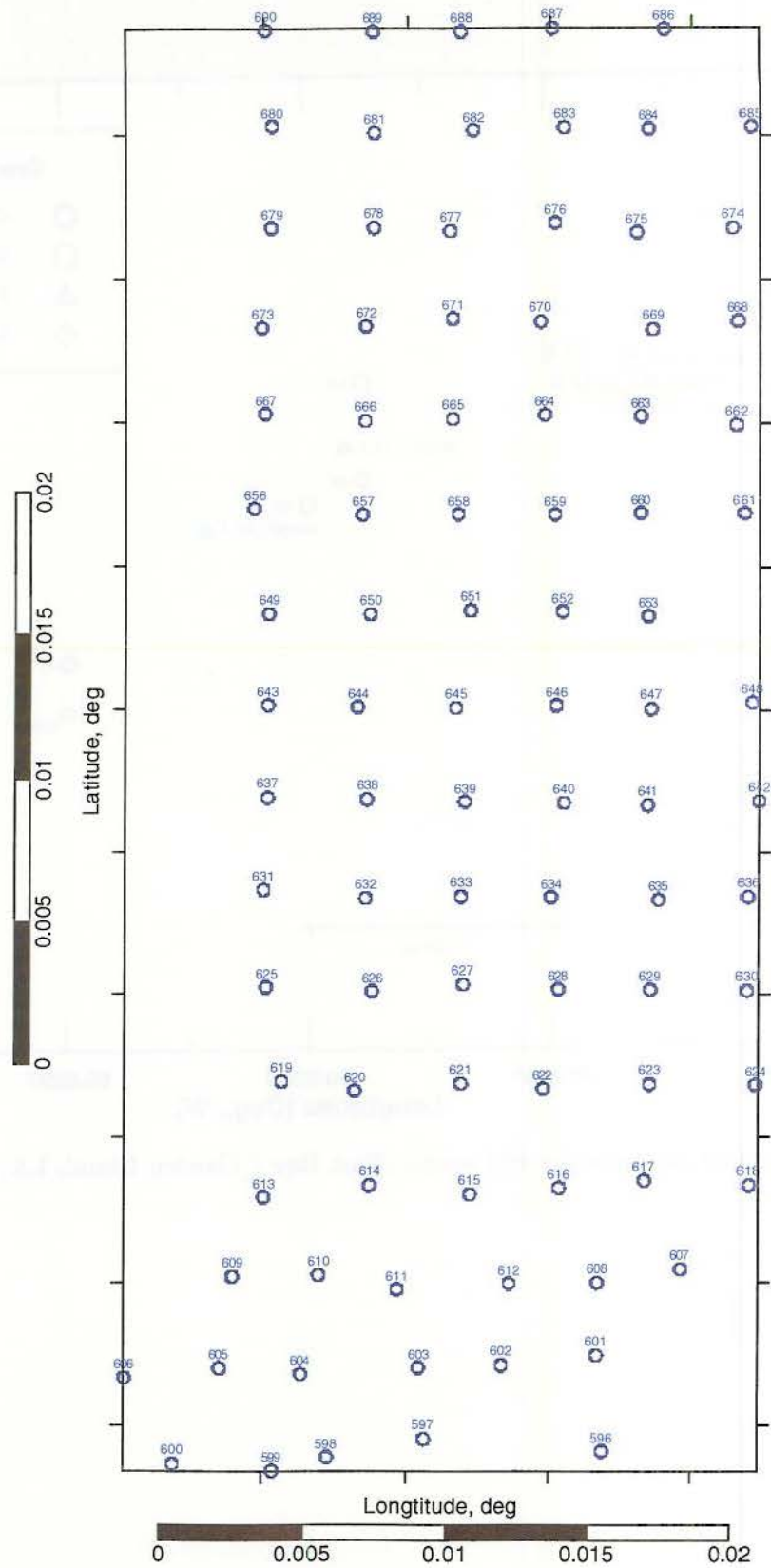


Fig. 10 Deployment locations and station numbers for SS cruise (Baltic, 2004)

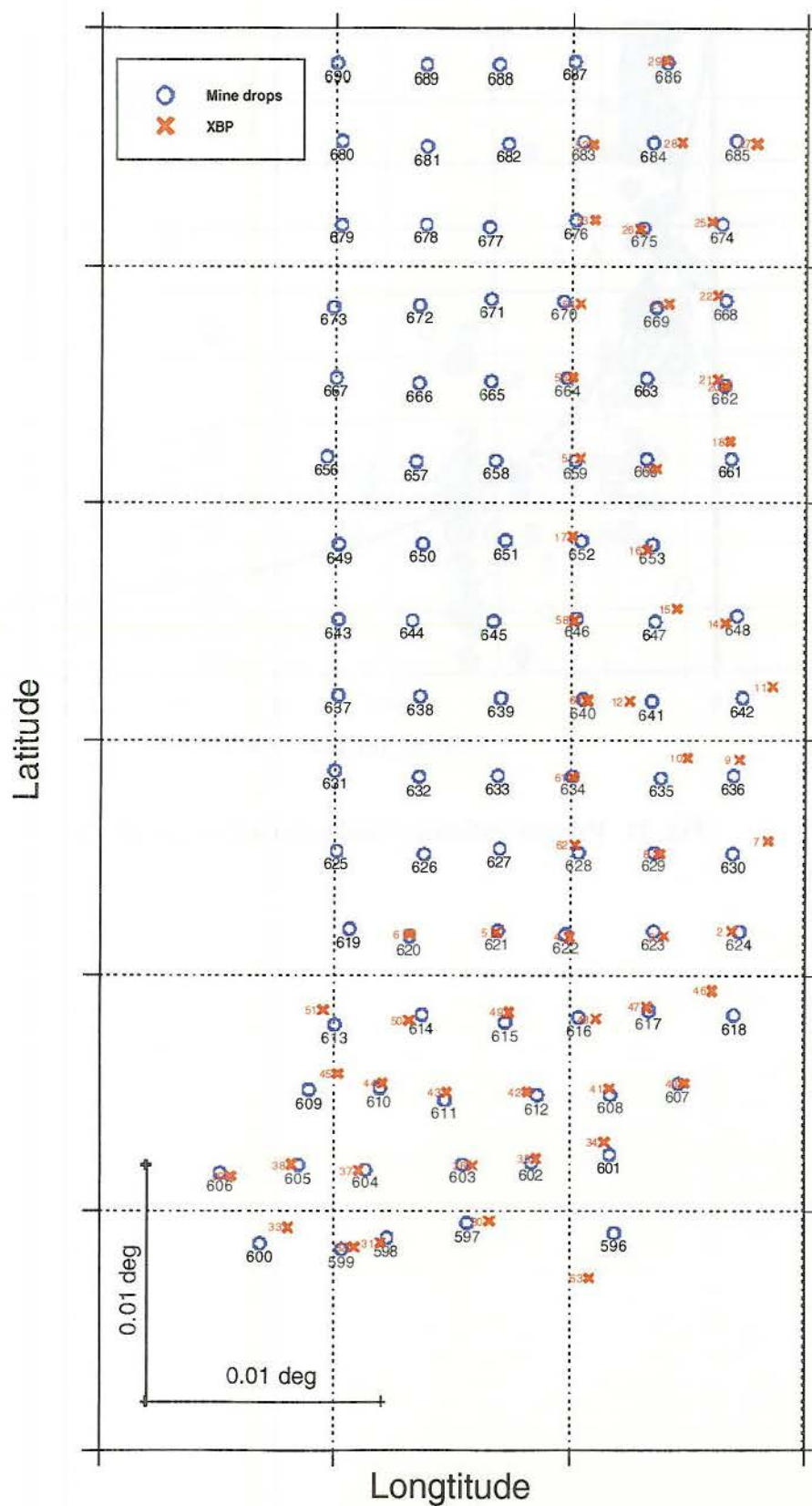


Fig. 11 Station numbers and locations of XBP drops for SS cruise (Baltic, 2004)

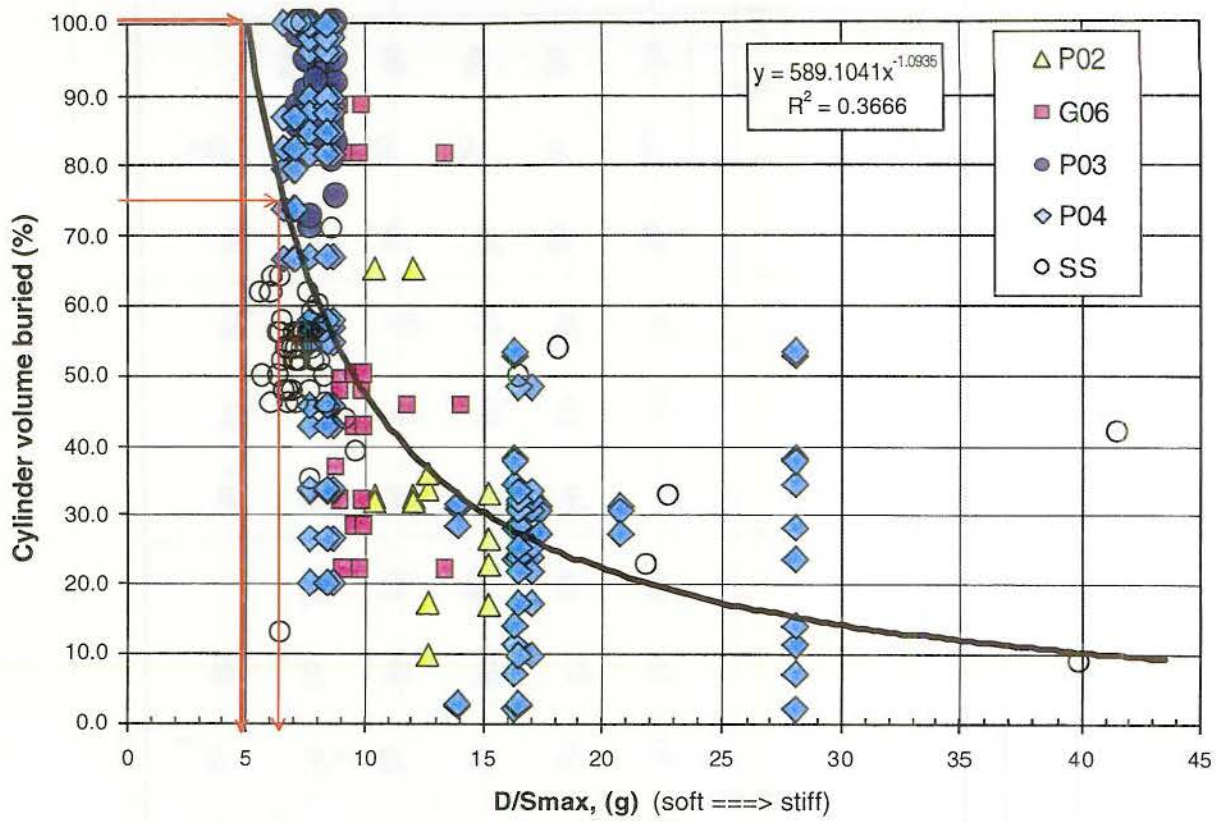


Fig. 12 Percent cylinder volume buried vs. D/S_{max}

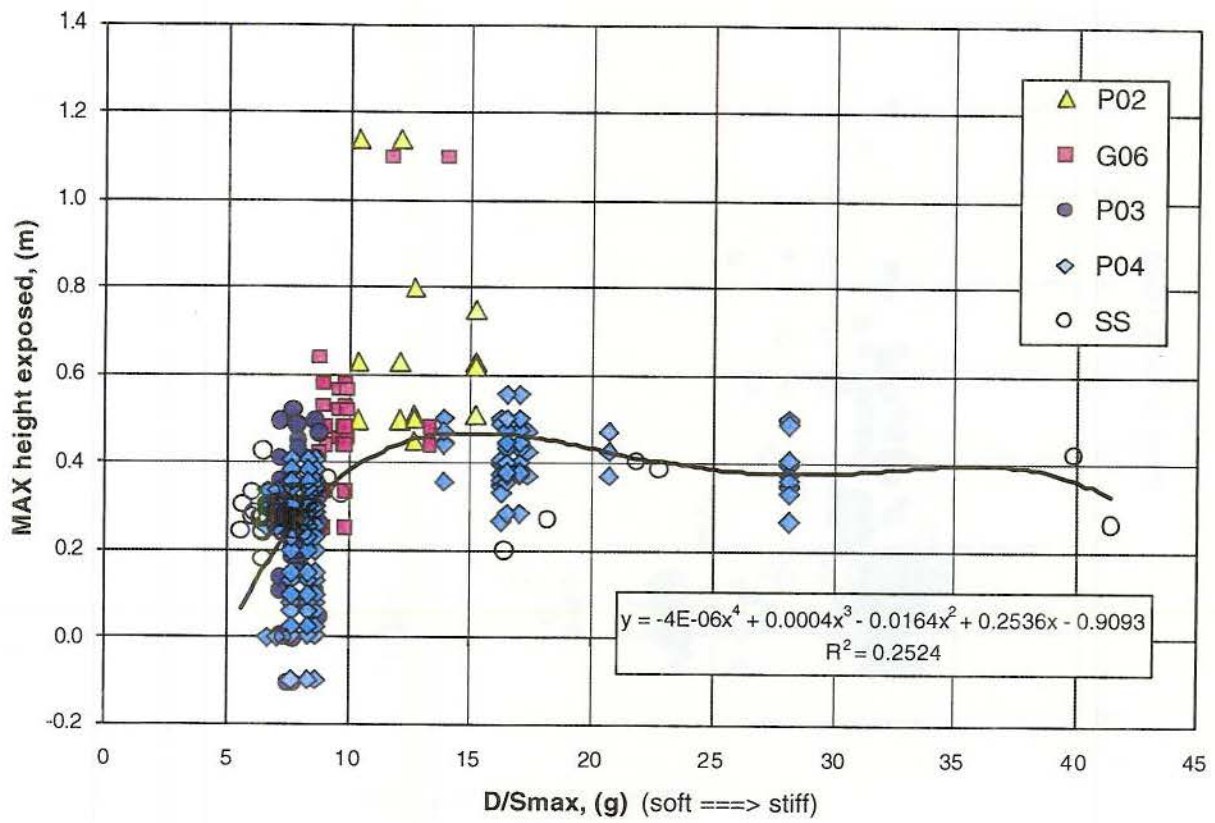


Fig. 13 Maximum cylinder height exposed vs. D/S_{max}

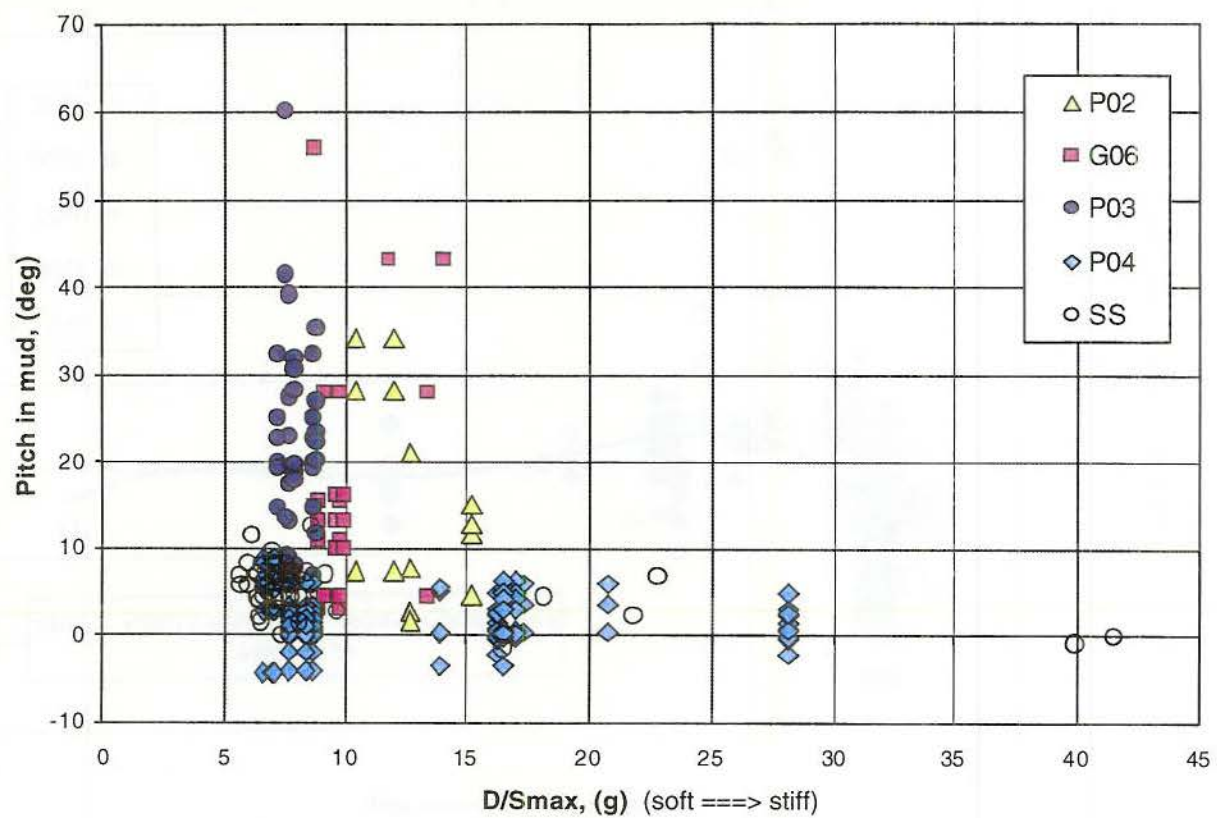


Fig. 14 Cylinder pitch in mud vs. D/S_{max}

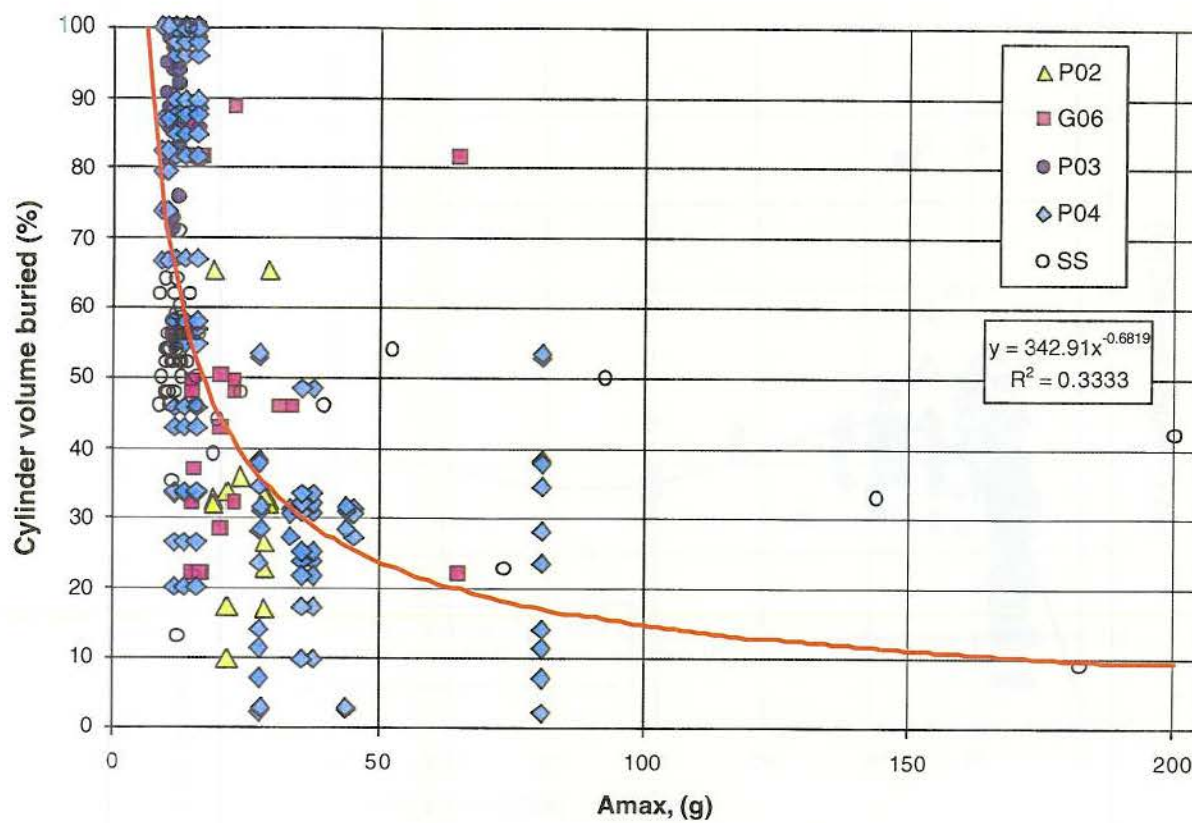


Fig. 15 Percent cylinder volume buried vs. XBP peak deceleration

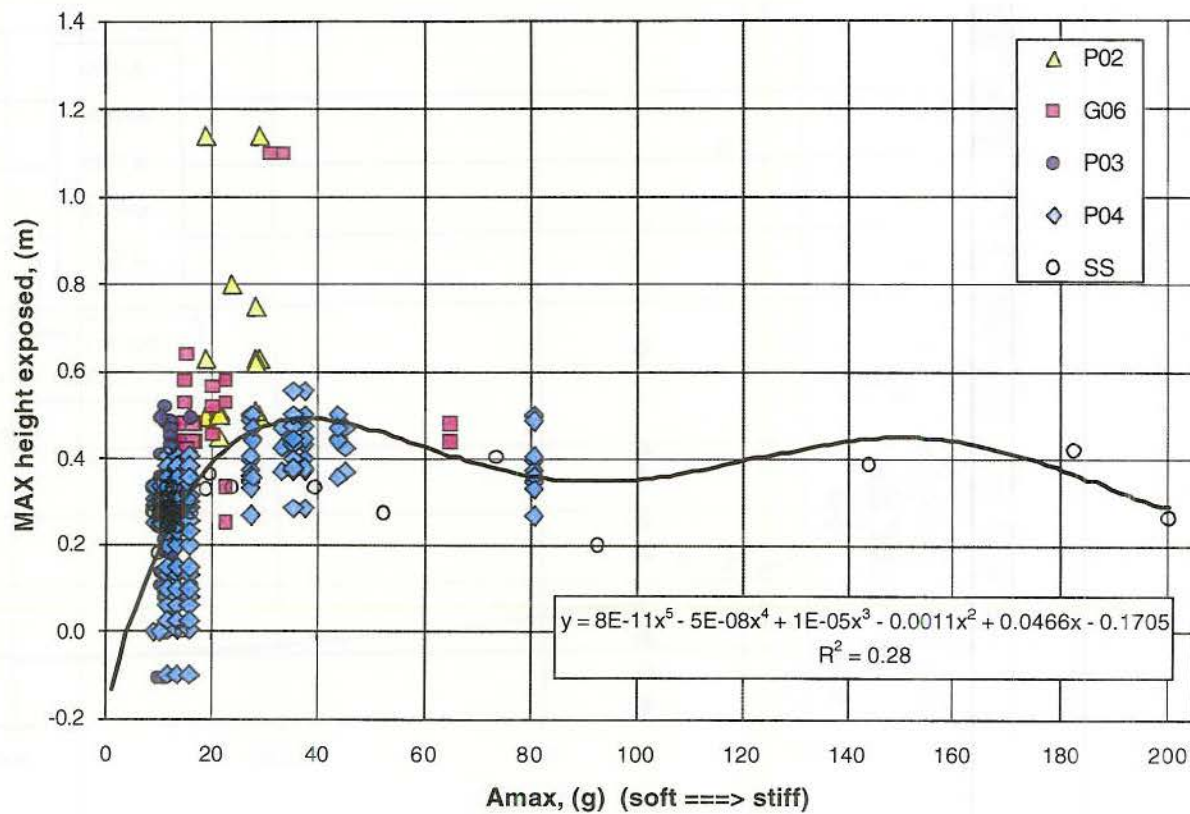


Fig. 16 Cylinder maximum height exposed vs. XBP peak deceleration

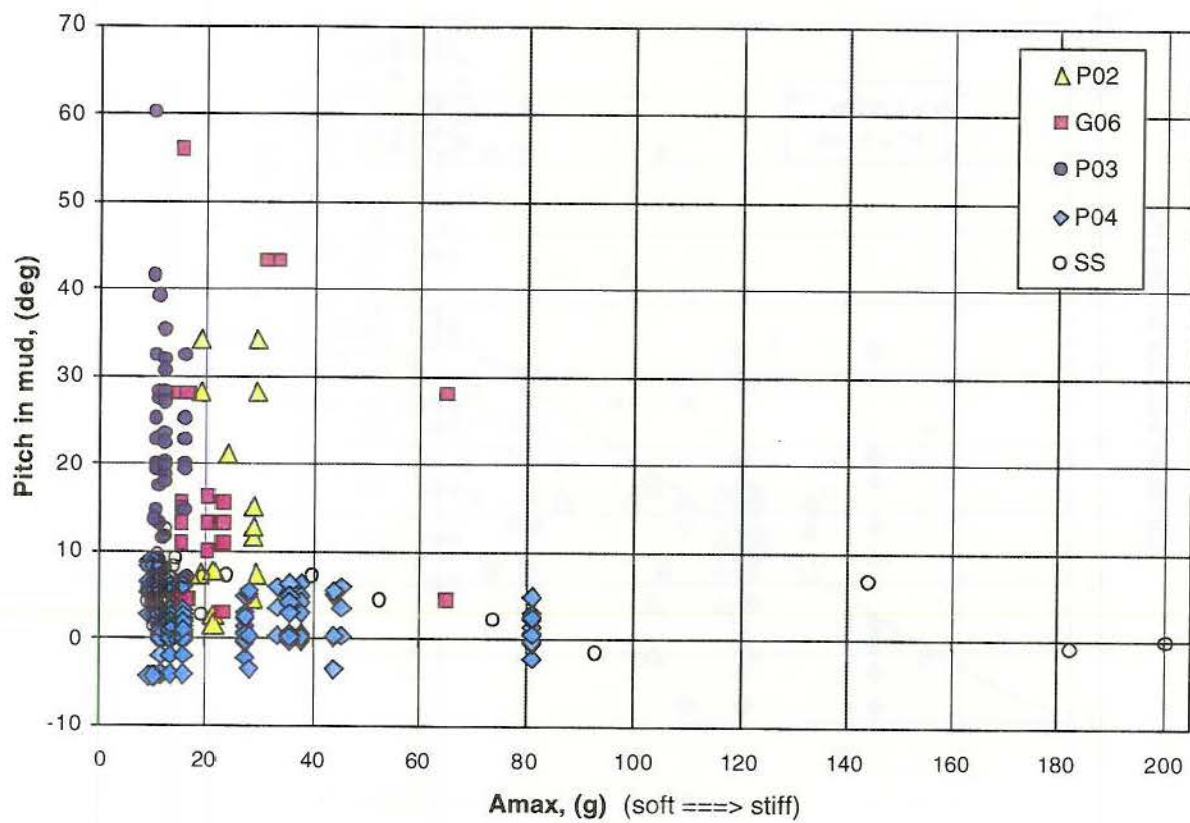


Fig. 17 Cylinder pitch in mud vs. XBP peak deceleration

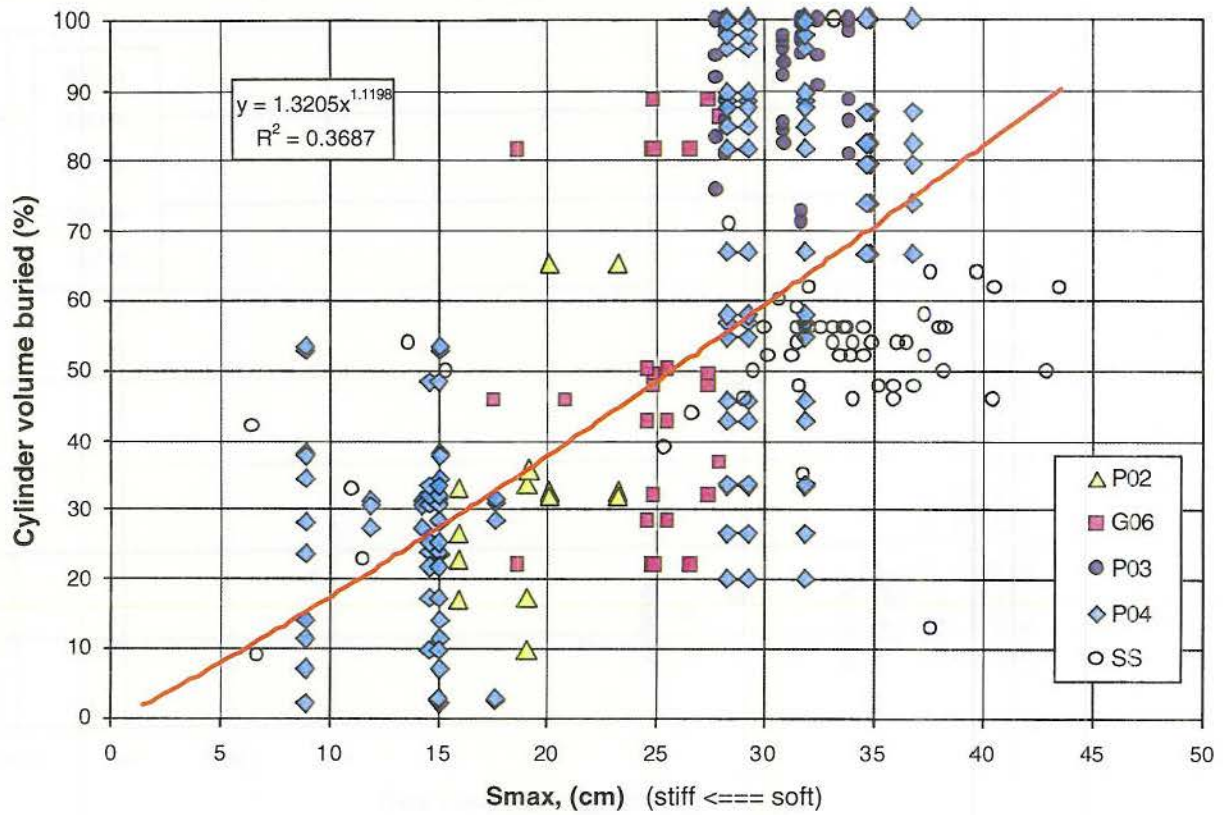


Fig. 18 Percent cylinder volume buried vs. XBP maximum penetration distance

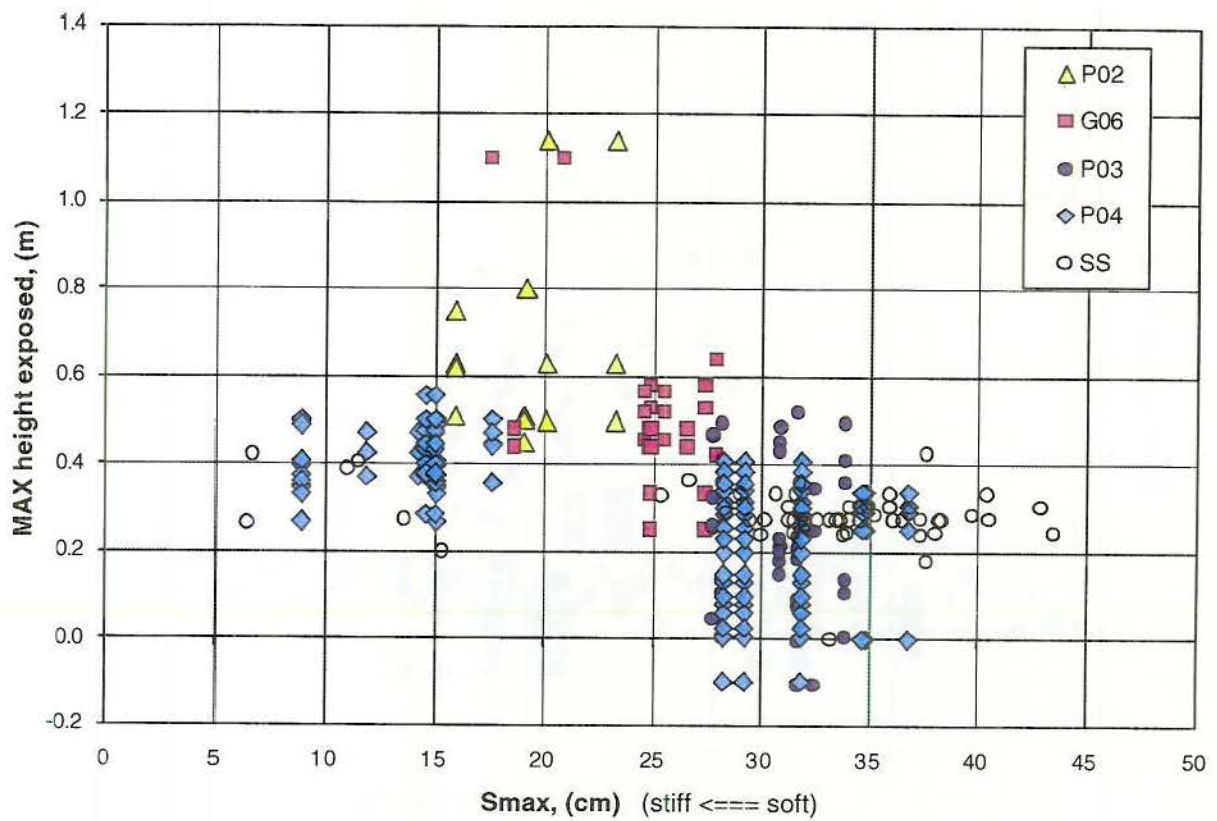


Fig. 19 Cylinder maximum height exposed vs. XBP maximum penetration distance

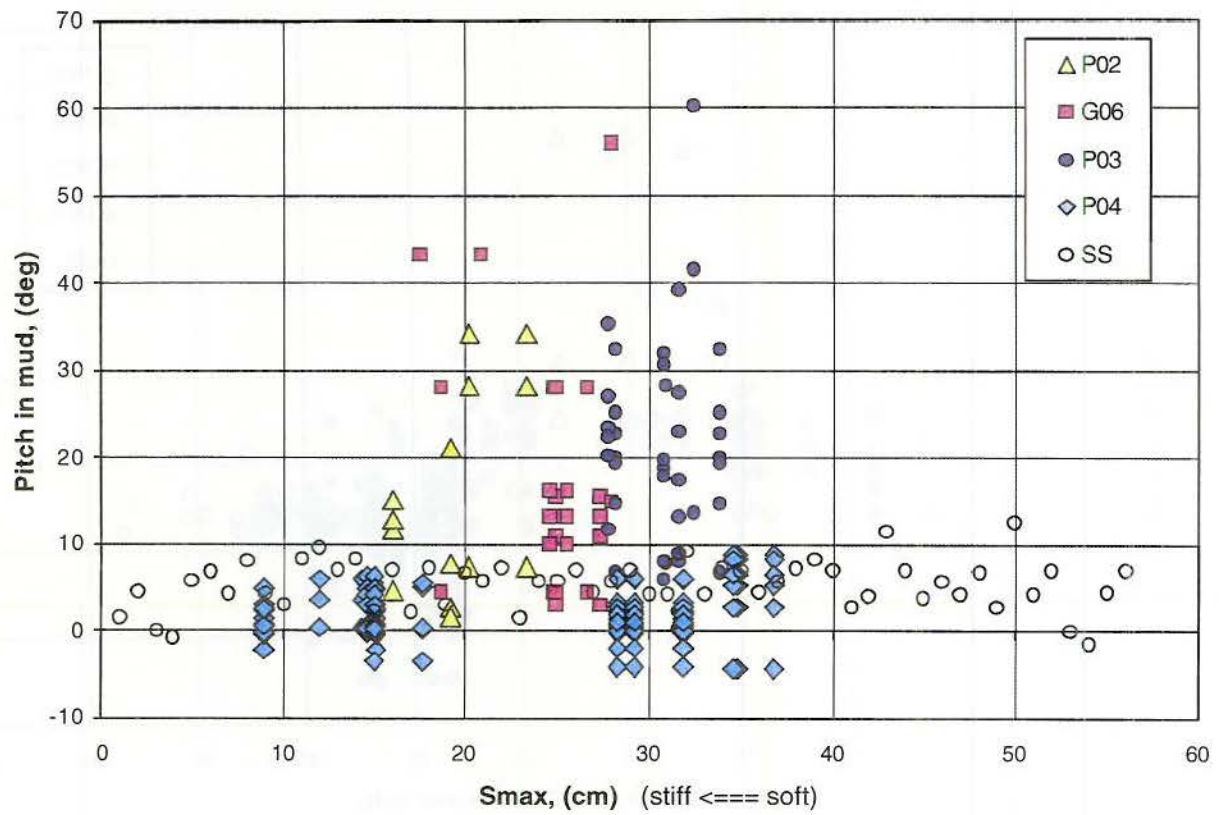


Fig. 20 Cylinder pitch in mud vs. XBP maximum penetration distance

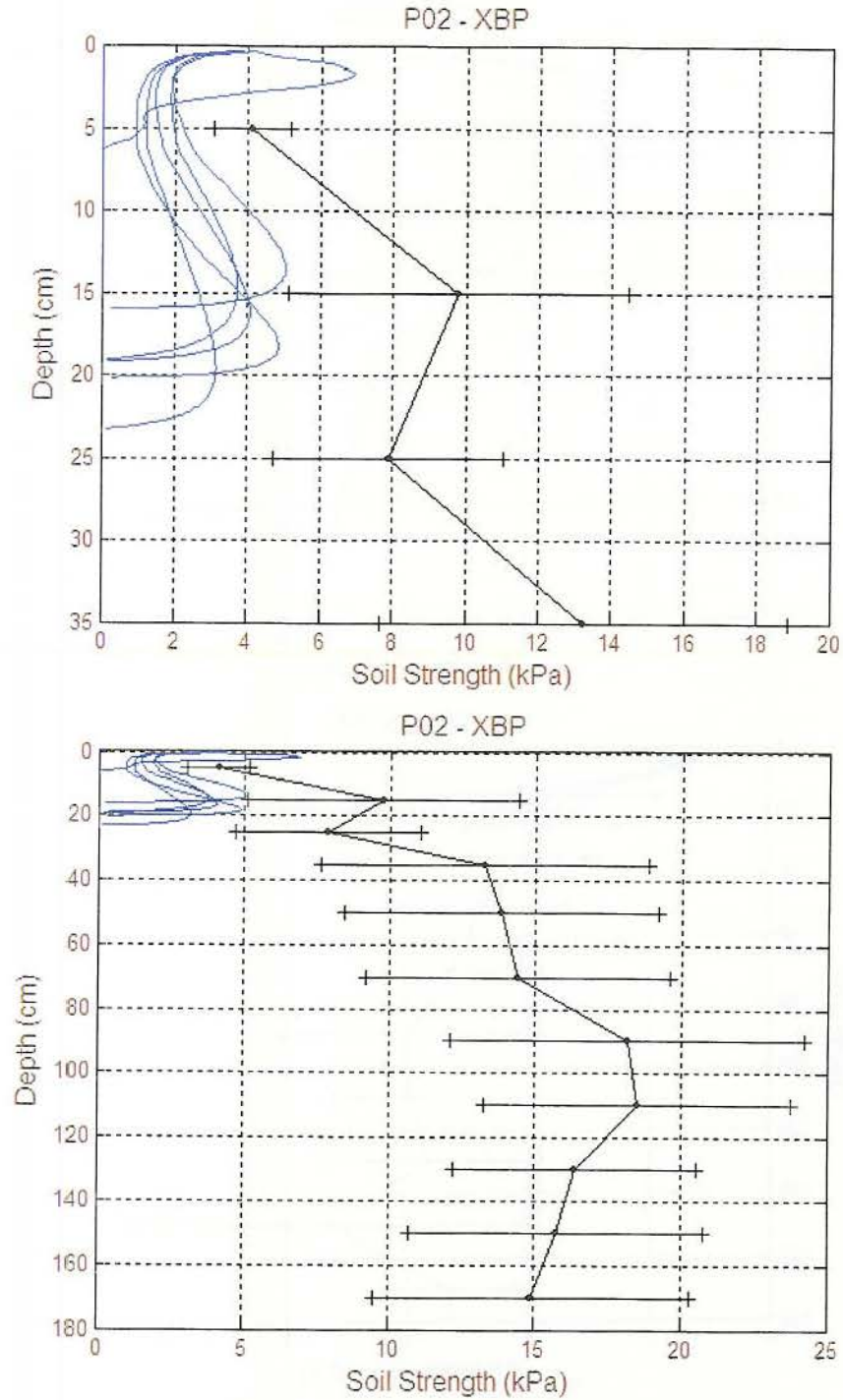


Fig. 21 Depth vs. XBP predicted shear strength and lab measured vane shear strength for P02
(site average and standard deviation shown as error bars)

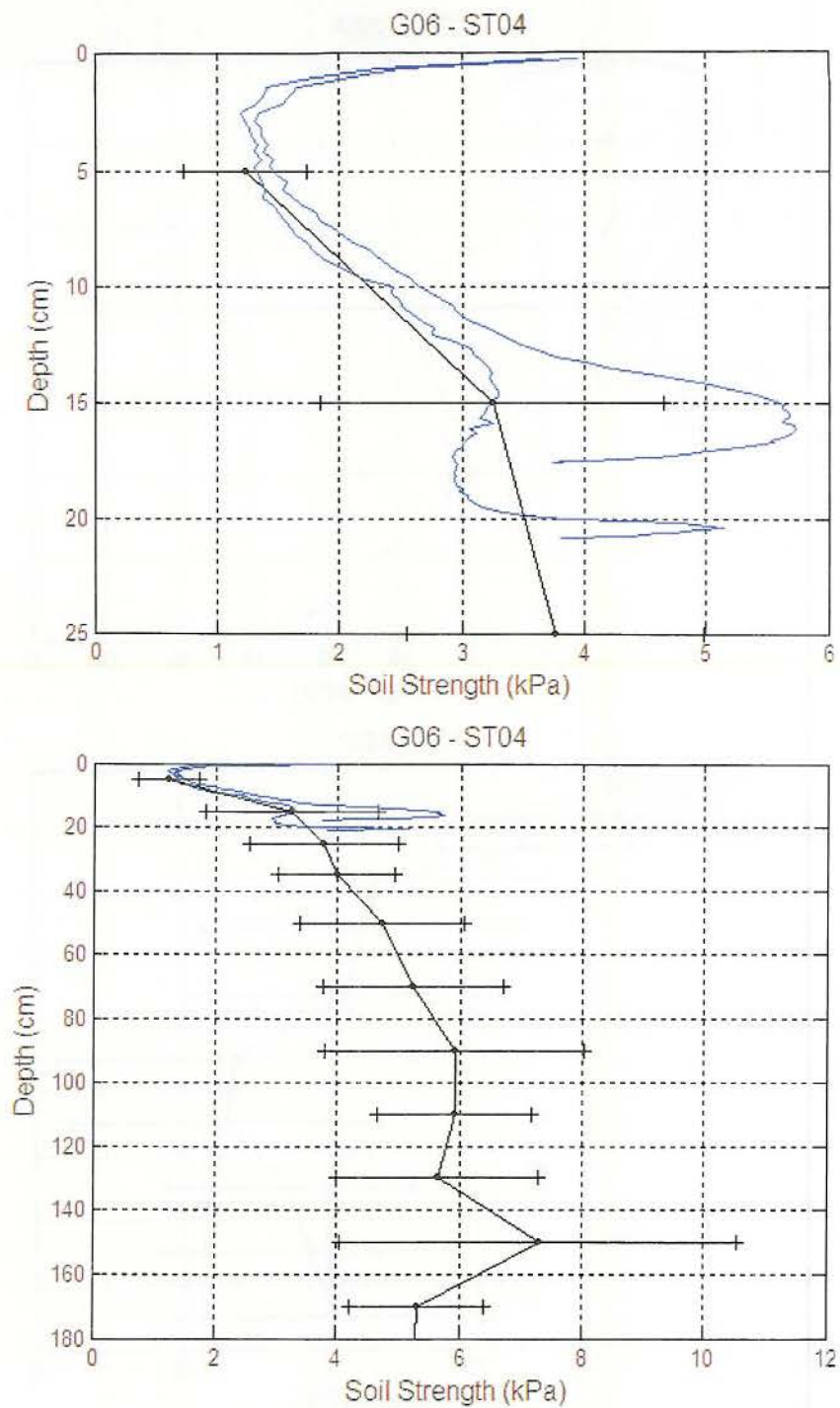


Fig. 22 Depth vs. XBP predicted shear strength and lab measured vane shear strength for G06, Station 04 (site average and standard deviation shown as error bars)

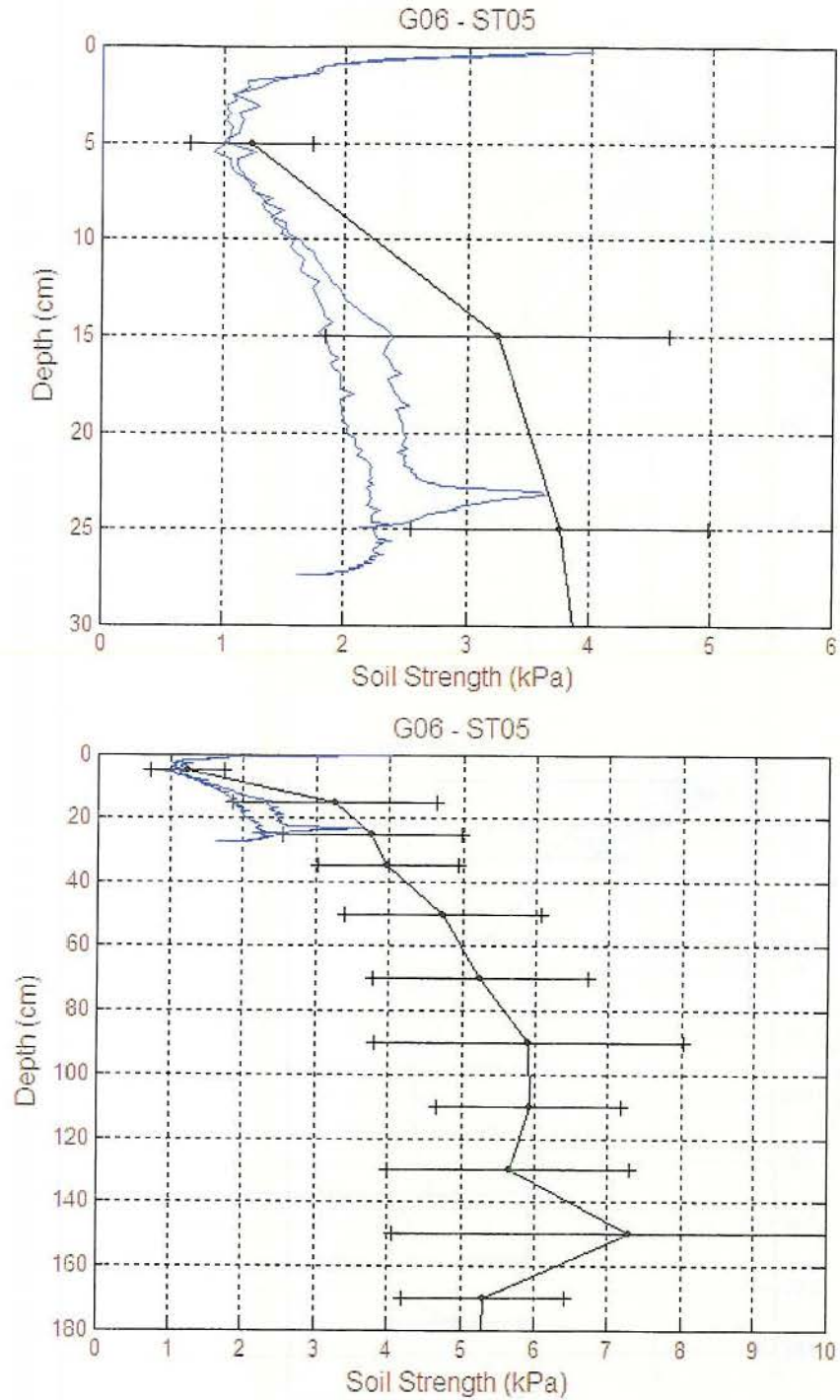


Fig. 23 Depth vs. XBP predicted shear strength and lab measured vane shear strength for G06, Station 05 (site average and standard deviation shown as error bars)

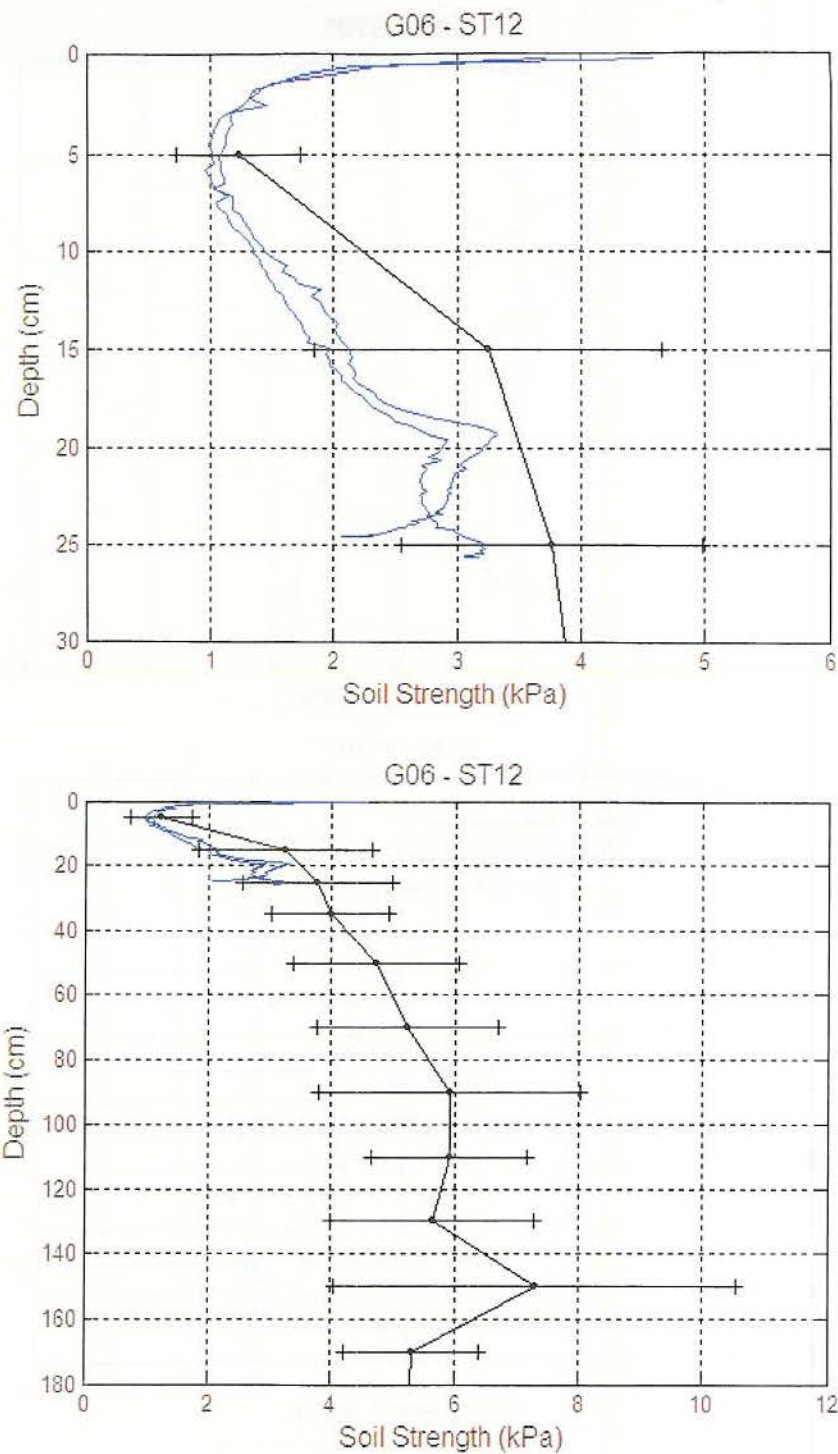


Fig. 24 Depth vs. XBP predicted shear strength and lab measured vane shear strength for G06, Station 12 (site average and standard deviation shown as error bars)

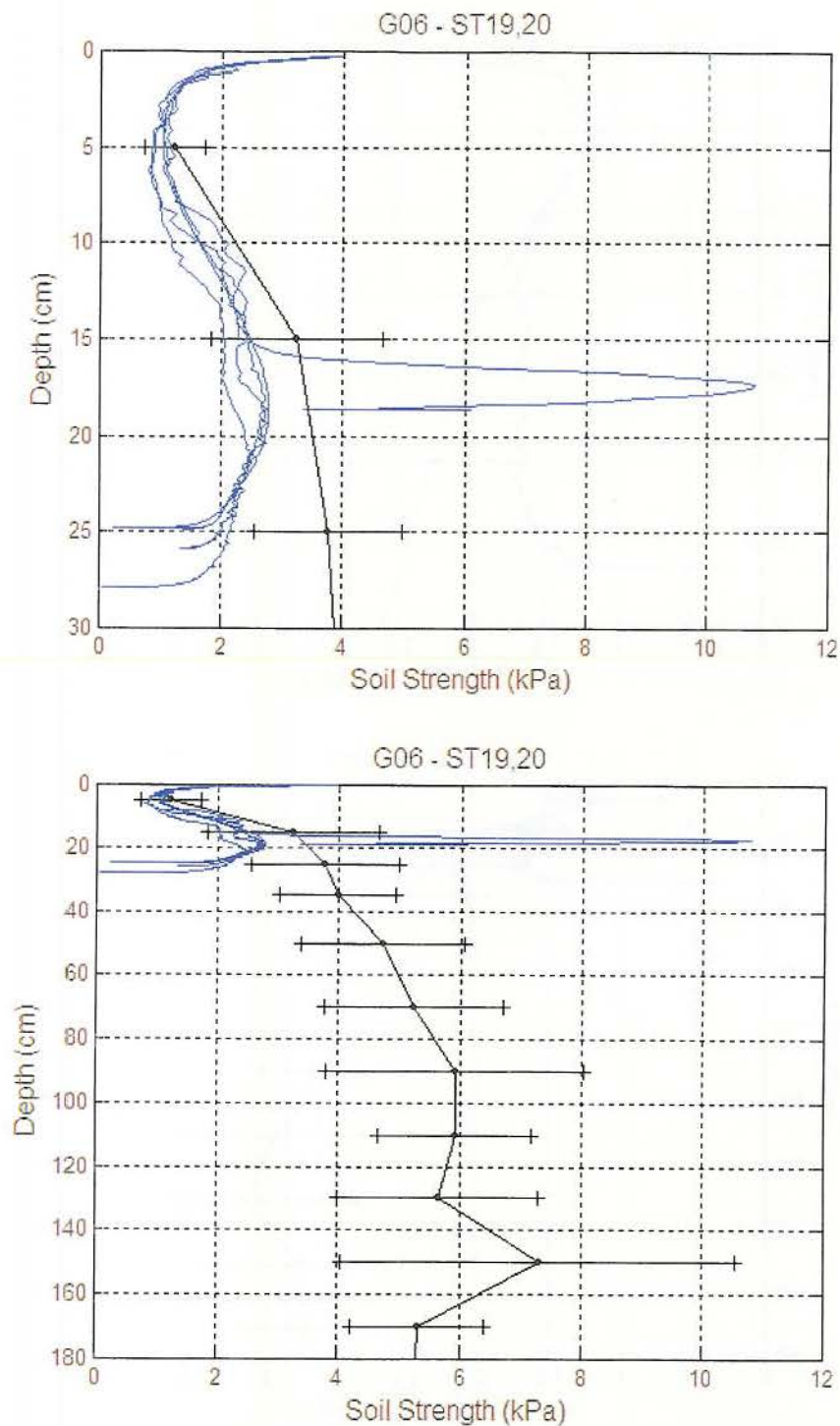


Fig. 25 Depth vs. XBP predicted shear strength and lab measured vane shear strength for G06, Stations 19 and 20 (site average and standard deviation shown as error bars)

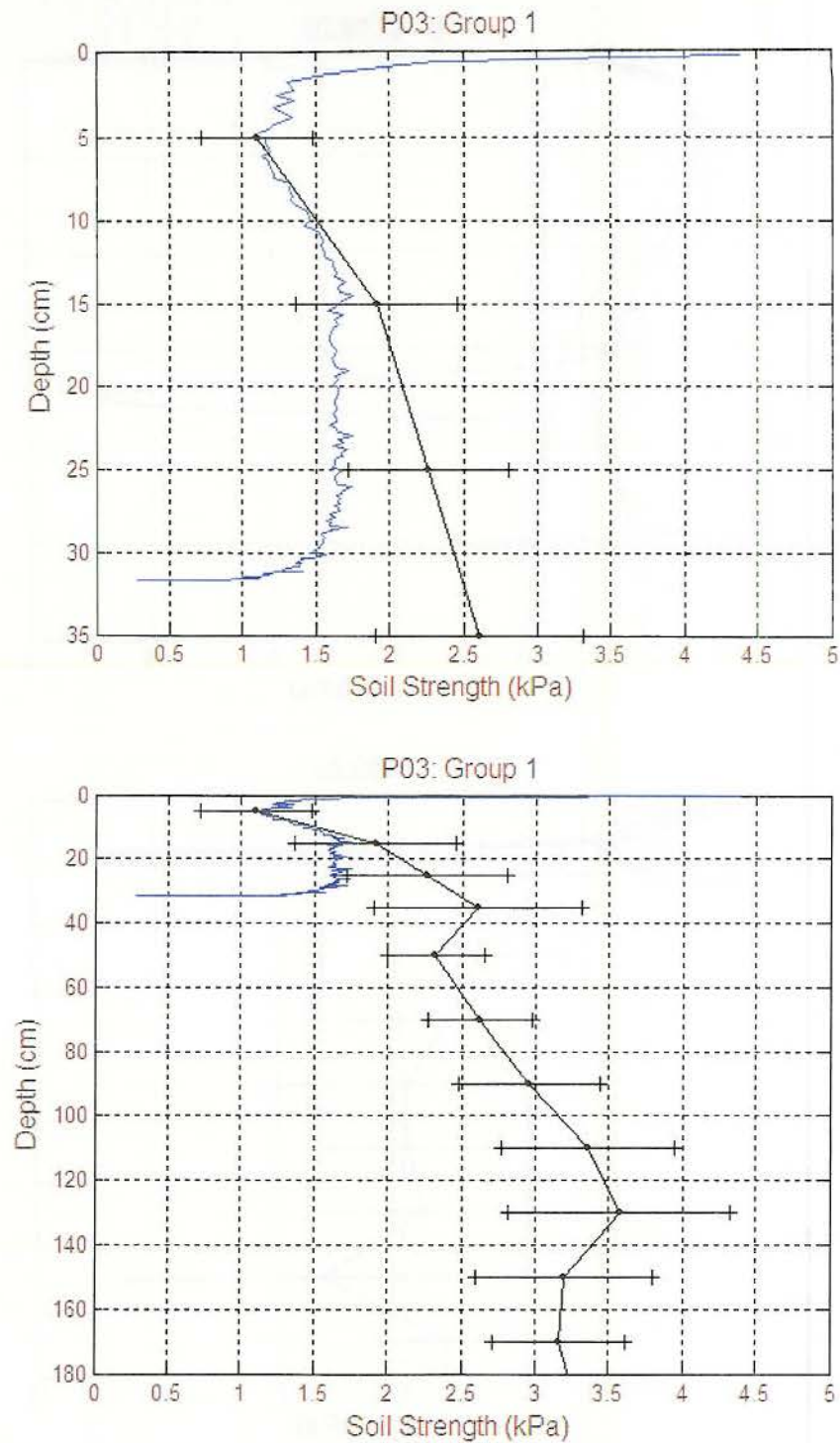


Fig. 26 Depth vs. XBP predicted shear strength and lab measured vane shear strength for P03, Group 1 (site average and standard deviation shown as error bars)

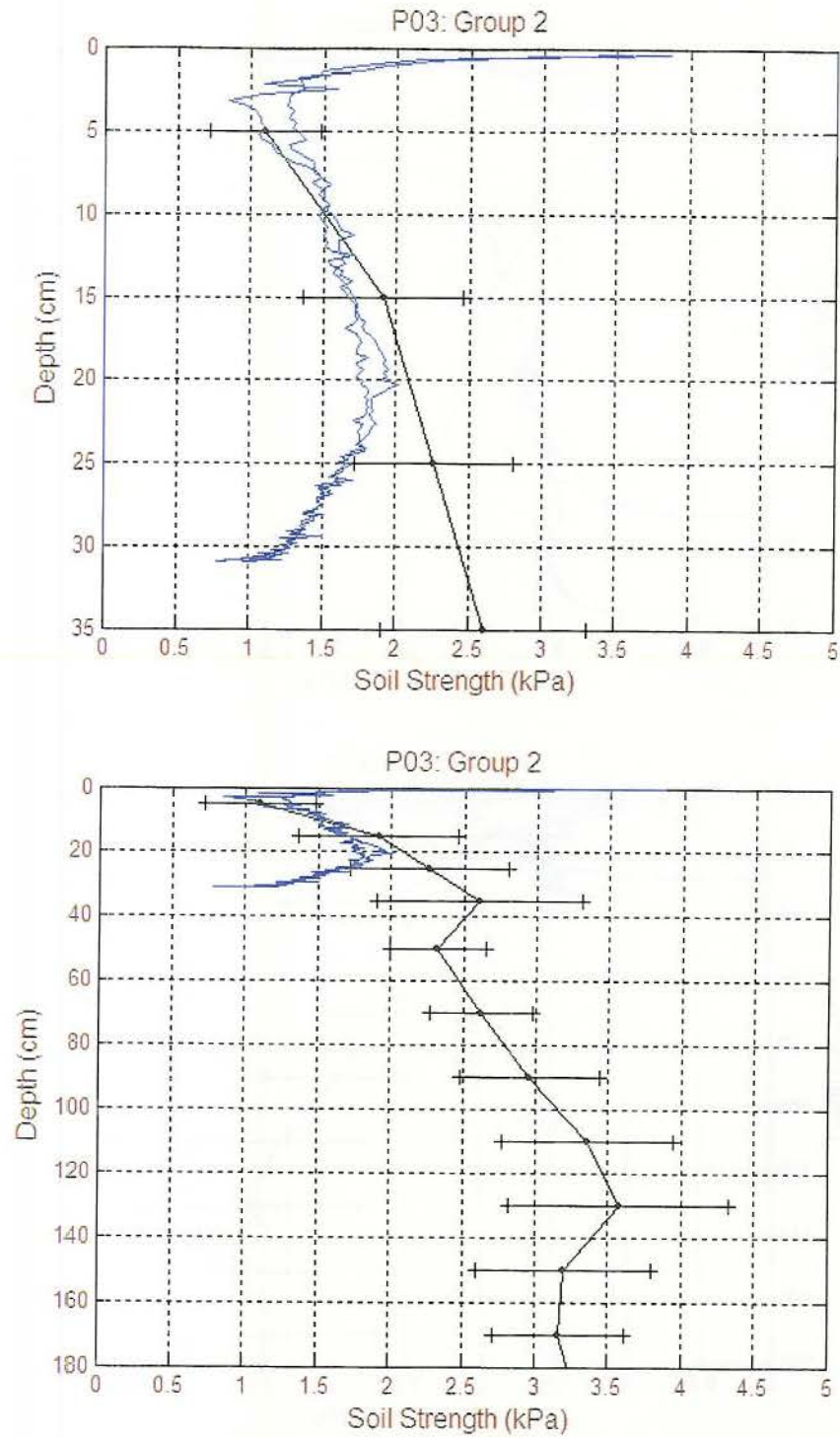


Fig. 27 Depth vs. XBP predicted shear strength and lab measured vane shear strength for P03, Group 2 (site average and standard deviation shown as error bars)

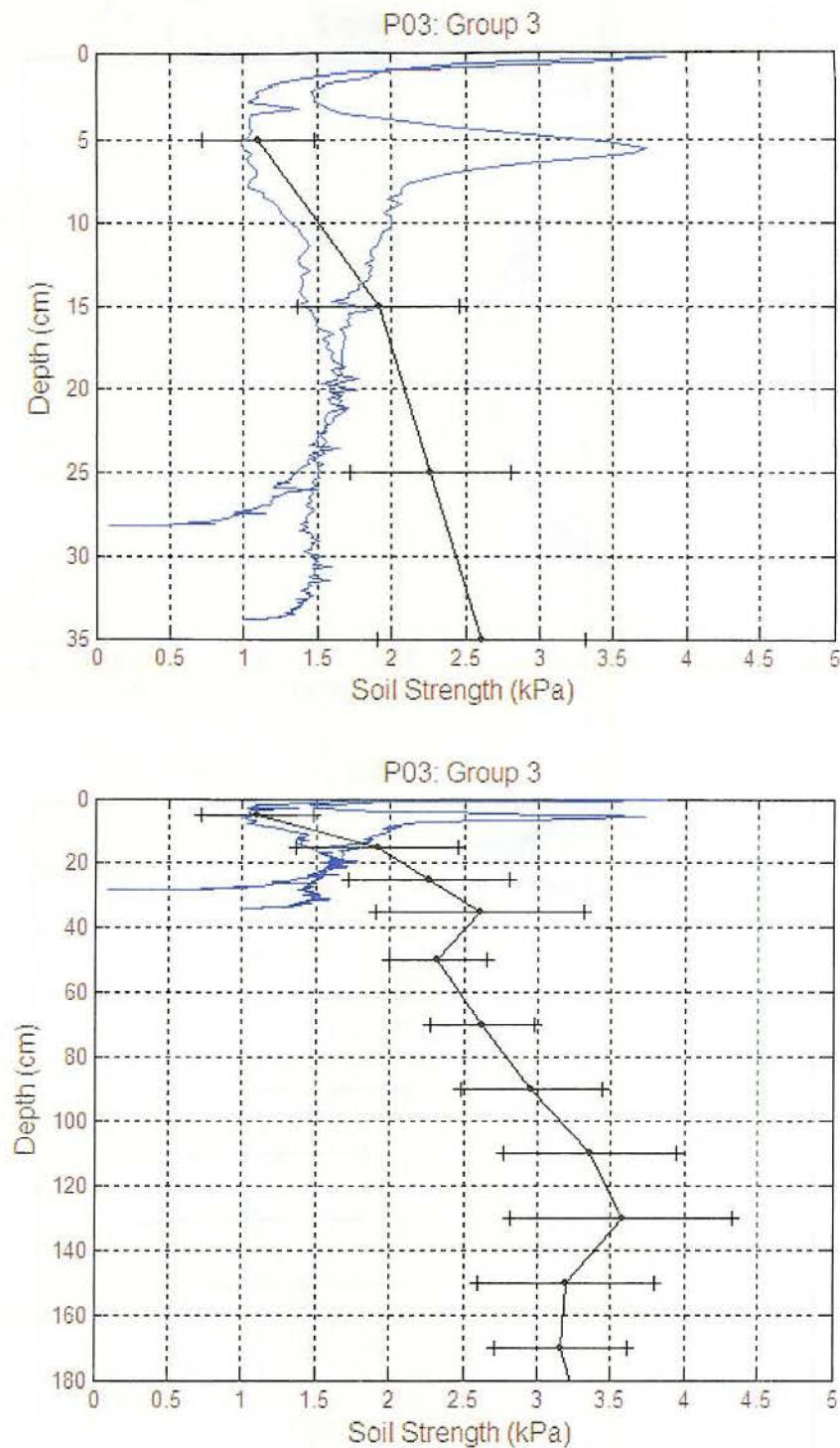


Fig. 28 Depth vs. XBP predicted shear strength and lab measured vane shear strength for P03, Group 3 (site average and standard deviation shown as error bars)

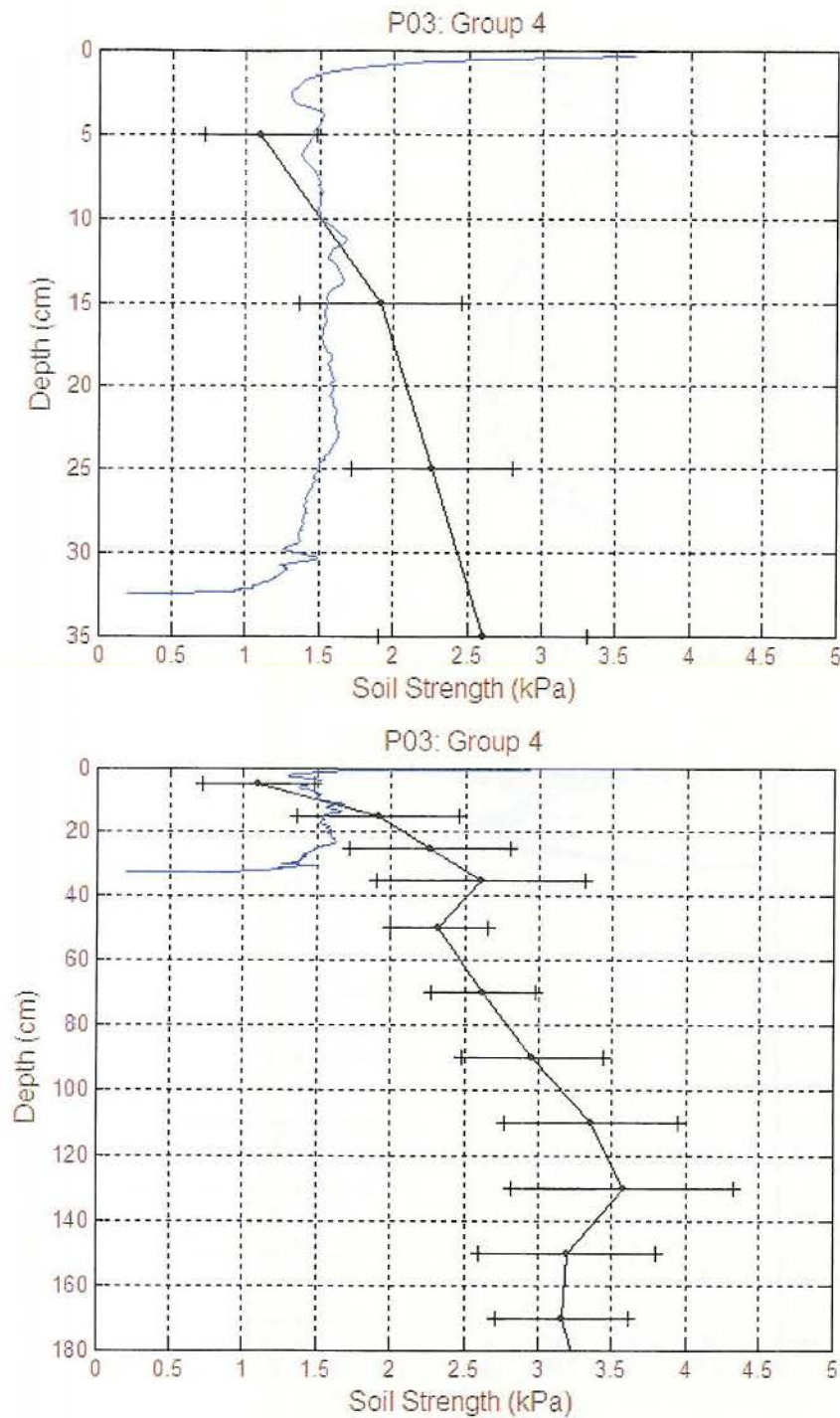


Fig. 29 Depth vs. XBP predicted shear strength and lab measured vane shear strength for P03, Group 4 (site average and standard deviation shown as error bars)

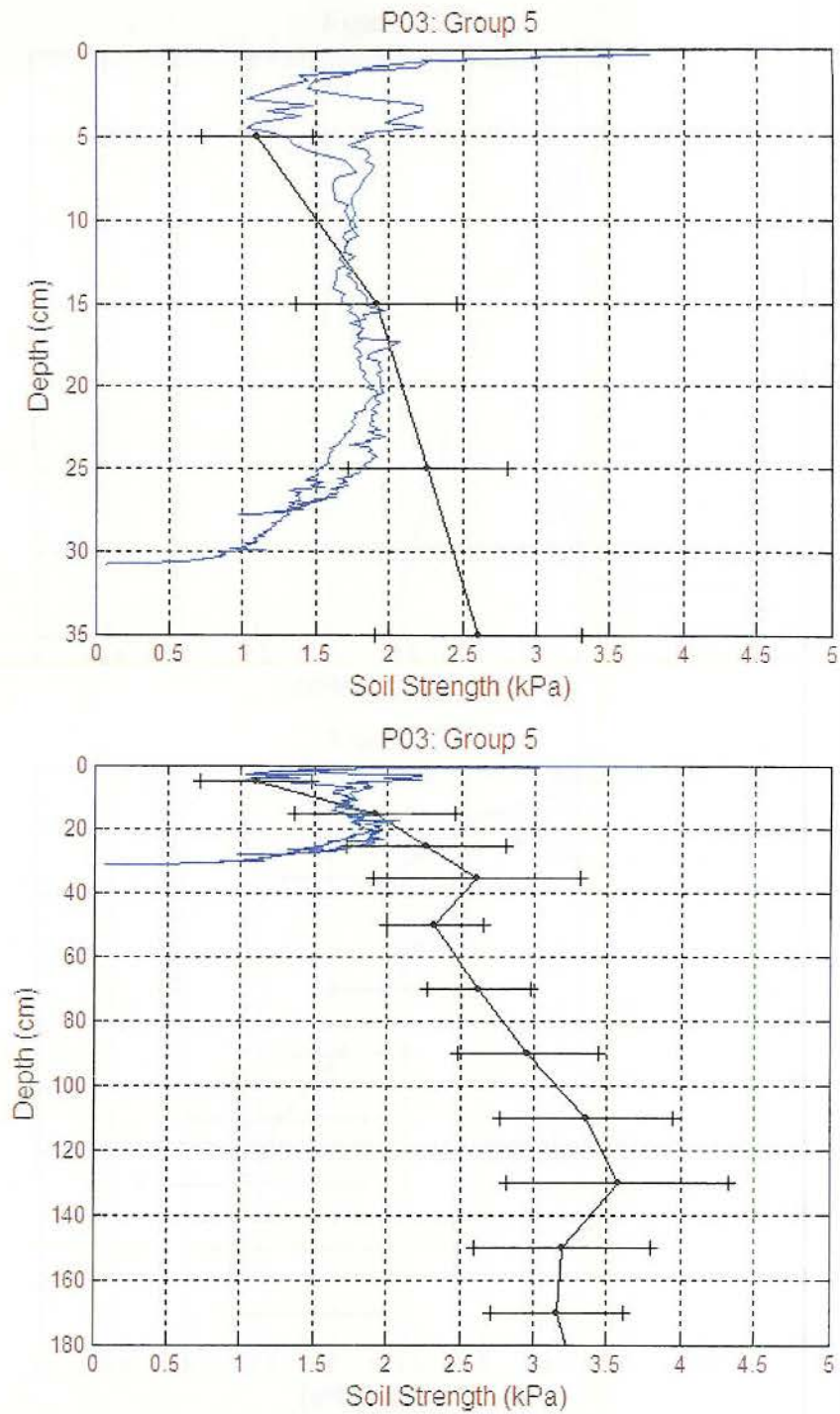


Fig. 30 Depth vs. XBP predicted shear strength and lab measured vane shear strength for P03, Group 5 (site average and standard deviation shown as error bars)

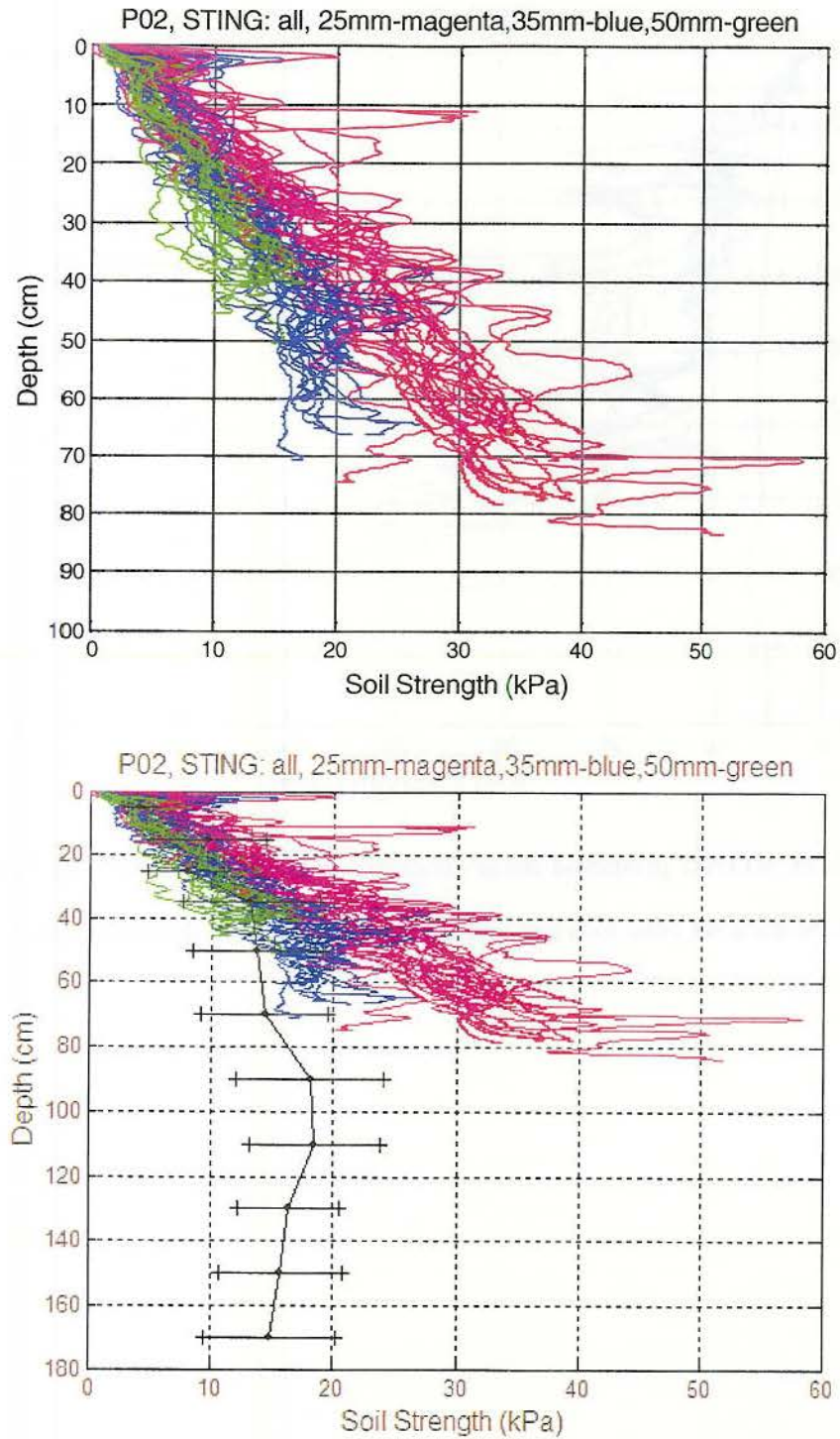


Fig. 31 Depth vs. STING predicted shear strength and lab measured vane shear strength for P02 (site average and standard deviation shown as error bars)

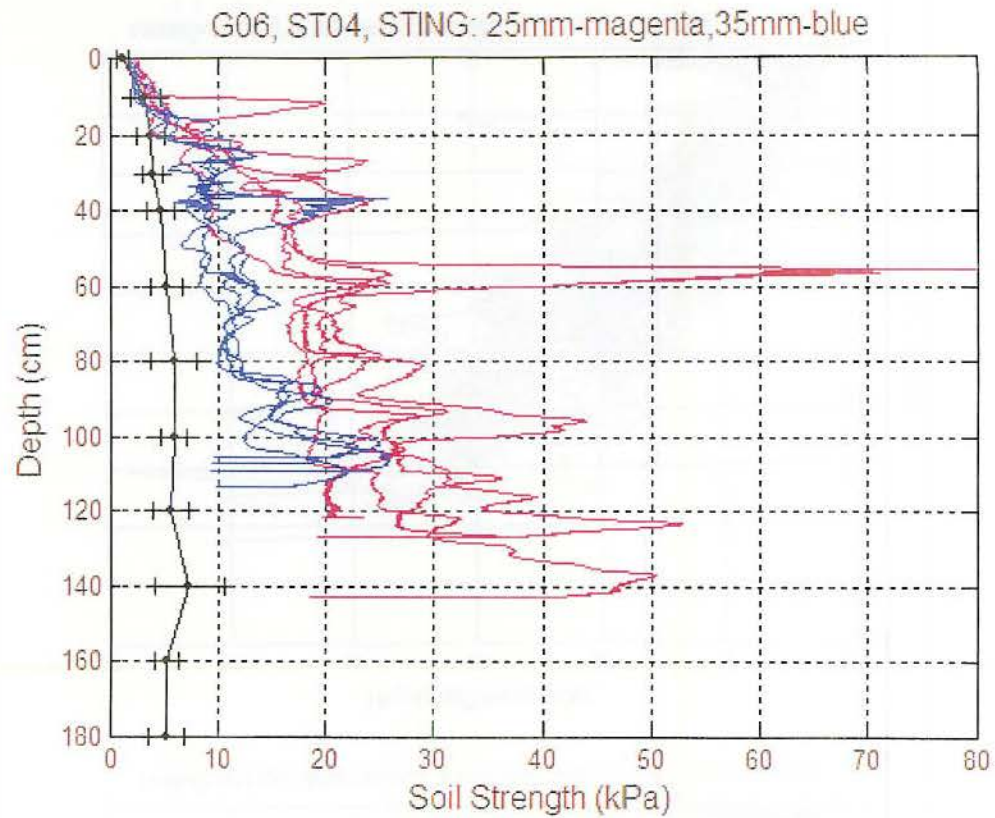


Fig. 32 Depth vs. STING predicted shear strength and lab measured vane shear strength for G06, Station 04 (site average and standard deviation shown as error bars)

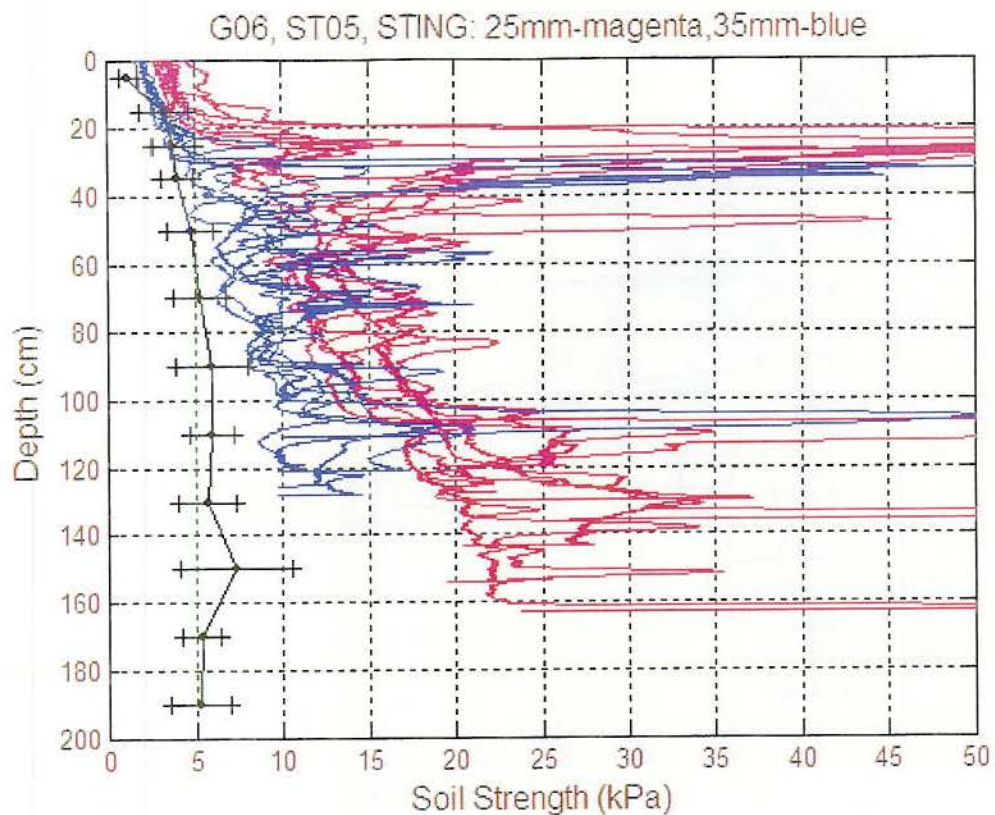


Fig. 33 Depth vs. STING predicted shear strength and lab measured vane shear strength for G06, Station 05 (site average and standard deviation shown as error bars)

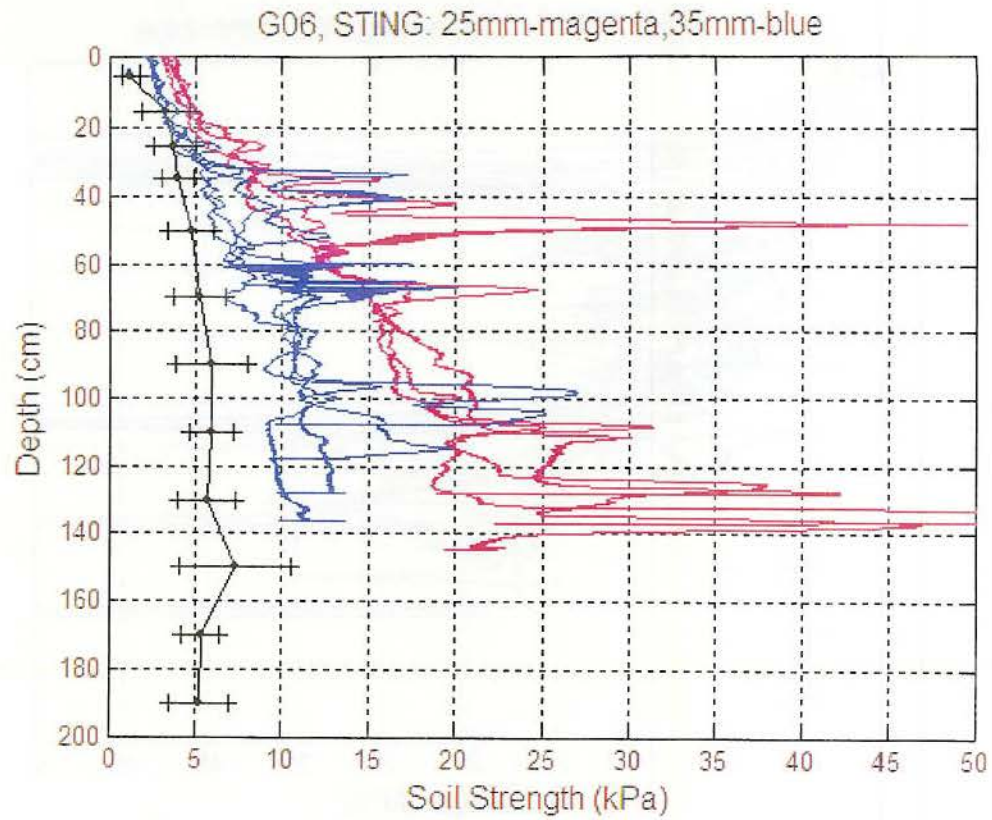


Fig. 34 Depth vs. STING predicted shear strength and lab measured vane shear strength for G06, Station 12 (site average and standard deviation shown as error bars)

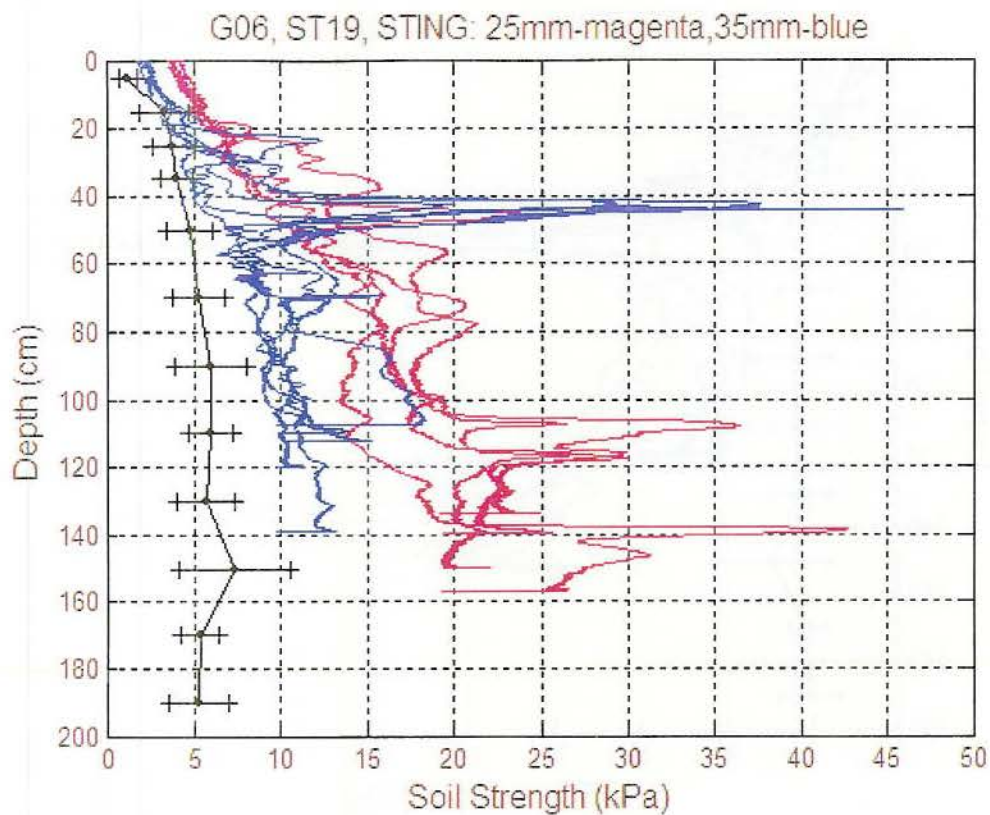


Fig. 35 Depth vs. STING predicted shear strength and lab measured vane shear strength for G06, Station 19 (site average and standard deviation shown as error bars)

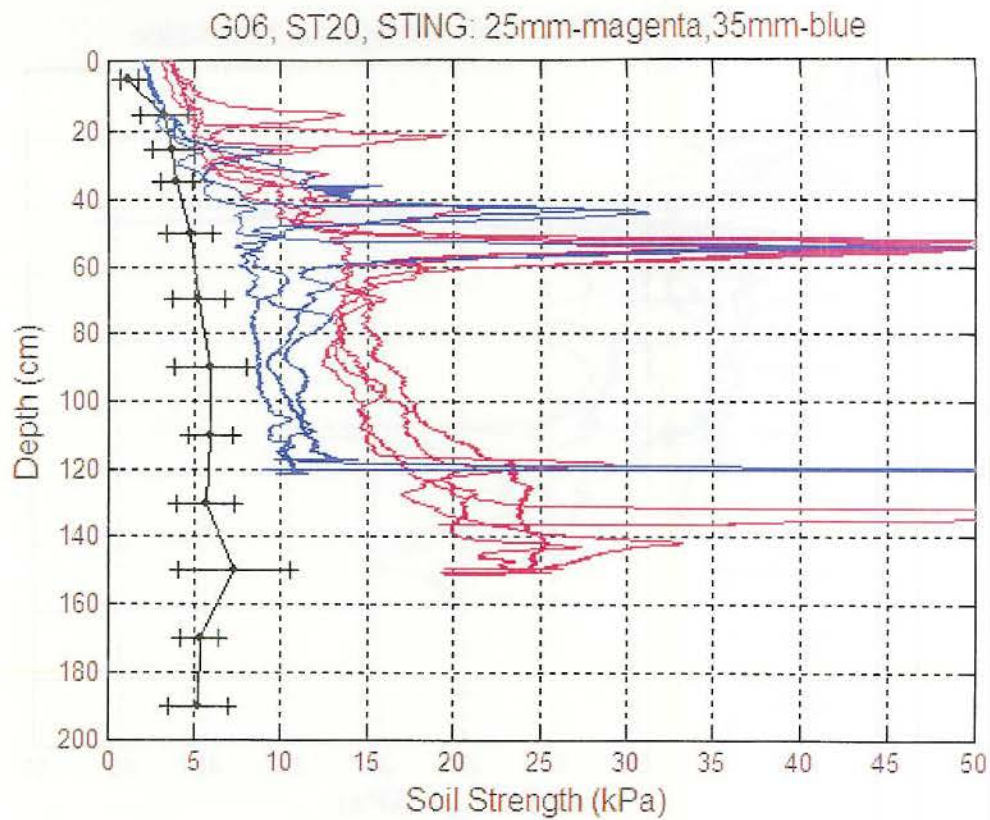


Fig. 36 Depth vs. STING predicted shear strength and lab measured vane shear strength for G06, Station 20 (site average and standard deviation shown as error bars)

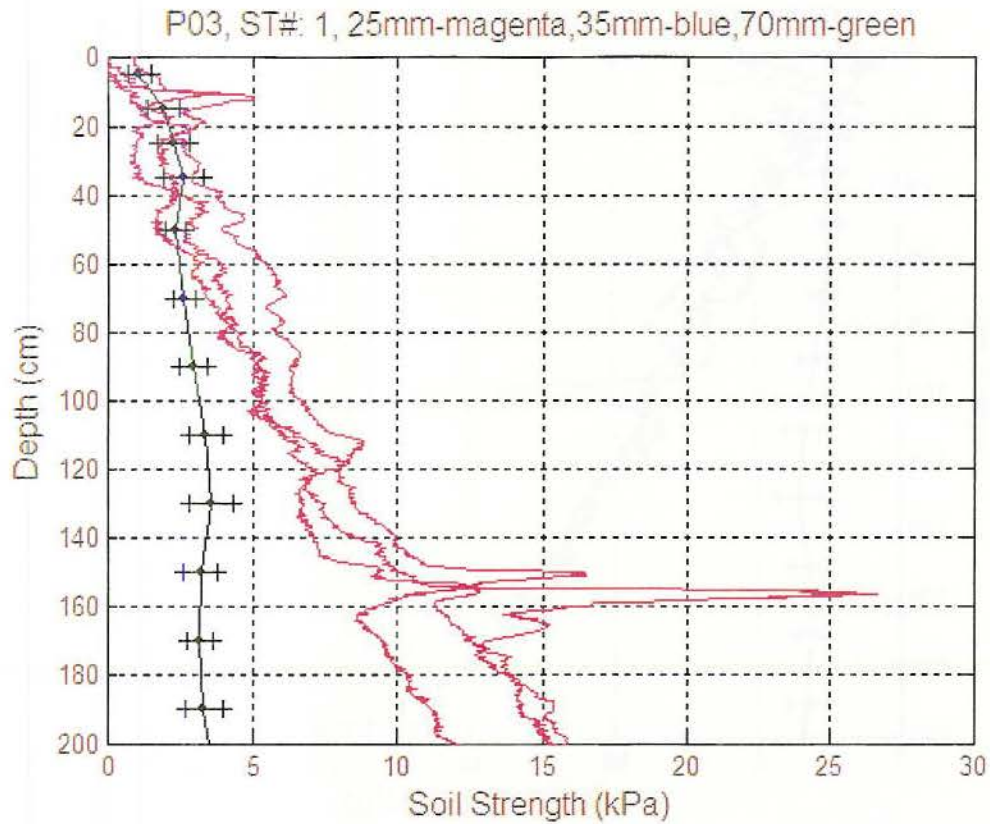


Fig. 37 Depth vs. STING predicted shear strength and lab measured vane shear strength for P03, STING drop 1 (site average and standard deviation shown as error bars)

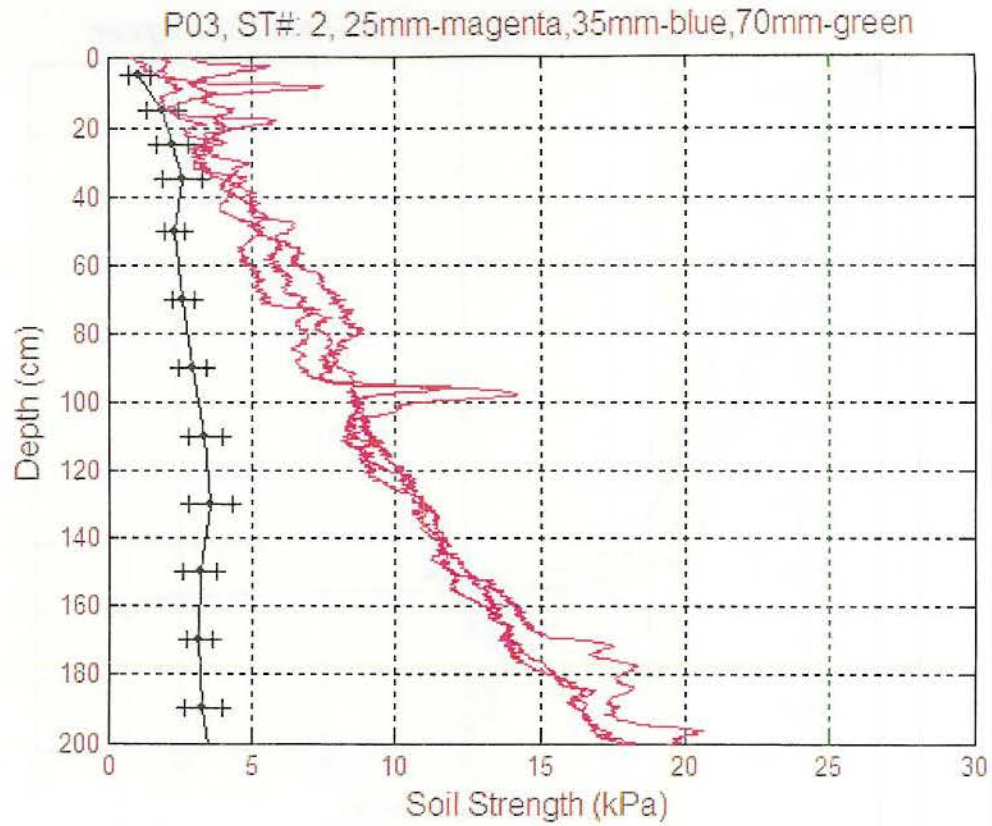


Fig. 38 Depth vs. STING predicted shear strength and lab measured vane shear strength for P03, STING drop 2 (site average and standard deviation shown as error bars)

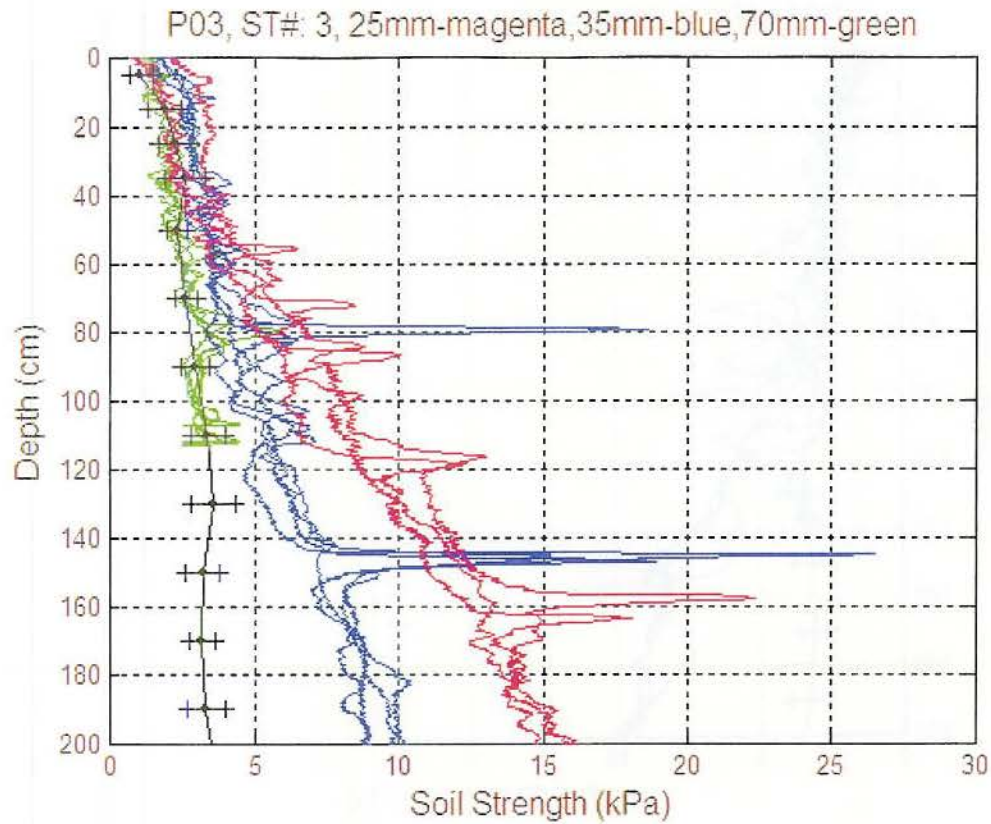


Fig. 39 Depth vs. STING predicted shear strength and lab measured vane shear strength for P03, STING drop 3 (site average and standard deviation shown as error bars)

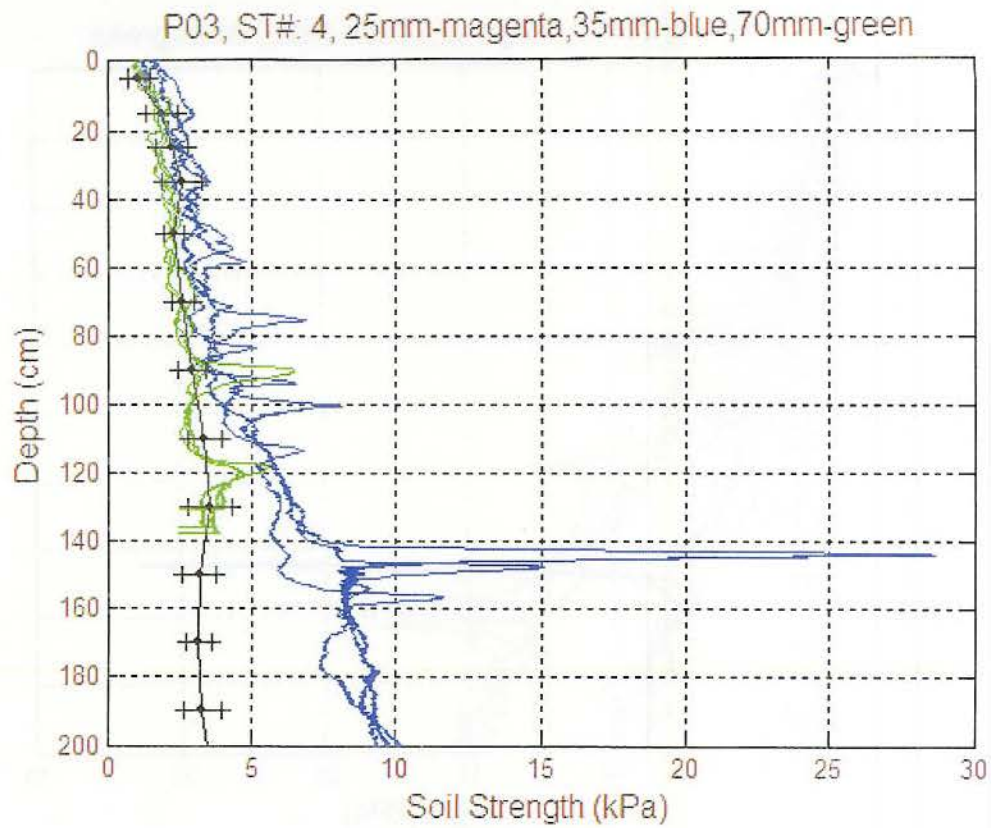


Fig. 40 Depth vs. STING predicted shear strength and lab measured vane shear strength for P03, STING drop 4 (site average and standard deviation shown as error bars)

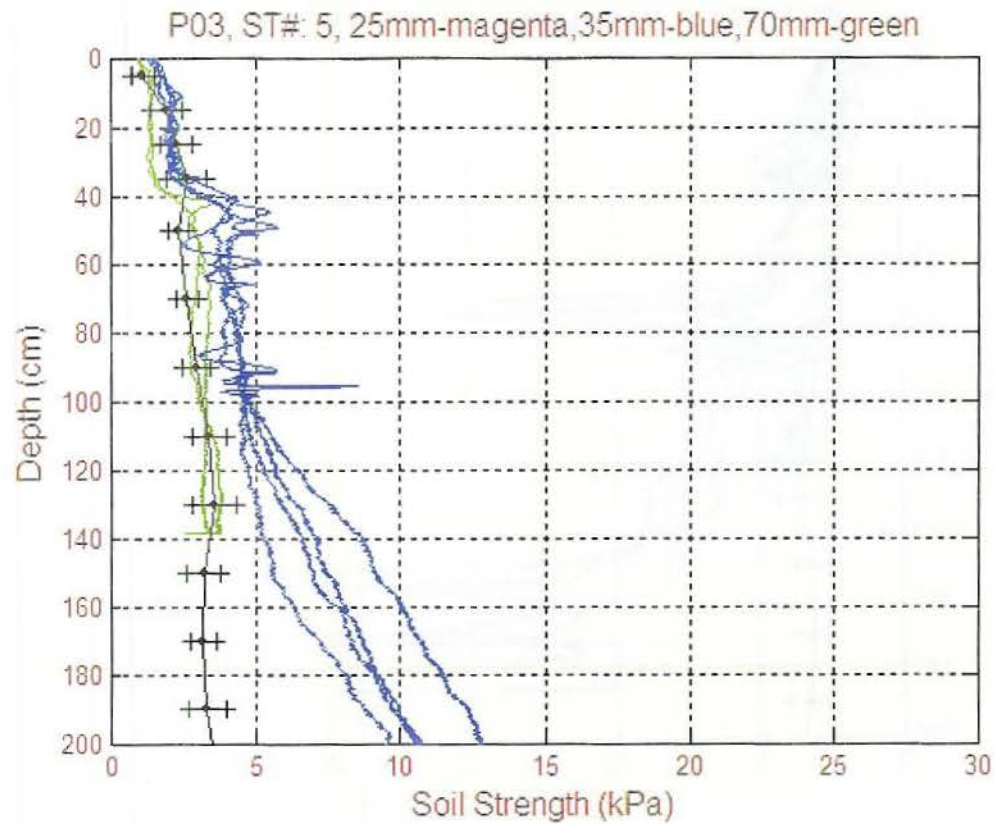


Fig. 41 Depth vs. STING predicted shear strength and lab measured vane shear strength for P03, STING drop 5 (site average and standard deviation shown as error bars)

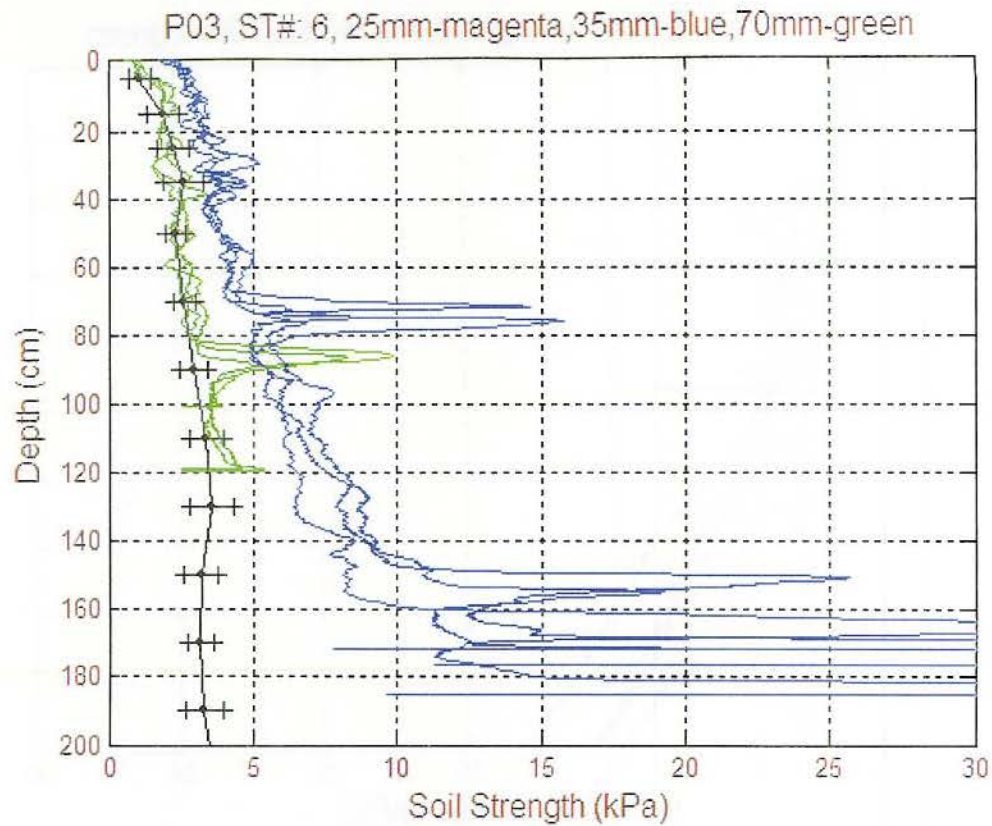


Fig. 42 Depth vs. STING predicted shear strength and lab measured vane shear strength for P03, STING drop 6 (site average and standard deviation shown as error bars)

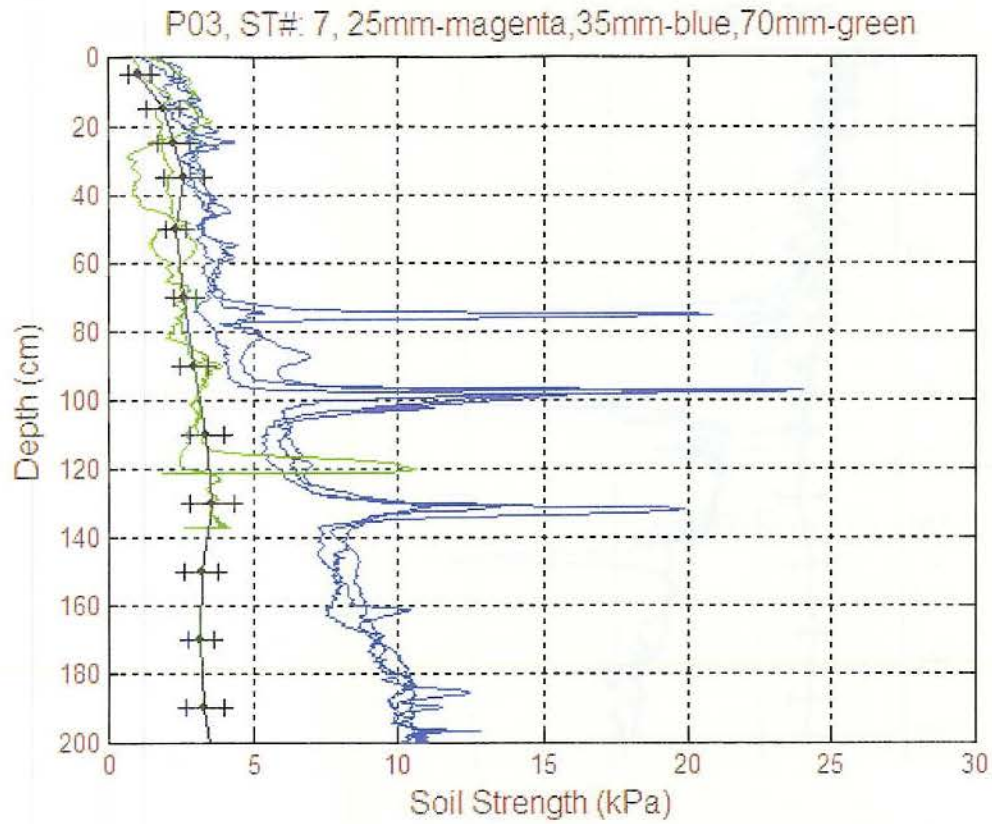


Fig. 43 Depth vs. STING predicted shear strength and lab measured vane shear strength for P03, STING drop 7 (site average and standard deviation shown as error bars)

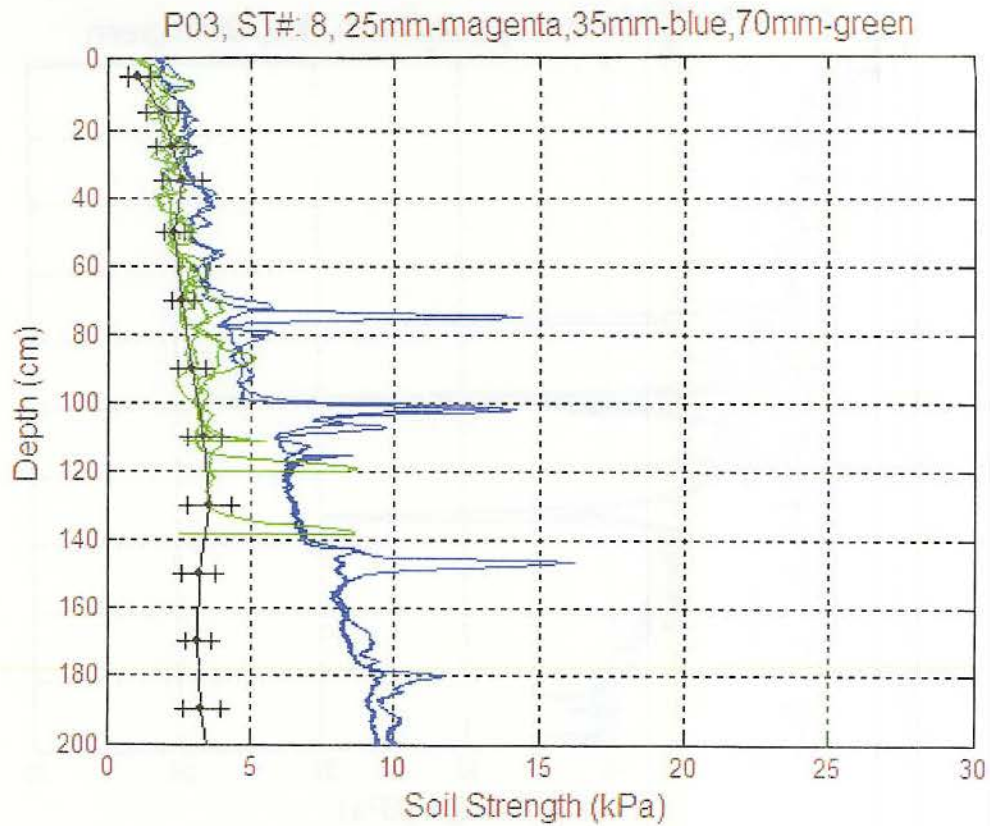


Fig. 44 Depth vs. STING predicted shear strength and lab measured vane shear strength for P03, STING drop 8 (site average and standard deviation shown as error bars)

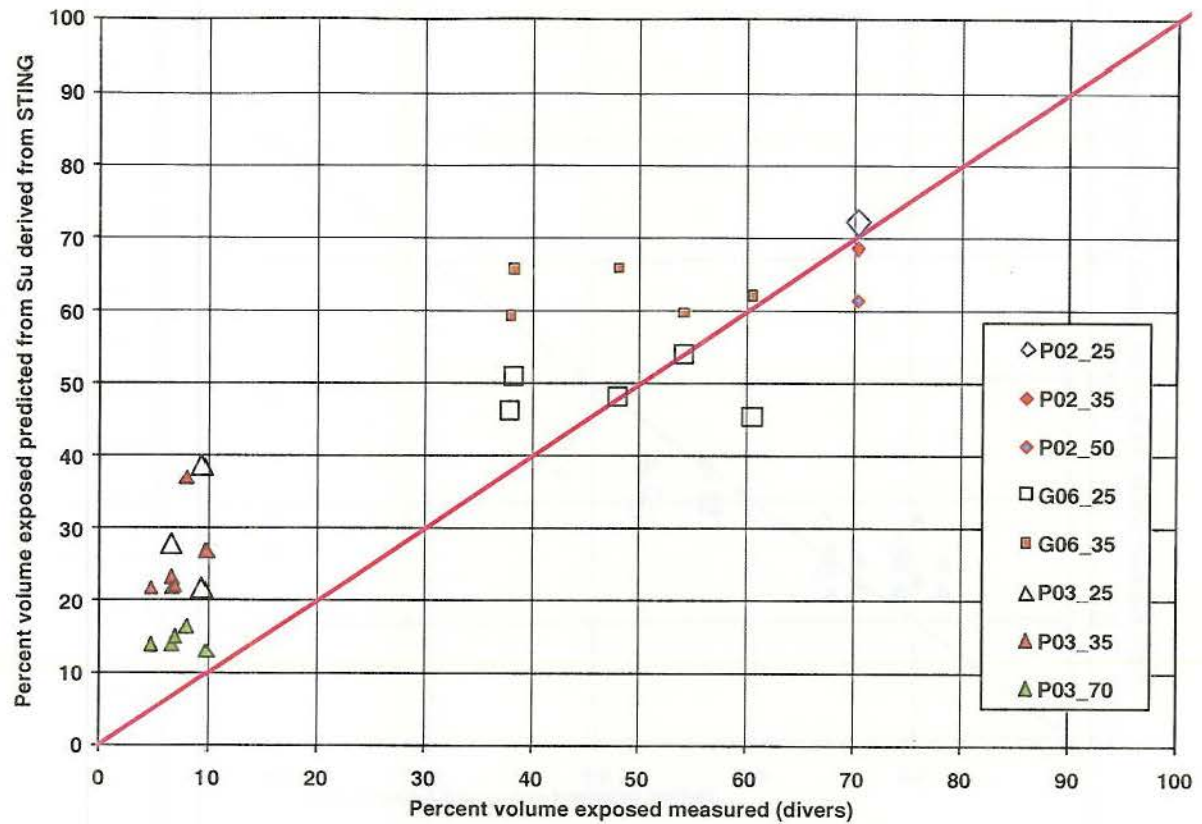


Fig. 45 Diver measured vs. predicted percent volume exposed. Predictions are based on averaged cylinder configuration and dynamics on impact, and STING inferred shear strength

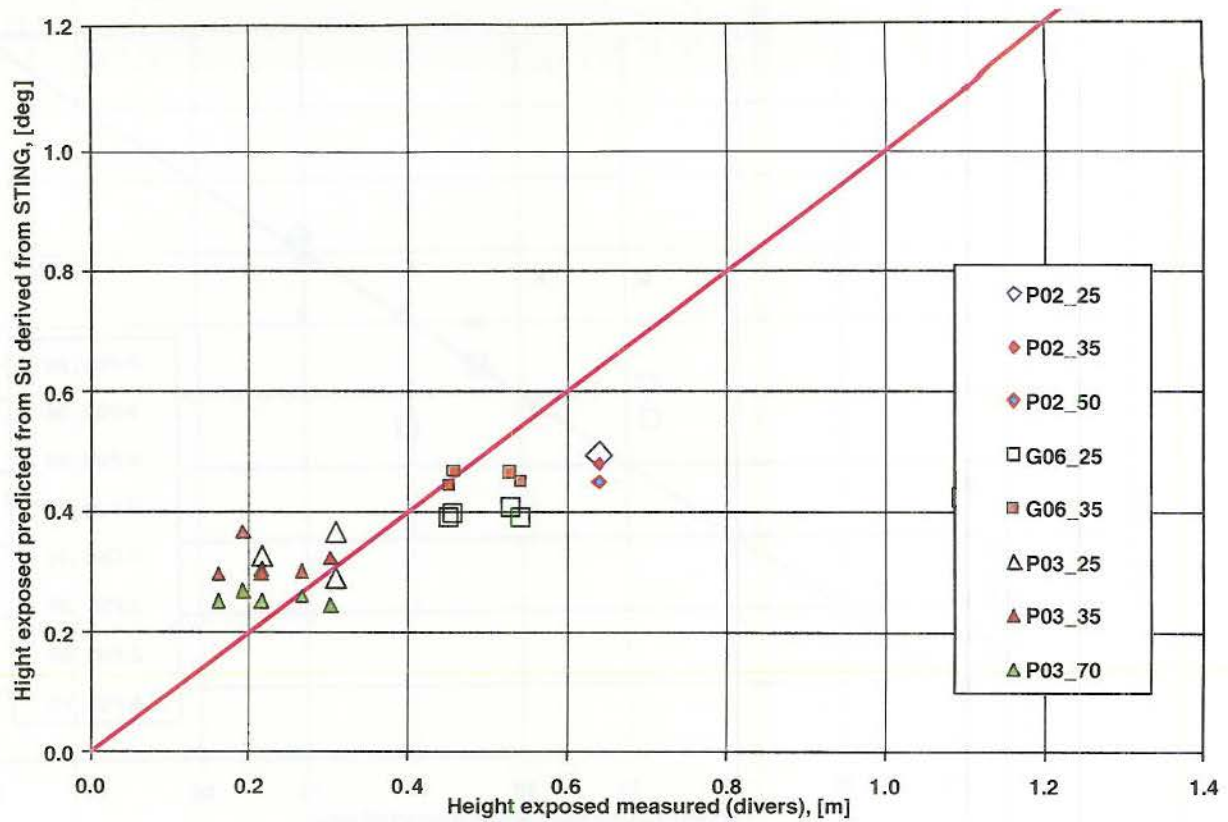


Fig. 46 Diver measured vs. predicted maximum height exposed. Predictions are based on averaged cylinder configuration and dynamics on impact, and STING inferred shear strength

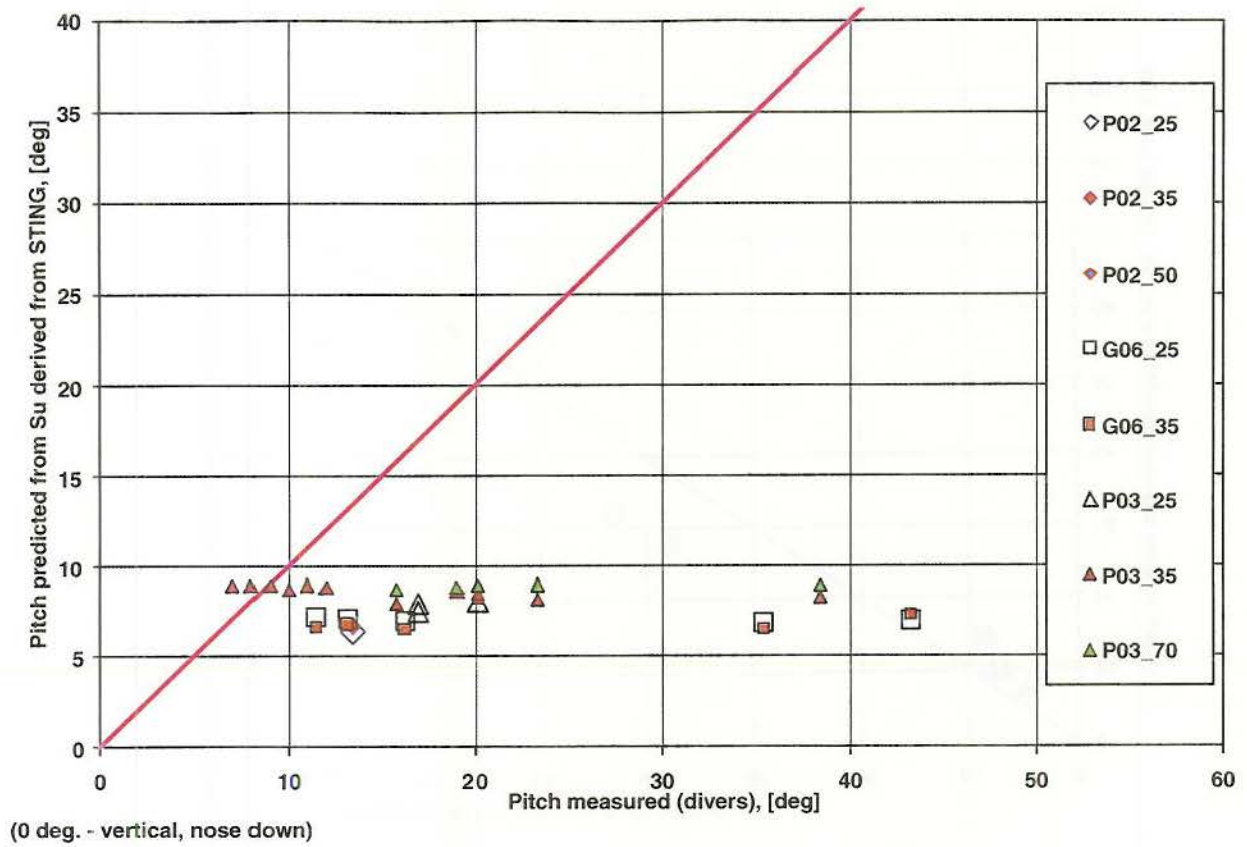


Fig. 47 Diver measured vs. predicted final pitch. Predictions are based on averaged cylinder configuration and dynamics on impact, and STING inferred shear strength

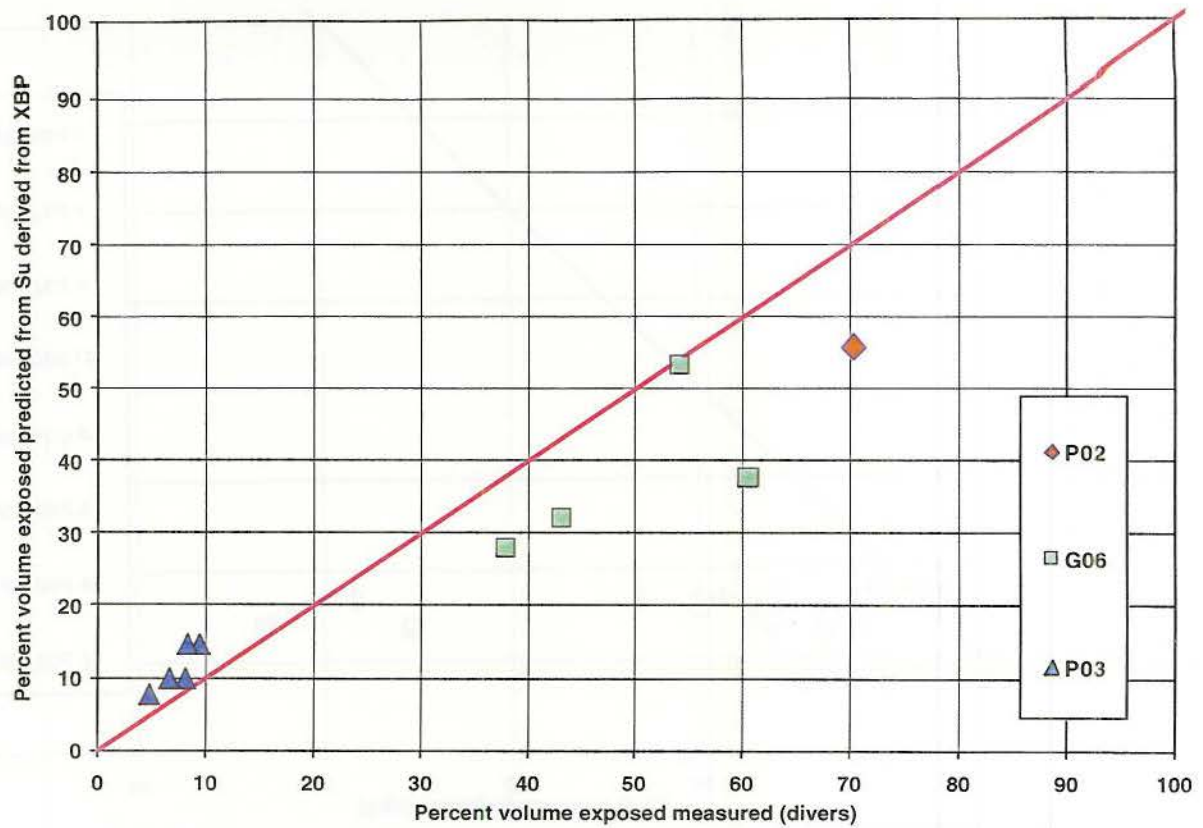


Fig. 48 Diver measured vs. predicted percent volume exposed. Predictions are based on averaged cylinder configuration and dynamics on impact, and XBP inferred shear strength

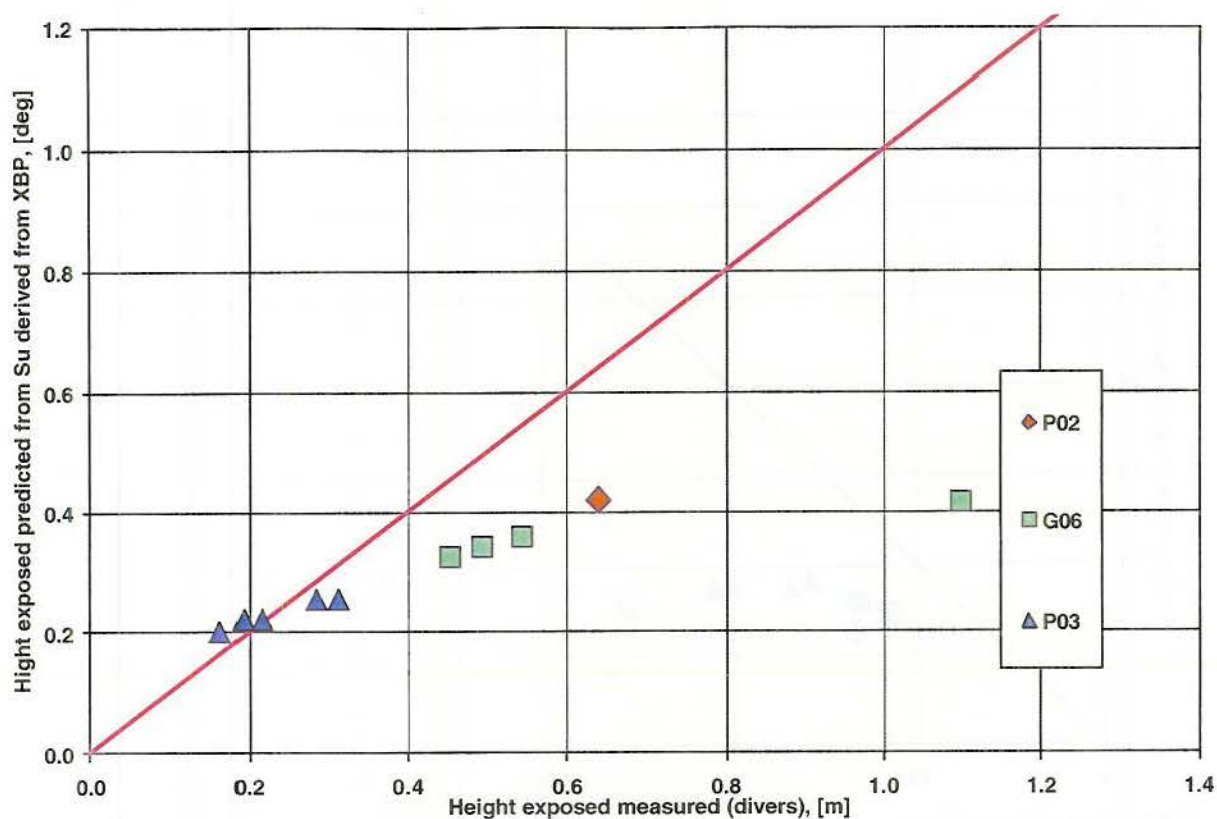


Fig. 49 Diver measured vs. predicted maximum height exposed. Predictions are based on averaged cylinder configuration and dynamics on impact, and XBP inferred shear strength

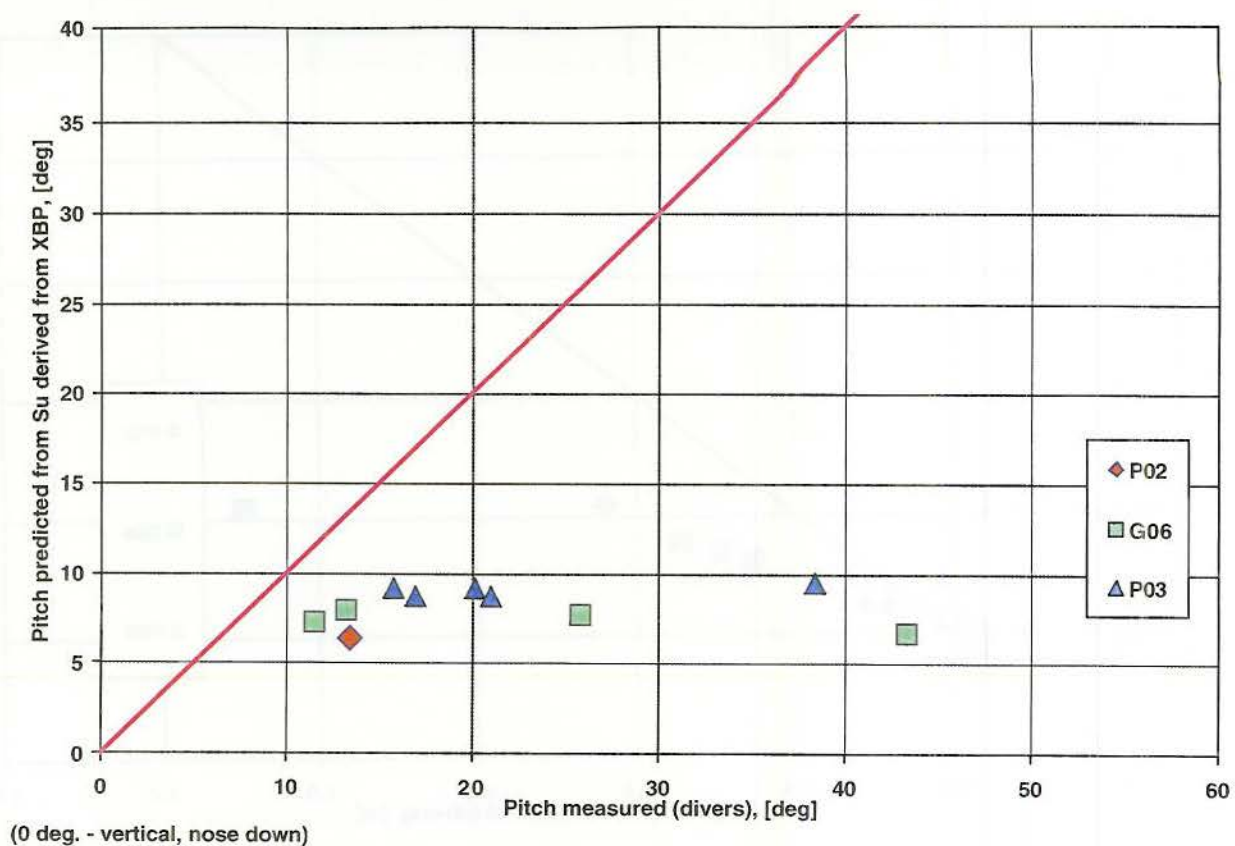


Fig. 50 Diver measured vs. predicted final pitch. Predictions are based on averaged cylinder configuration and dynamics on impact, and XBP inferred shear strength

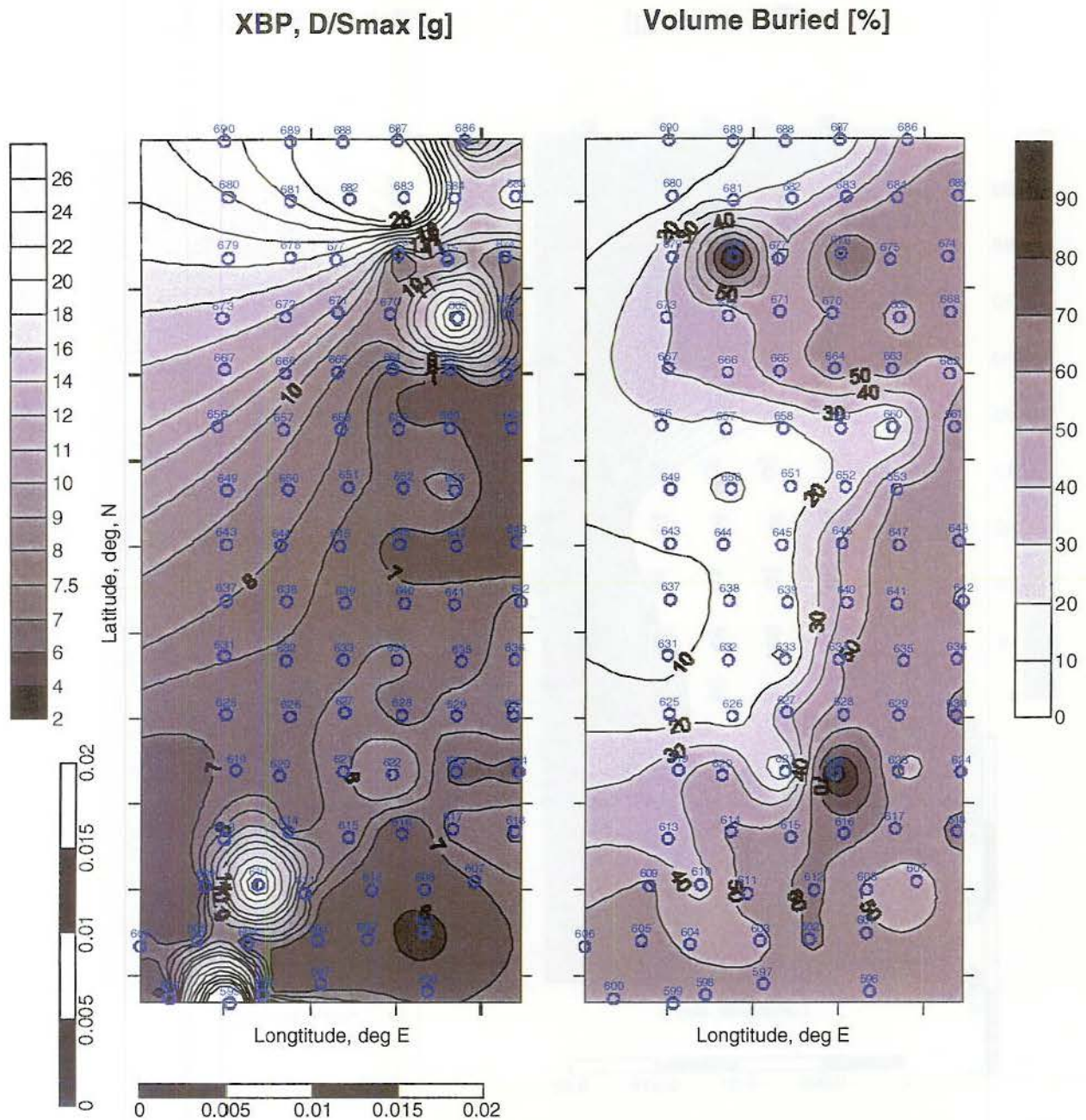


Fig. 51 Contour plots of the cylinder volume buried percentage (right) vs. D/S_{max} (left) calculated from XBP records for the SS location, Baltic Sea

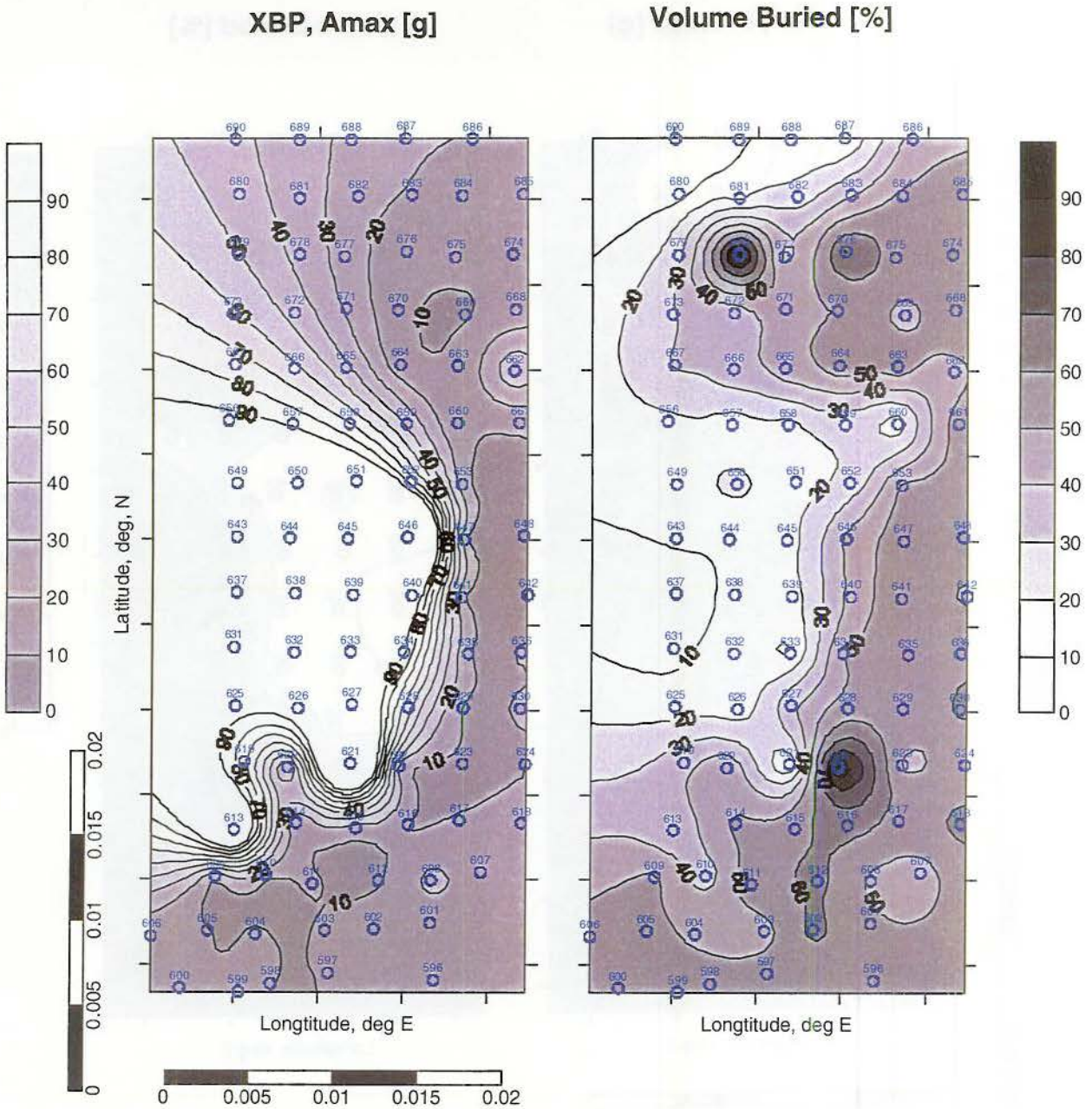


Fig. 52 Contour plots of the cylinder volume buried percentage (right) vs. peak deceleration, A_{max} , (left) calculated from XBP records for the SS location, Baltic Sea

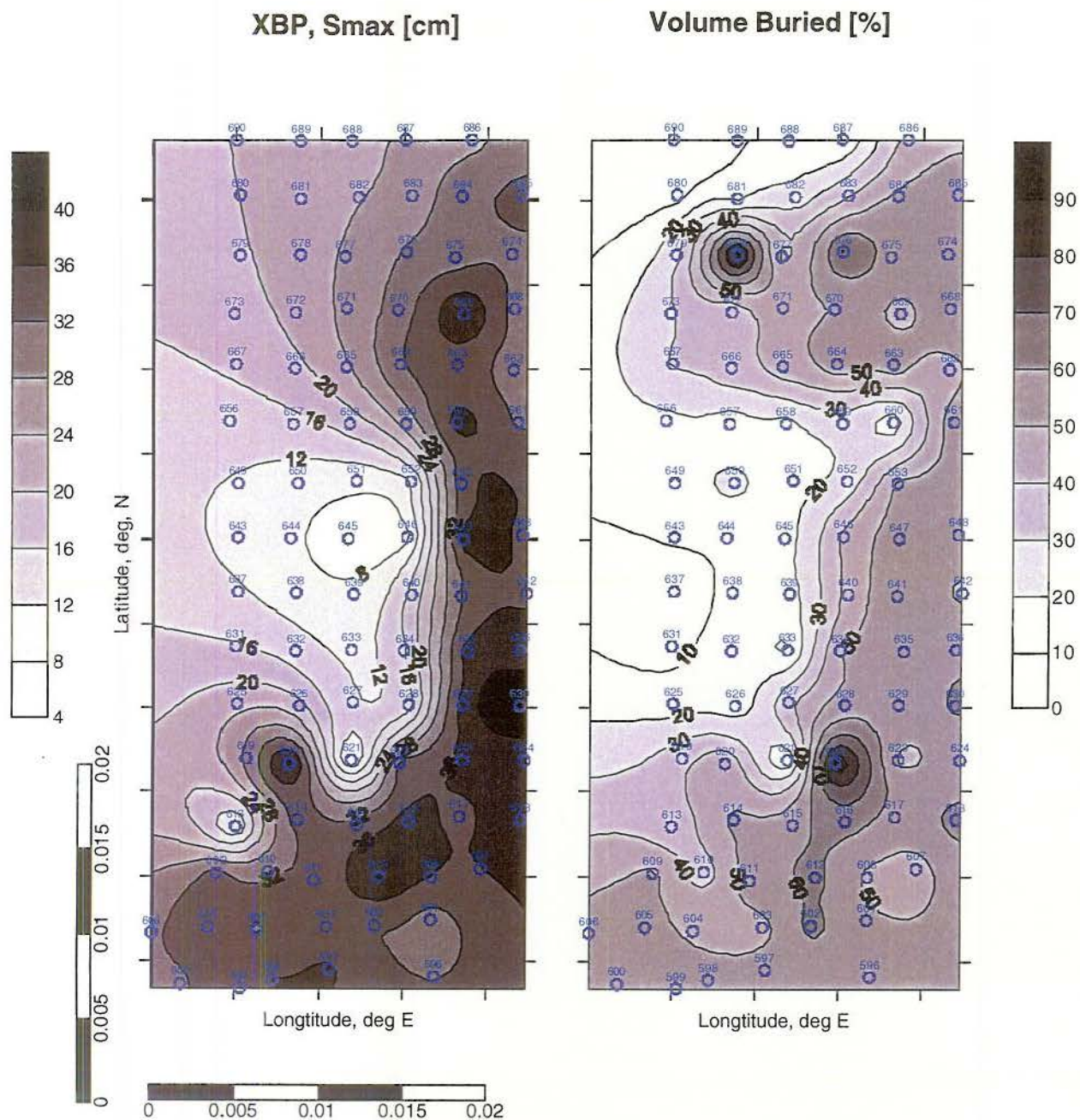


Fig. 53 Contour plots of the cylinder volume buried percentage (right) vs. maximum penetration distance, S_{max} , (left) calculated from XBP records for the SS location, Baltic Sea

Appendix A

A note on filtering the XBP signals contaminated with extraneous noise

A number of files processed up to date were contaminated with noise of variable complexity. The origin of this noise is believed to be in improper grounding of the XBP instrument during deployment. The nature of the noise is such that the amplitude of the noise increases after the probe comes in contact with the water surface and continues to increase (in a non-linear fashion) for as long as the probe is in motion. The amplitude of this noise stabilizes after all the movements of the probe have ceased, including the small oscillations in the acceleration after the initial impact due to the elastic rebound of the soil mass and time-delayed effects. The magnitude of the noise appears to remain constant after the probe comes to a complete stop.

Three different routines were created to de-noise the signals, depending on the complexity and the nature of the noise:

- using IIR filtering techniques (Butterworth filter)
- using wavelet decomposition methods (Haar and Symlet wavelets)
- using spline techniques.

General considerations

In general, each data file was processed using all three filtering methods. The solution, perceived as optimal, was then chosen based on expert judgment and experience as well as direct comparison of filtered response with results of other XBP tests that were not contaminated with noise. In cases where results of other tests were available in the general vicinity of the filtered test, the parameters compared included peak deceleration, overall duration of impact, and maximum penetration achieved. The de-noising was termed acceptable if the parameters listed above were reasonably close to those more accurately measured in successful XBP tests. Natural variability of the

typical bottom media was also taken into consideration when comparing between the two tests.

In cases where adjacent successful tests were not available for comparison, the judgment was passed on whether the filtered signal is reasonable based on the collective experience, acquired heretofore.

IIR filtering

The first technique was applied to the following files:

08JA0752.P1B

08JA0823.P1B

08JA1235.P1B

09JA0754.P1B

09JA1056.P1B,

acquired during the cruise of R/V Pelican, near Cocodrie, LA in January 2002. The noise structure was relatively simpler in these cases and consistent throughout the set. The filtering was performed with the low-pass IIR Butterworth filters. The particular parameters (normalized cutoff frequency and filter order) of each filter were defined and

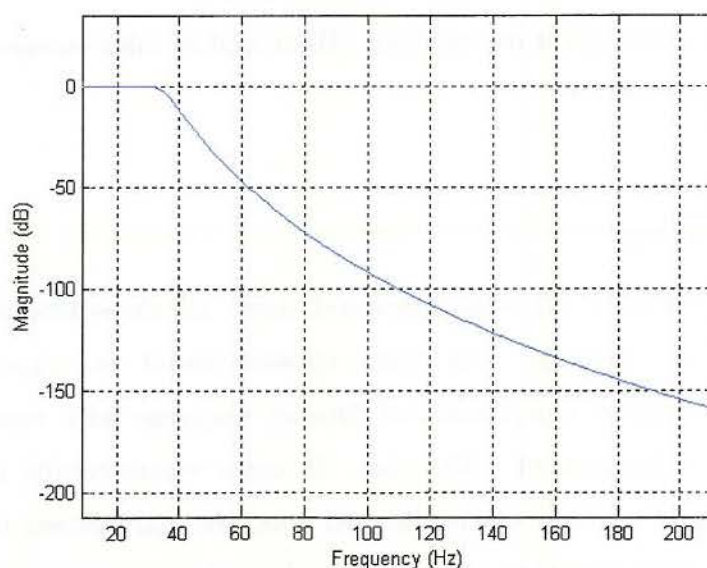


Figure A1. Example of an IIR Butterworth filter of order 10 with cutoff frequency of 35Hz and sampling frequency of 2kHz

tested for stability using the Matlab's Filter Design and Analysis Tool. The filter was then applied to the signal through double (forward and reverse) filtering technique with zero phase shift (filtfilt – function in the Matlab reference).

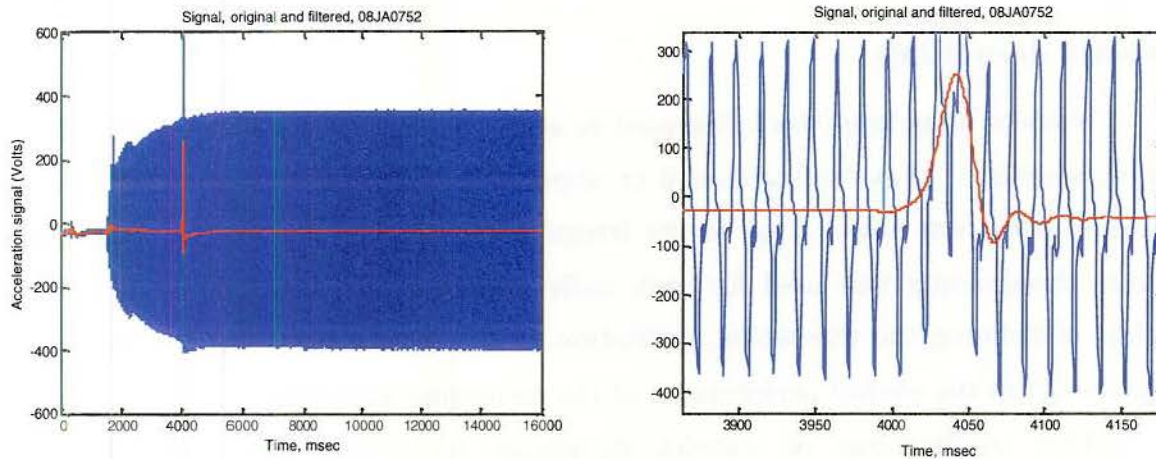


Figure A2 Example of an original and de-noised signals processed with IIR filter

This technique proved successful for the files listed, and relatively easy to apply as compared to other techniques discussed here. Figure A1 shows an example of such filter (magnitude response). Examples of the original noisy and filtered signal are shown in the following two figures. Figure A2 presents the original noisy signal with overlapped filtered one. The changing noise amplitude is obvious from the moment the probe comes in contact with water and until it comes to a complete stop, embedded in the

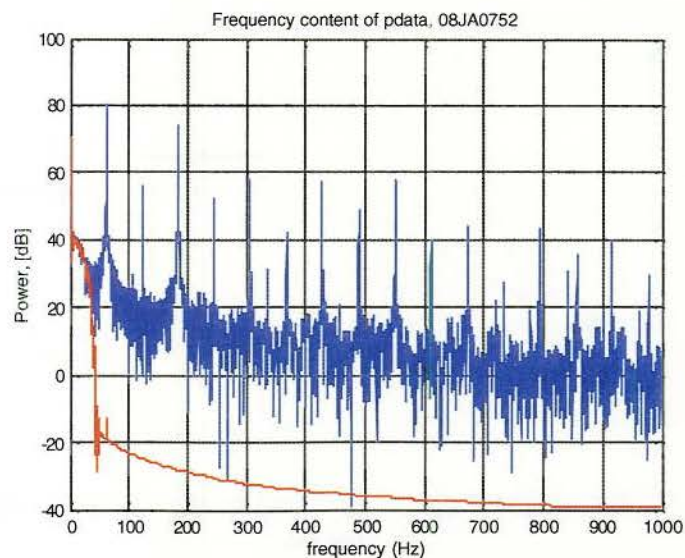


Figure A3. Power spectrum of the original and de-noised signal, an example

sediment. Figure A3 show the power spectrum of the noise contaminated and filtered signal, using the Butterworth IIR filtering technique.

Wavelet de-noising

Wavelet de-noising was attempted in several cases, primarily using the Haar and Symlet wavelets. Wavelet levels of 6 or above were required for successful removal of the broad-spectrum noise. Due to the irregular structure of some noise contaminants, manual thresholding was used for each individual level. It was found that with this method of defining the thresholds, utilization of different wavelet structures resulted in little change in the overall performance of the de-noising algorithm.

After applications of wavelet de-noising to several files, the method was abandoned in favor of the other two filtering techniques. This method could be helpful in the future, however, in case of complicated noise structure, contaminating the signal.

Example of using the wavelet transforms for signal de-noising is given in Figure A4. Remnants of the low-frequency noise, close to the actual impact response of the probe proved difficult to filter out, as shown in the figure. Visually, the filtered signal may not be vastly different from tests performed without extraneous noise. Parameters,

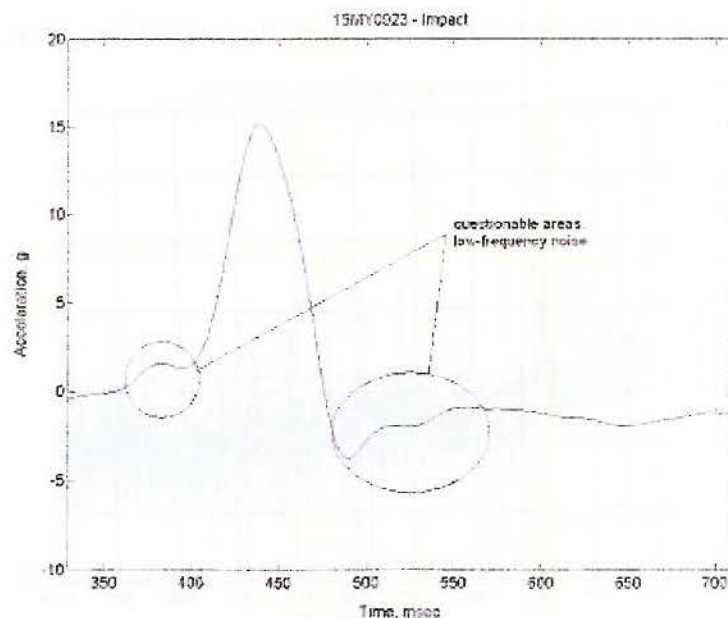


Figure A4. Example of a signal de-noised using wavelets

calculated from this curve proved, however, to be different from any other XBP test conducted in the vicinity. In the particular case shown above, the calculated maximum penetration achieved by the probe was about 45 cm, vastly different from any other drop conducted in the entire test area, of which none penetrated deeper than 30 cm and most no further than 20-25cm, or even less.

It is due to consideration of this nature, that other techniques, though not perfect on their own, were preferred to the wavelet processing, at least in these particular cases. It is quite conceivable, however, that that wavelet de-noising could perform better in other cases, dependent on the actual structure and composition of the noise.

(Note: Matlab's One-dimensional stationary wavelet analysis tool was used in this analysis.)

Spline smoothing and filtering

A simple procedure was devised for filtering particular difficult noise structures, with ambiguity on the frequency content to be filtered out and underperforming wavelet algorithms. The procedure is based on an observation that the lower local minima envelop of the noisy signal resembles the actual XBP response the closest. Figure A5 shows an example of the manually picked local minima, representing the lowest envelope of the signal. A cubic smoothing spline function with variable tension is then fitted to

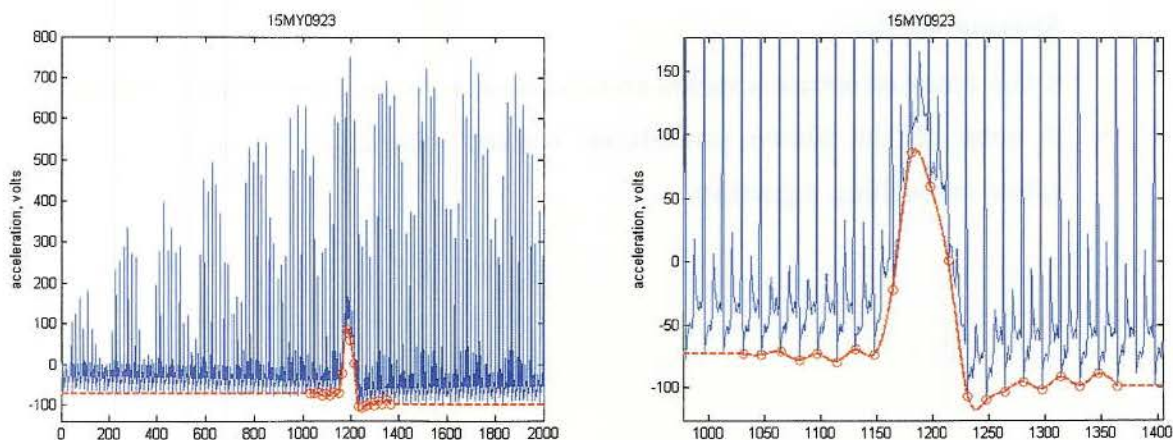


Figure A5. Noisy signal and splined local minima envelop

the points. The appropriate tension factor applied is arrived at through trial and error, arriving at what appears to be the most reasonable approximation.

The files filtered in this fashion included 2 drops from the Corpus Christi (May 2002) cruise of R/V Gyre:

15MY0921.P1B

15MY0923.P1B.

The resulting parameters, derived from signals denoised using this procedure compared most favorably to other deployments in the vicinity, producing results similar to those tests that were not contaminated with noise. These parameters, especially maximum penetration, appeared to be better approximation of the actual impact event than the IIR and Wavelet de-noising techniques.

Summary and recommendations

It should be pointed out that utmost care should be taken before the deployment of the XBP probe in properly grounding the device. This is far preferential to the inevitable subsequent de-noising if this grounding is not done or not done well. The XBP operator should remember that not every electrical 'ground' is identical and should pay most scrupulous attention to finding the best one.

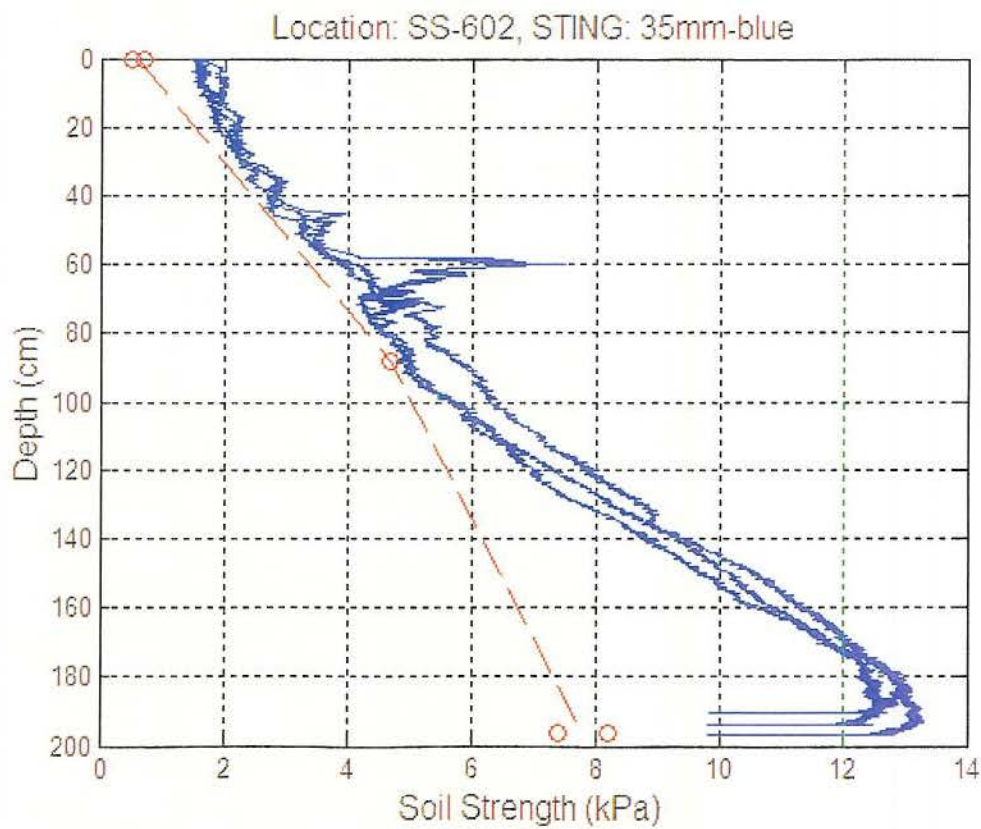
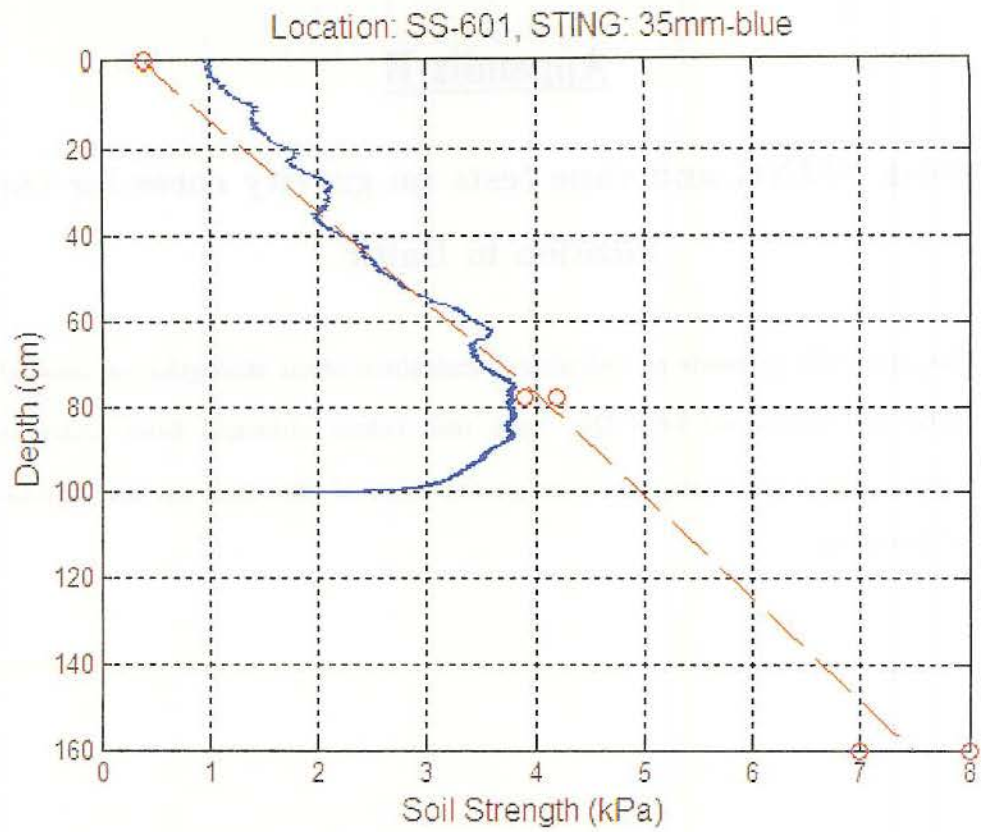
If, however, the resulting signal still contains noise, it is advised that the filtering procedure will proceed in the following order:

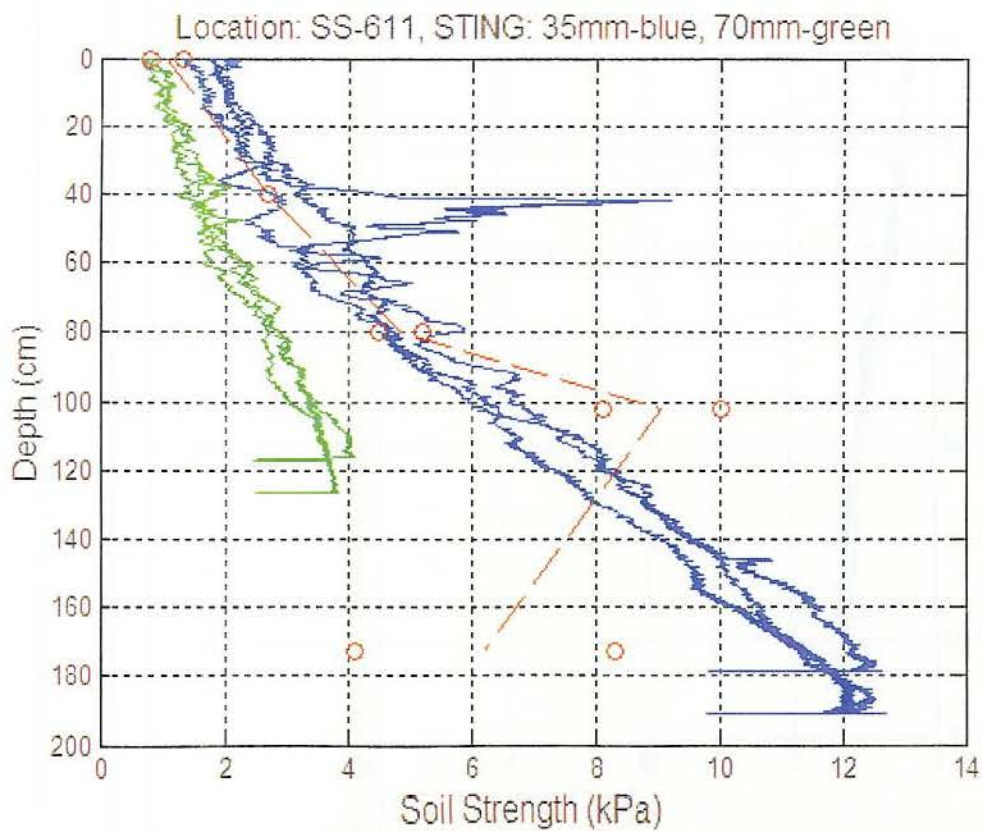
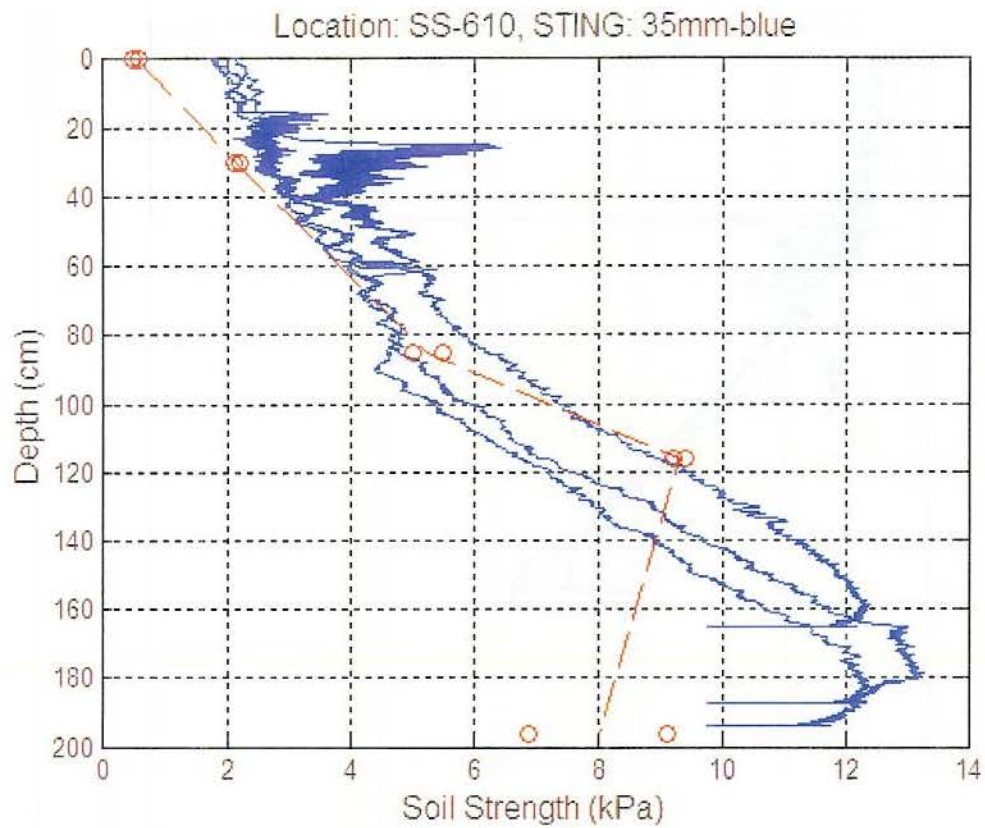
- examine the power spectrum of the noisy signal and, if simple, utilize the IIR filtering routine;
- if the noise structure appears to be complex, attempt wavelet de-noising;
- if none of the above procedures worked satisfactorily, proceed to manual spline smoothing algorithm.

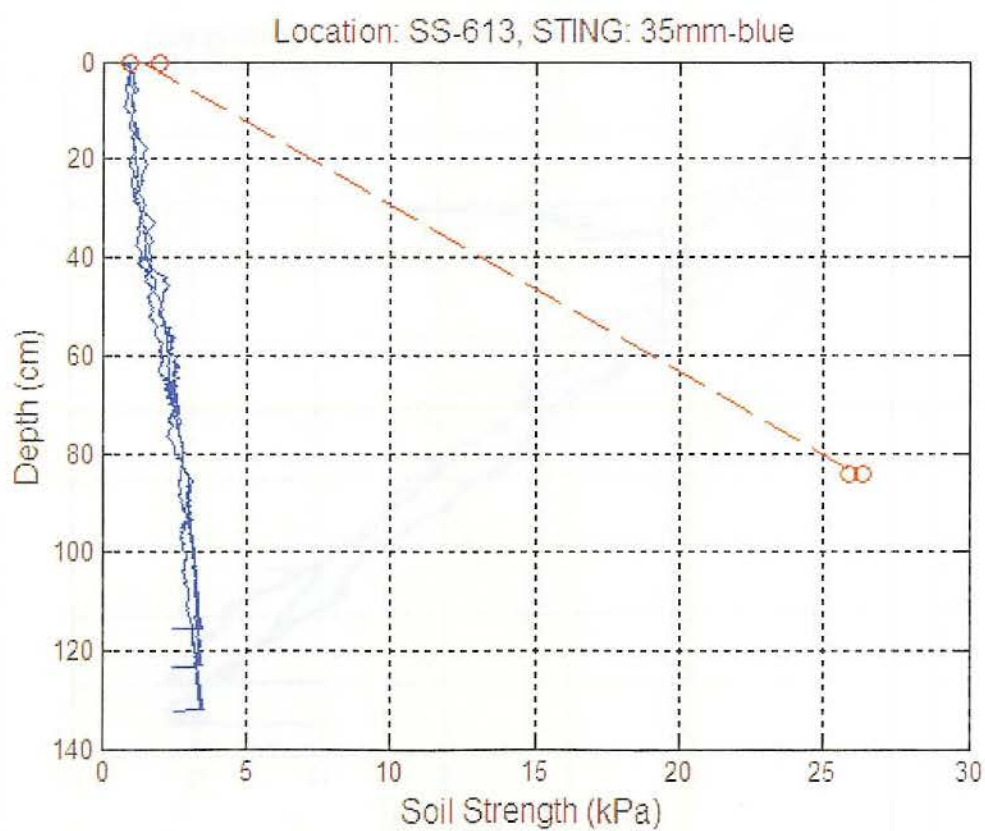
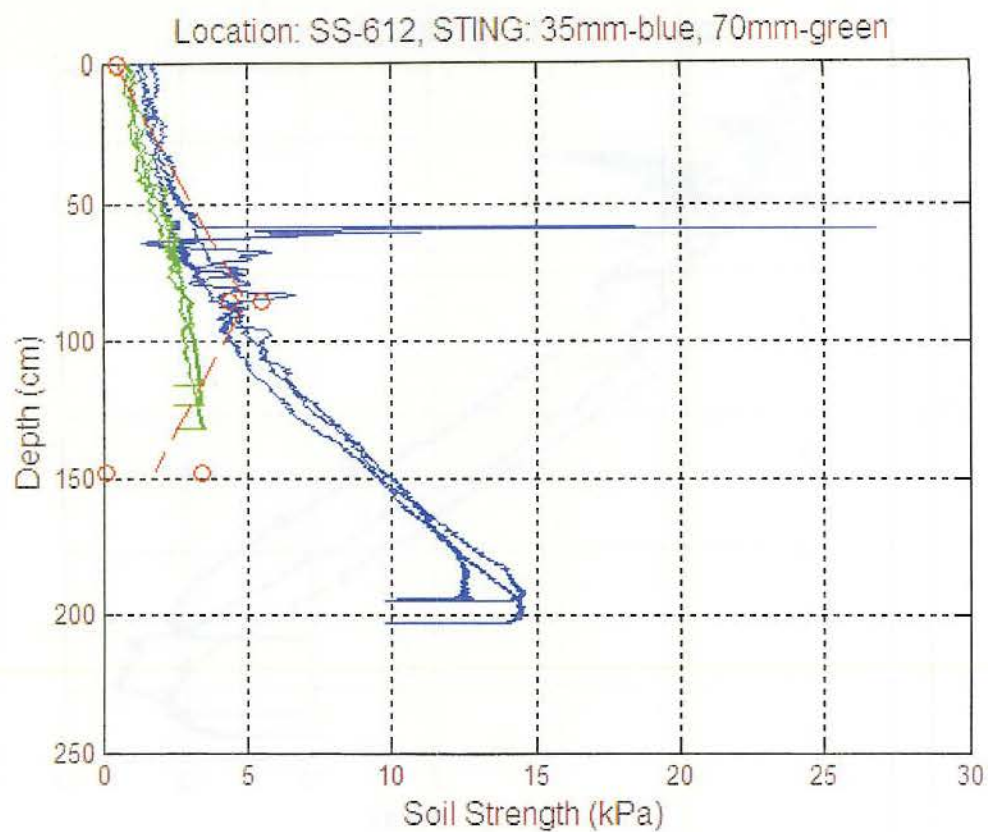
Appendix B

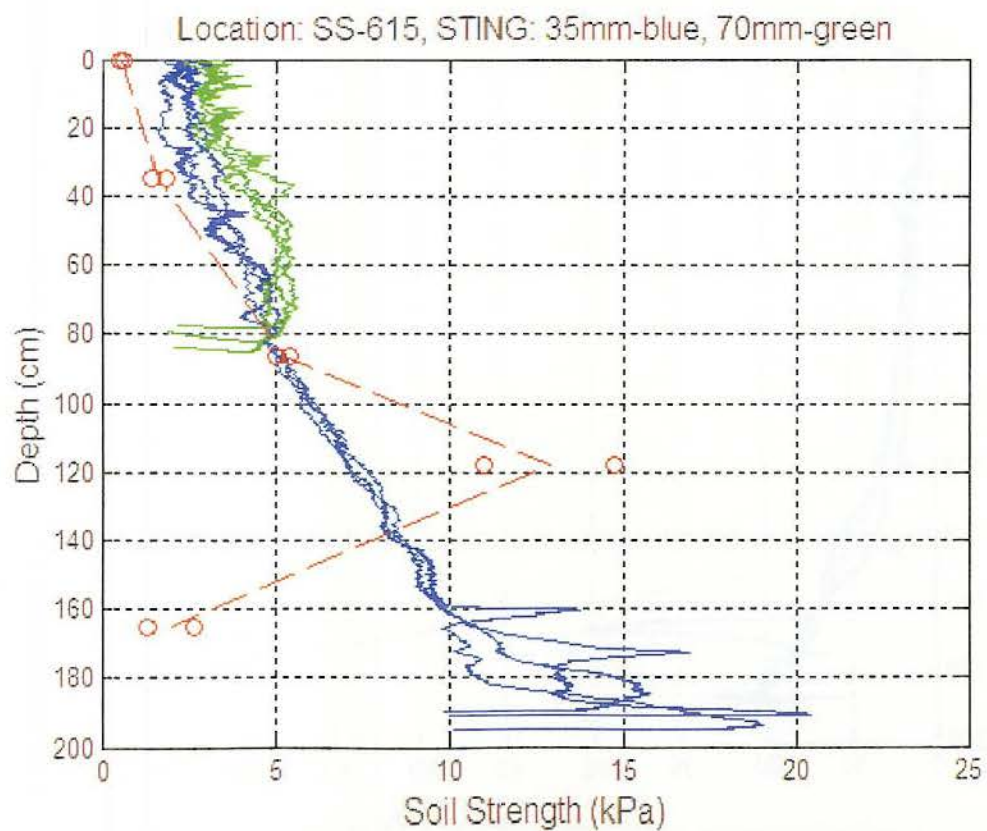
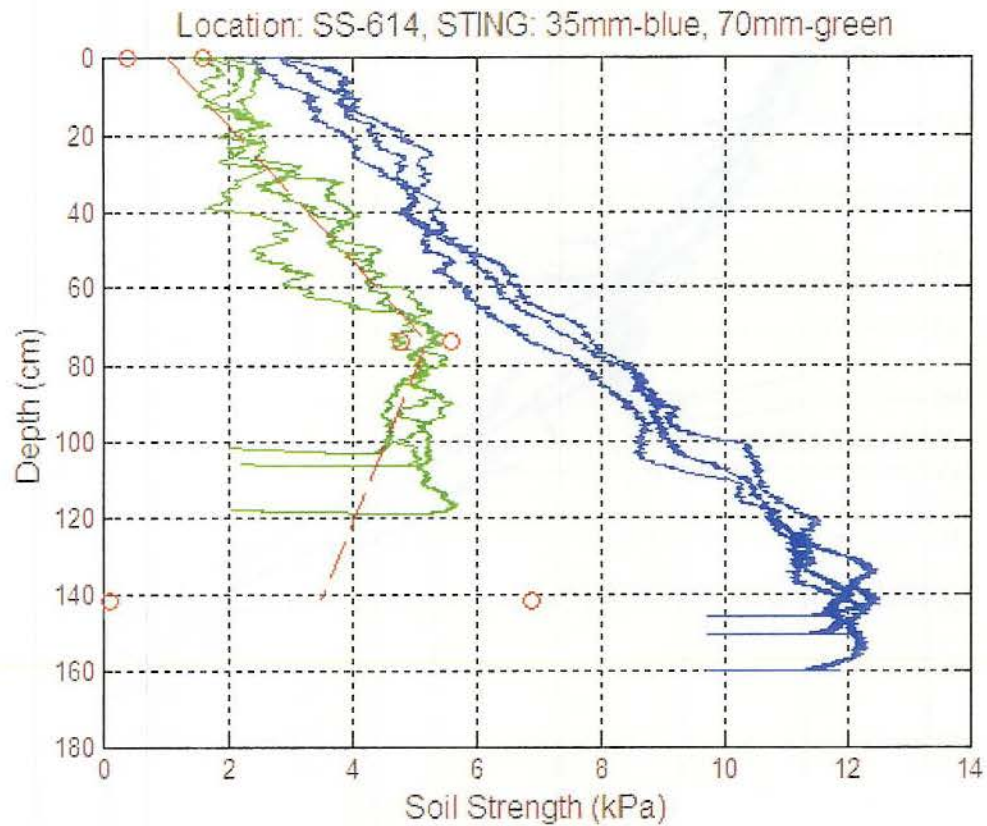
Processed STING and vane tests on gravity cores for the SS location in Baltic

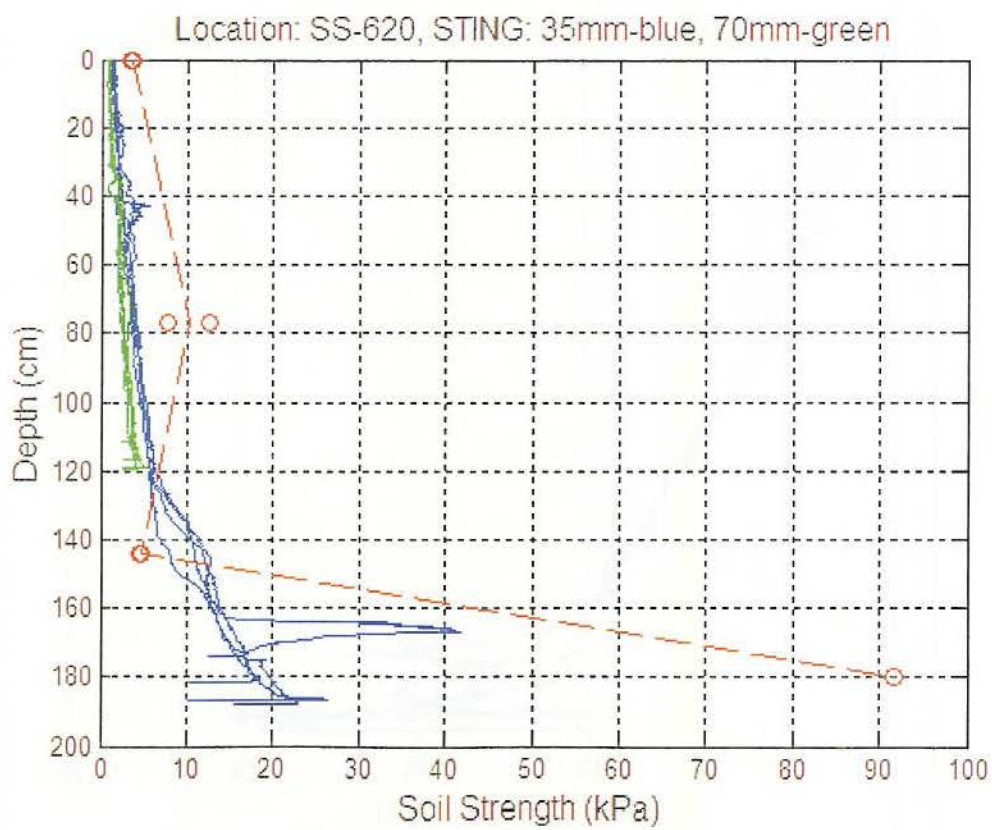
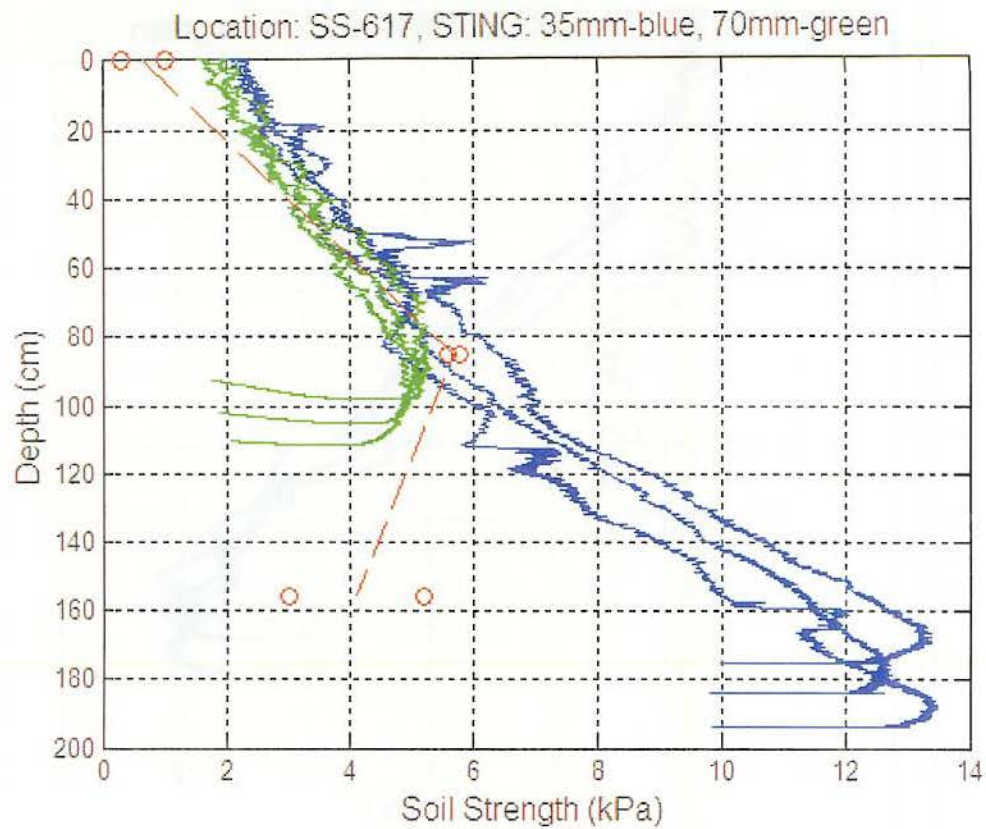
This appendix presents all calculated undrained shear strengths, as derived from STING data and compared with the vane test values obtained from analyzing the gravity cores. The vane tests were run in the vertical direction on the sub-sampled sections of the cores.

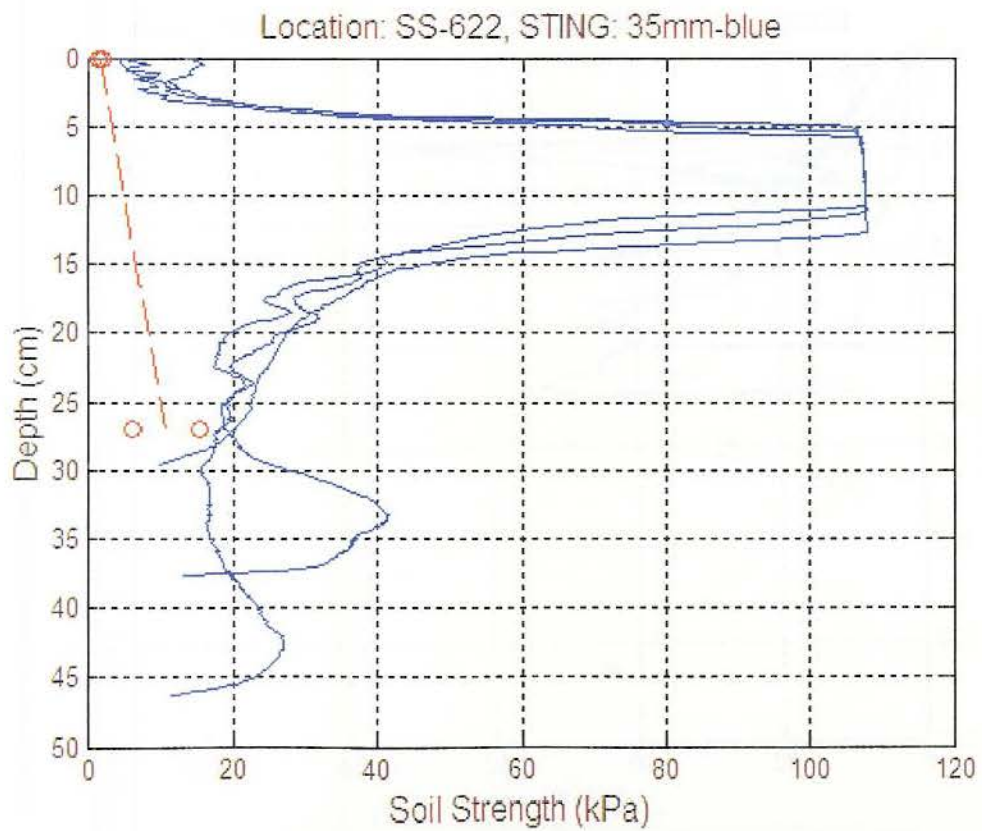
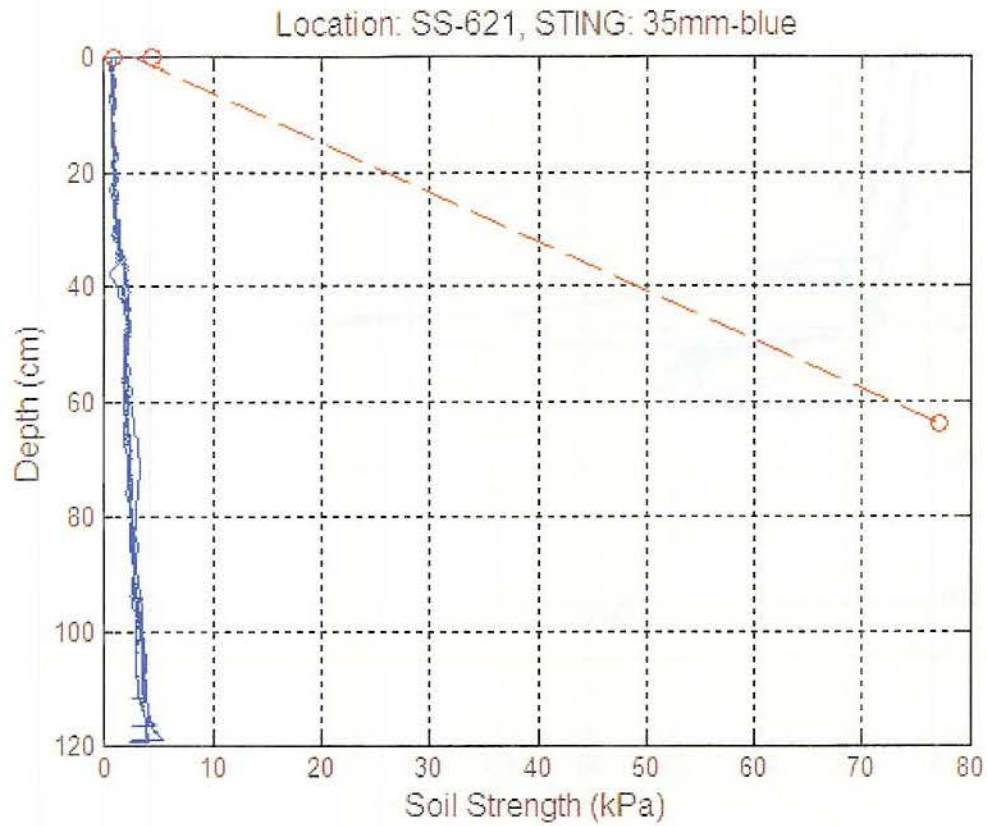


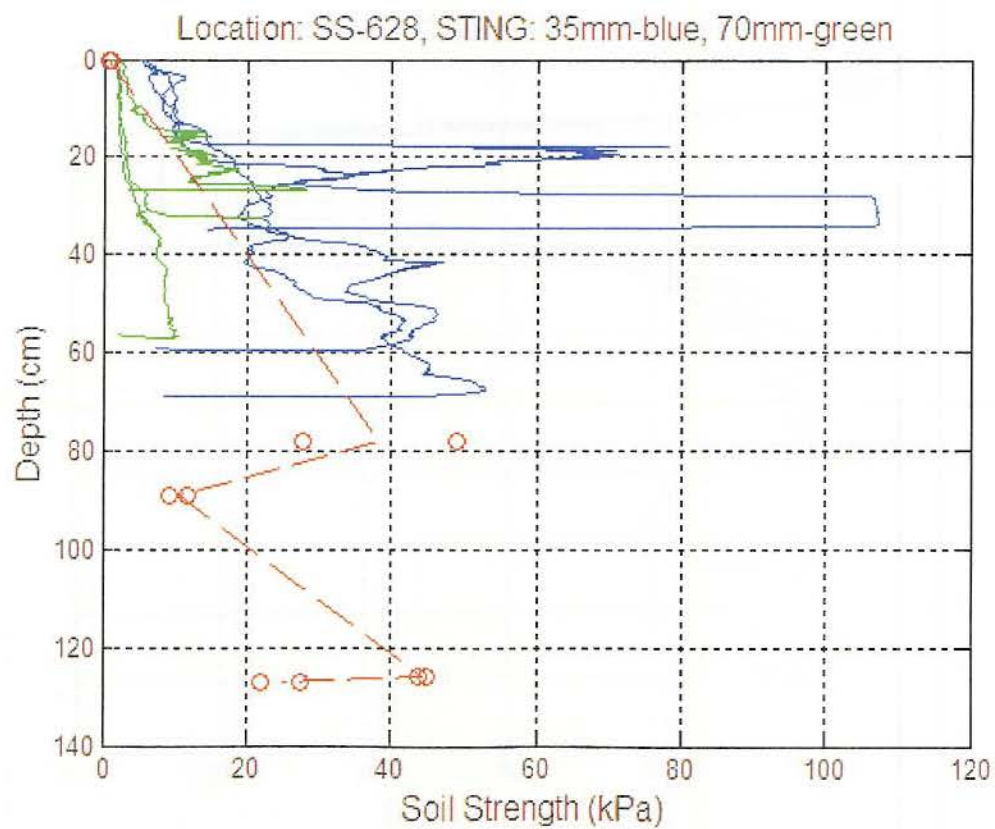
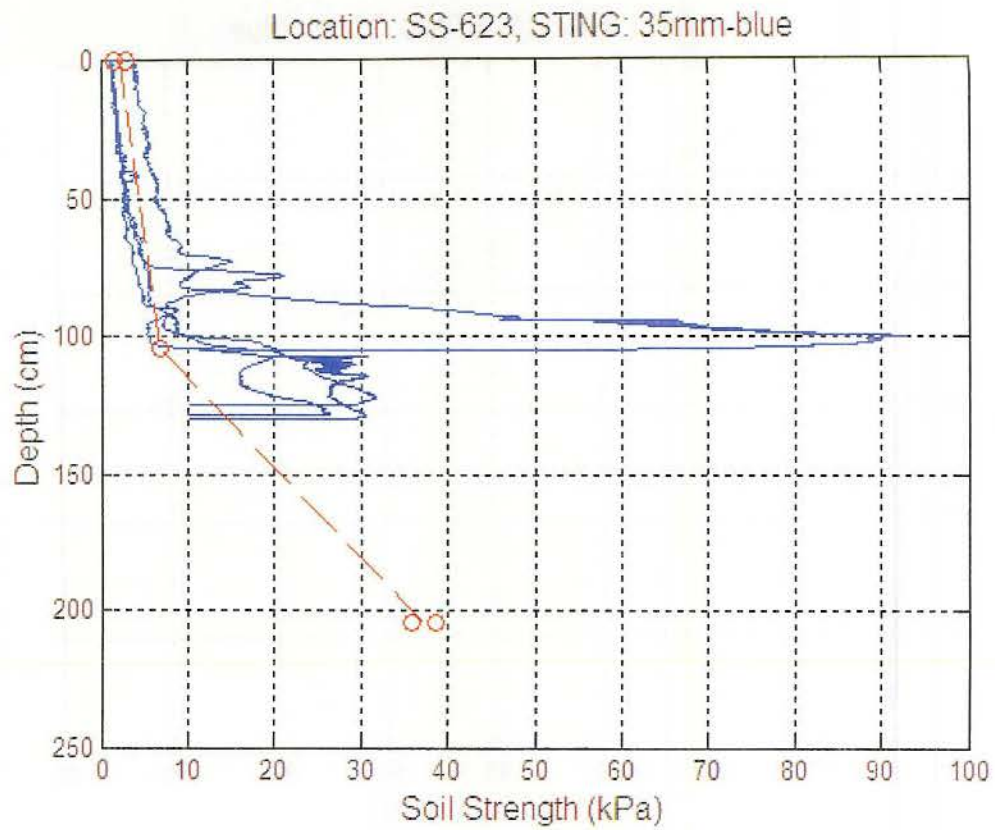


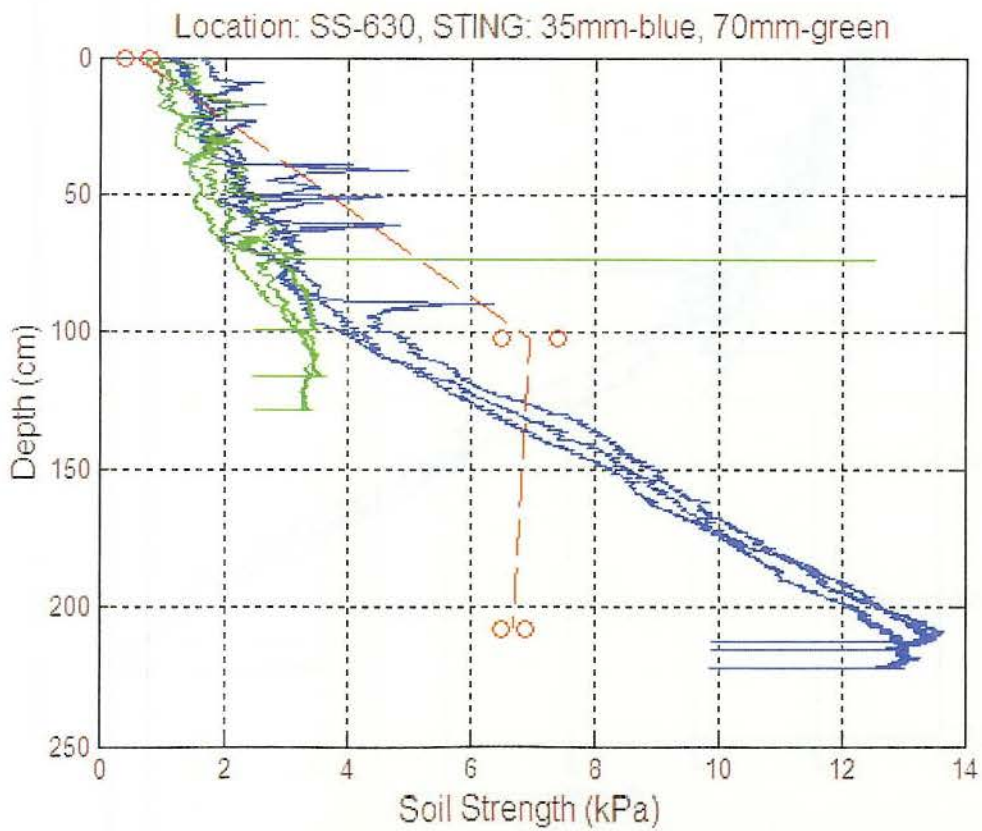
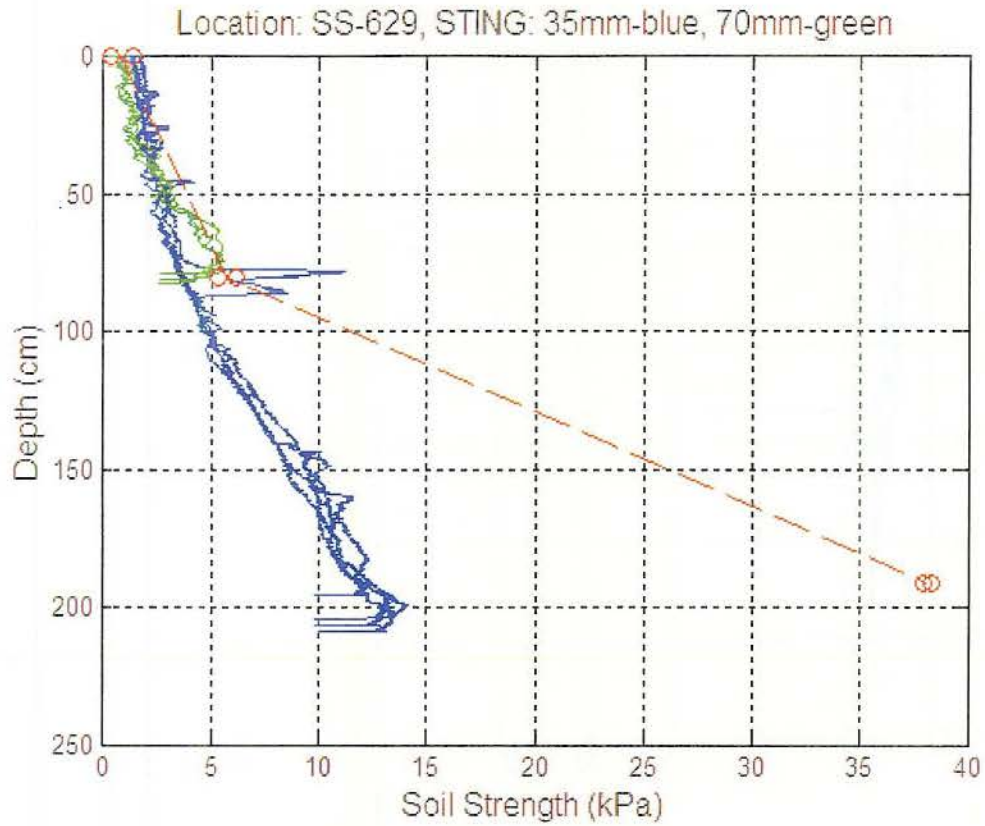


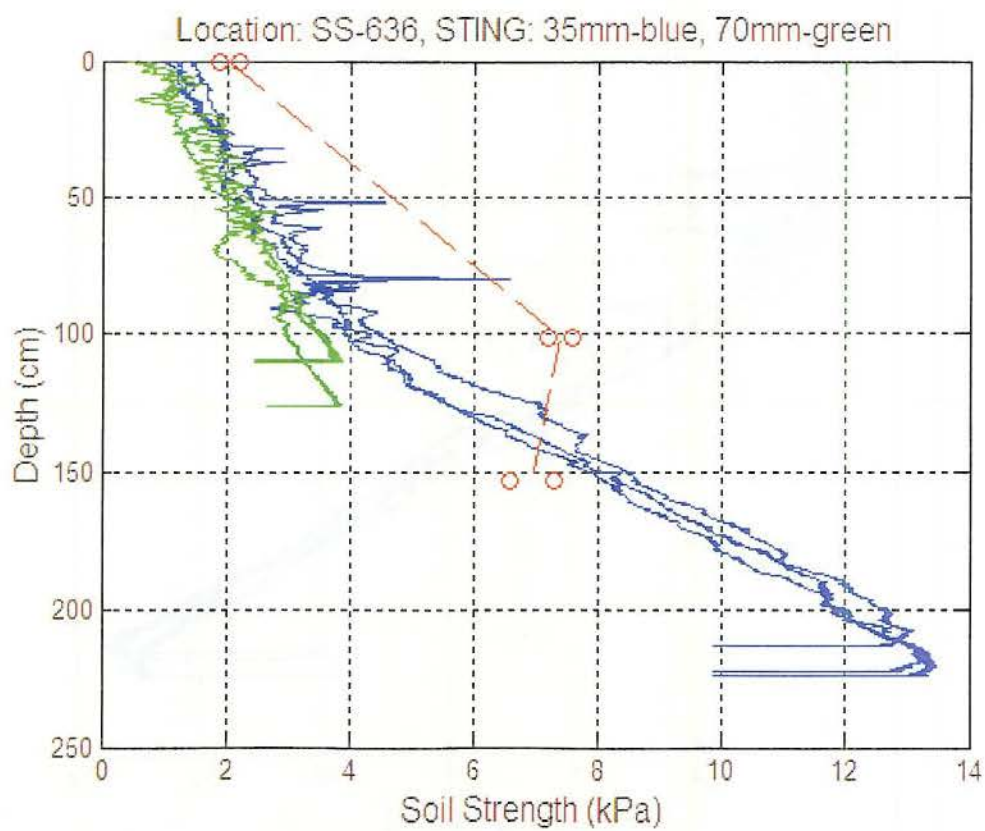
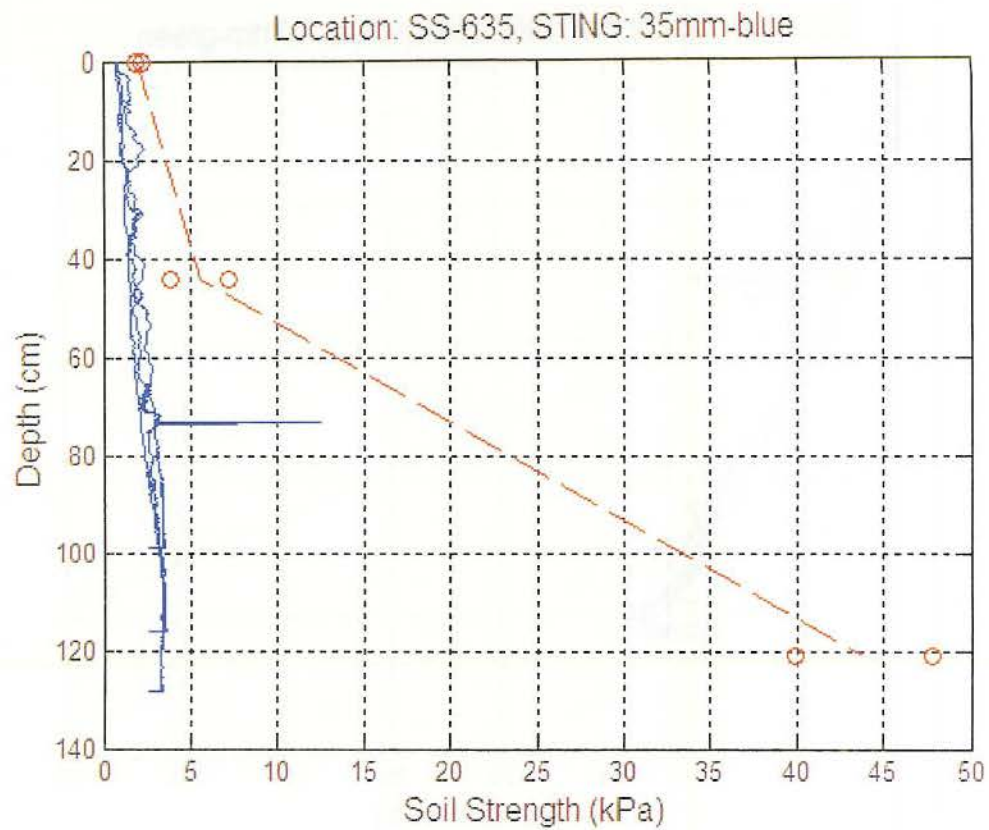


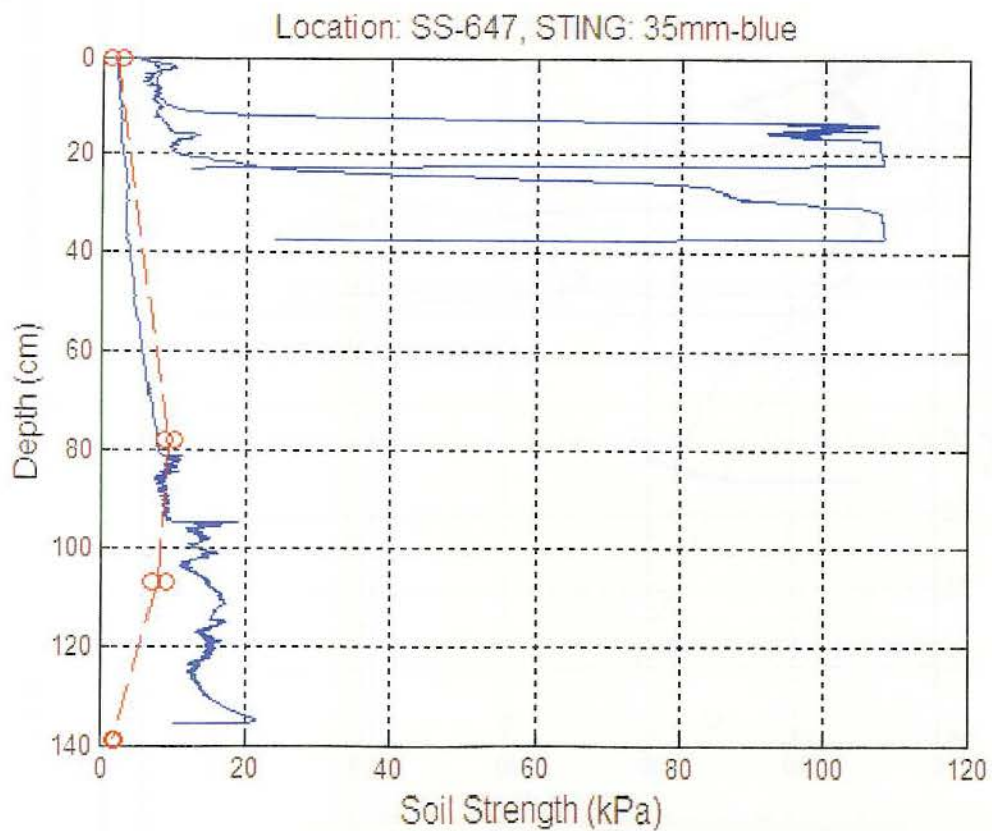
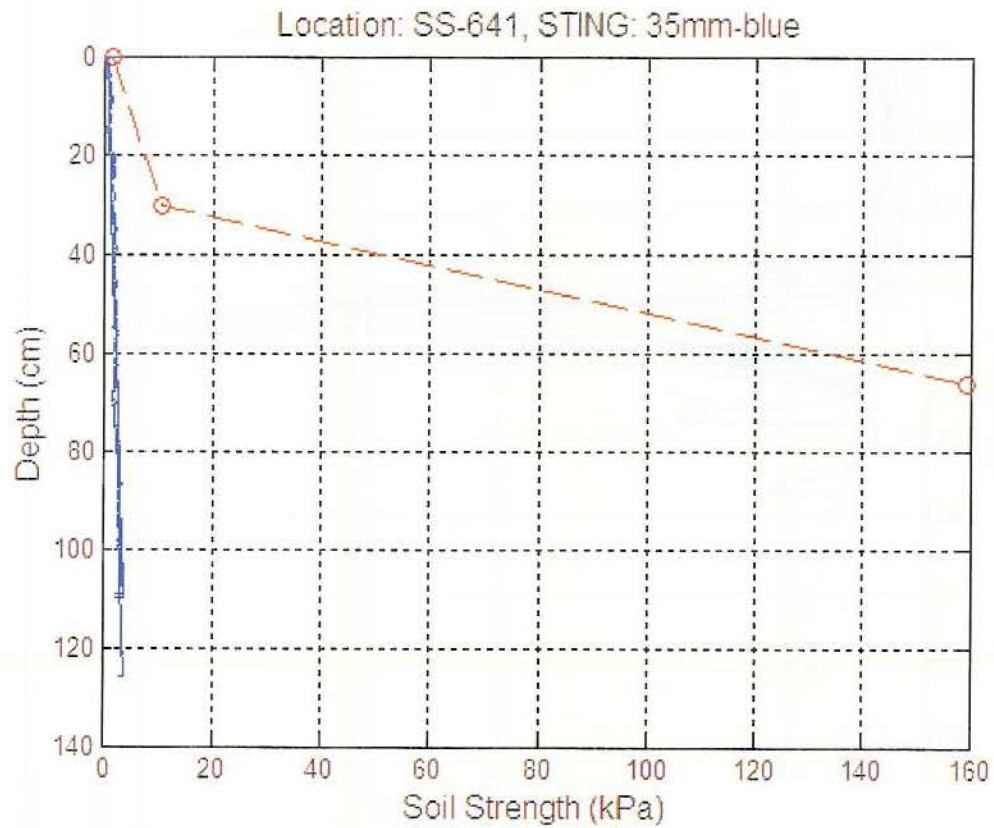


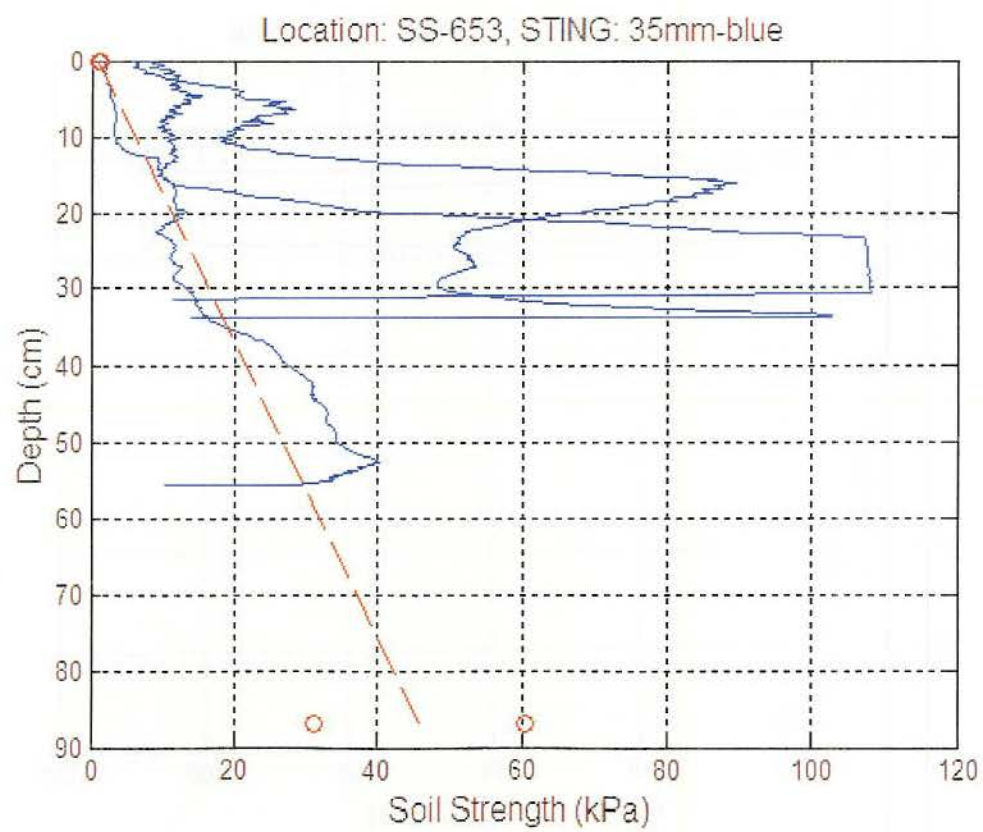
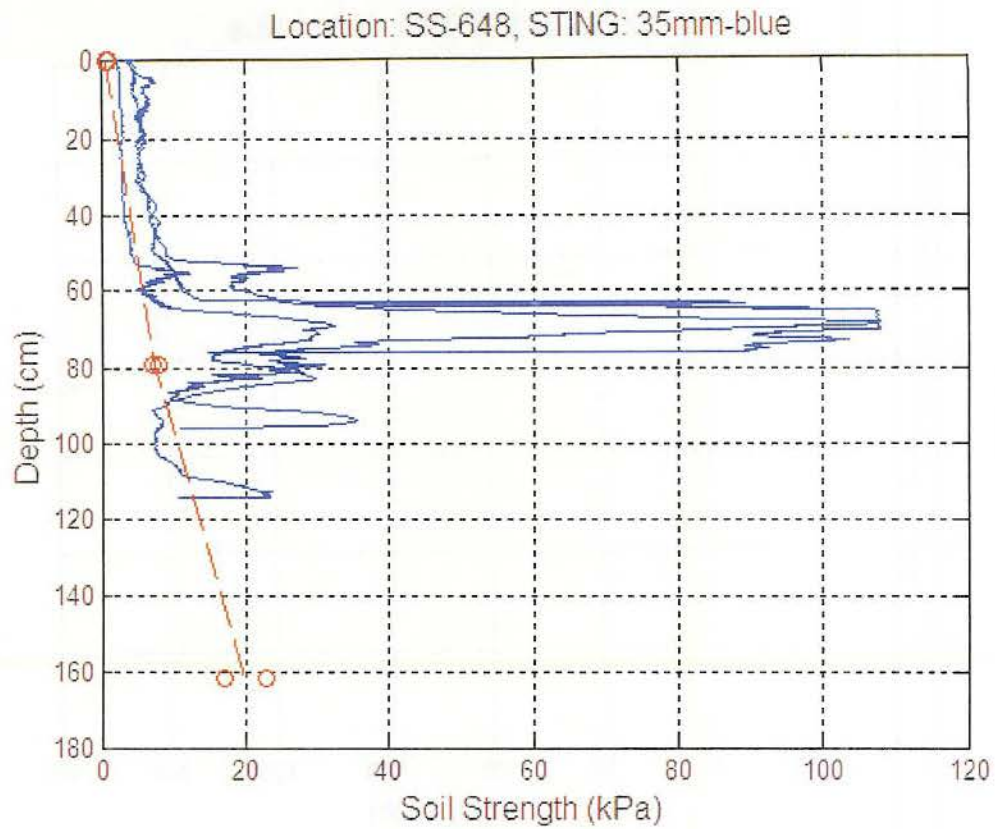


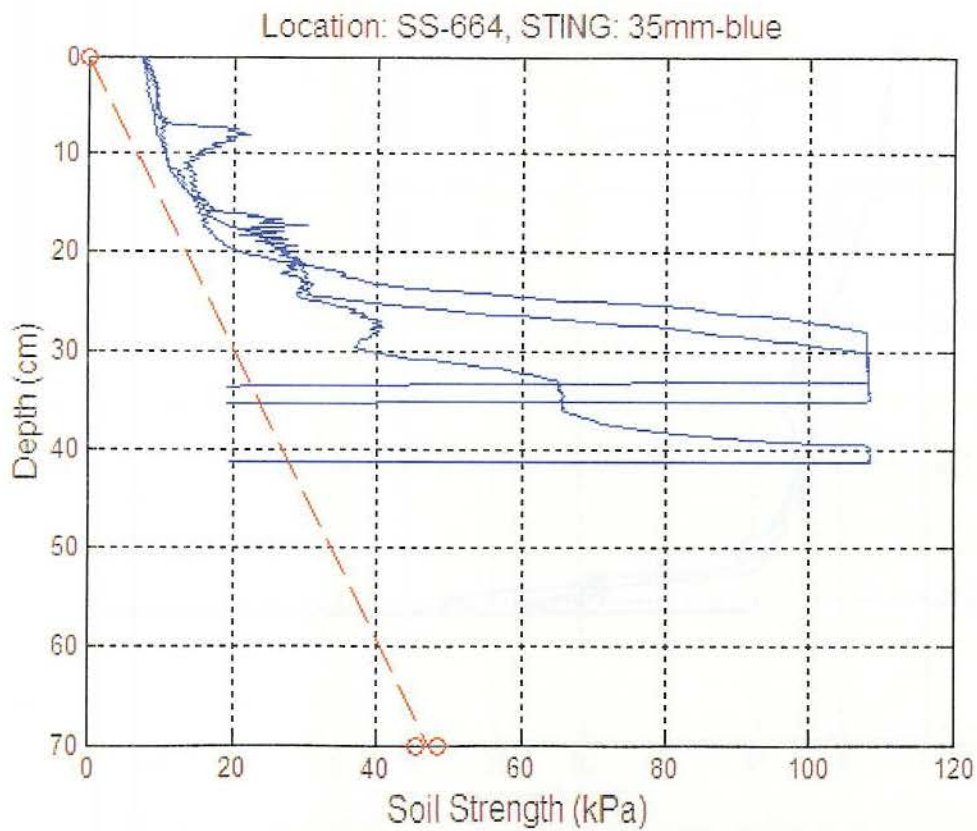
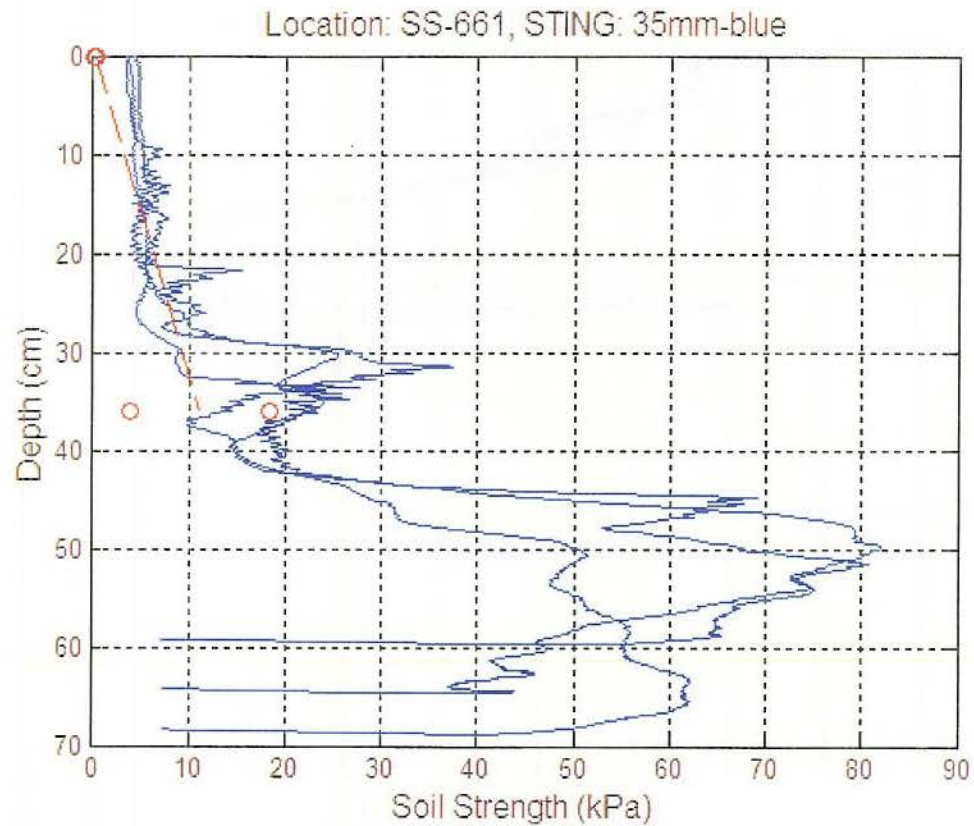


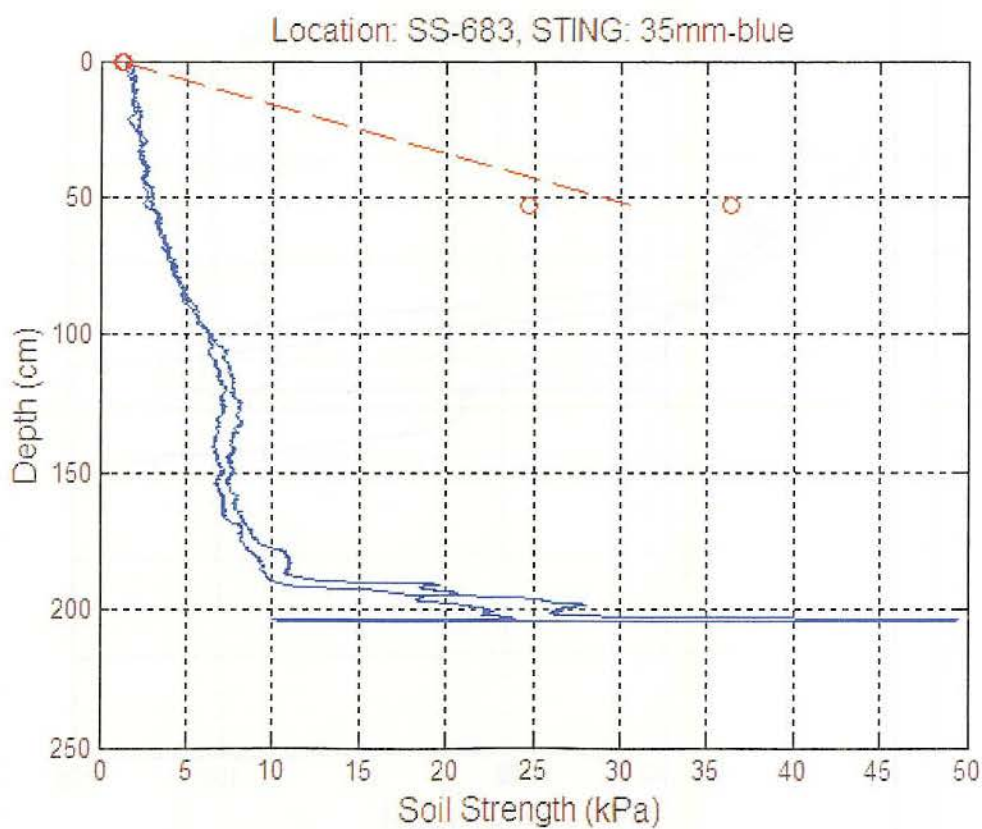
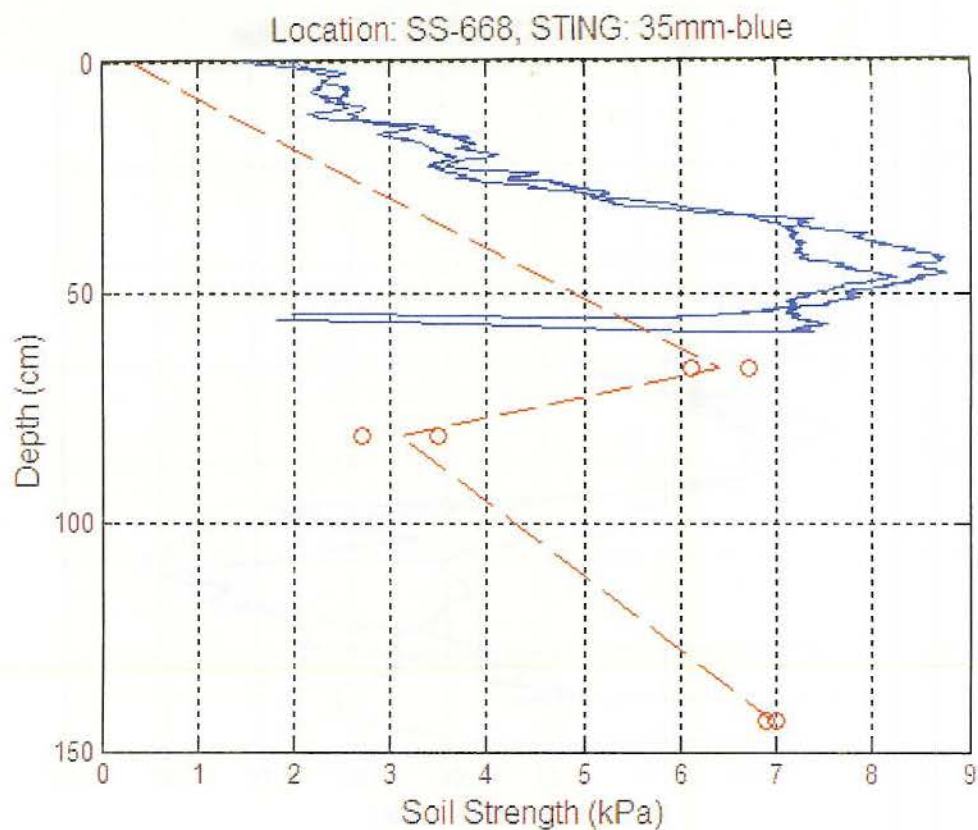


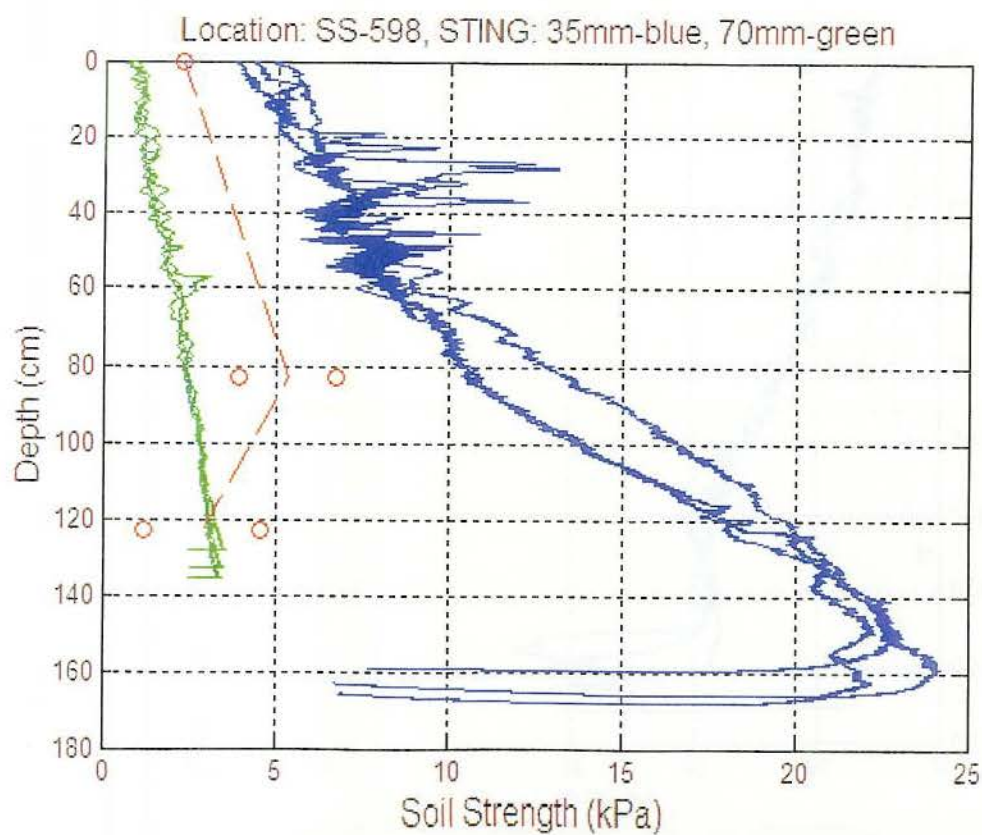
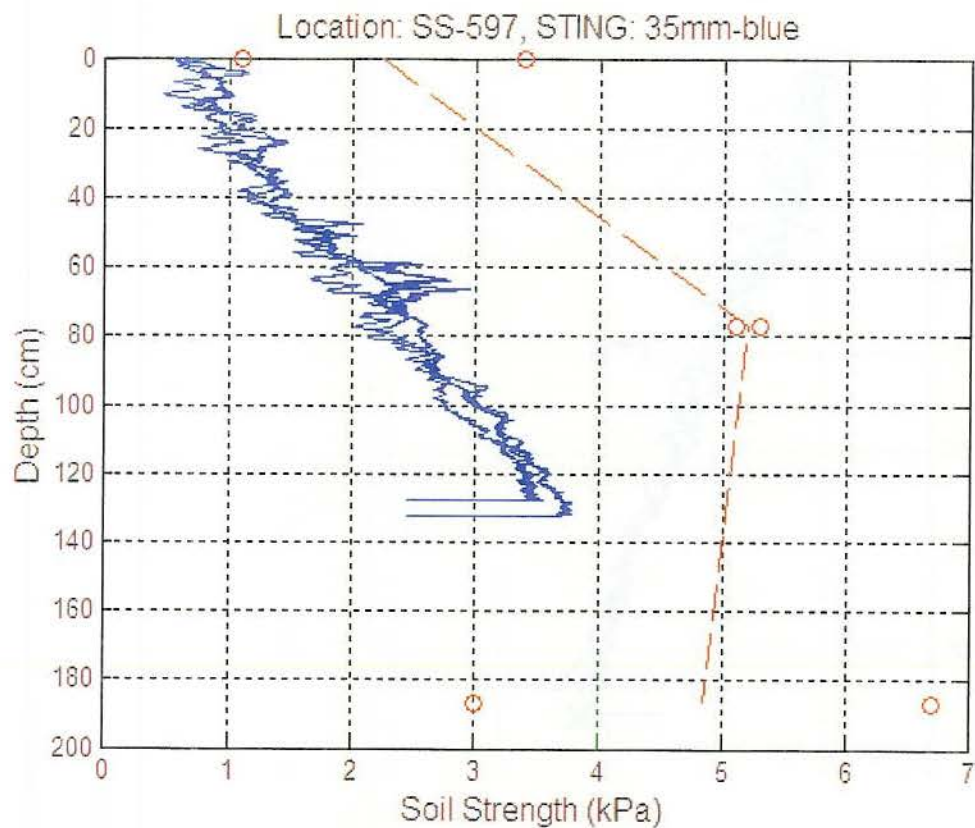


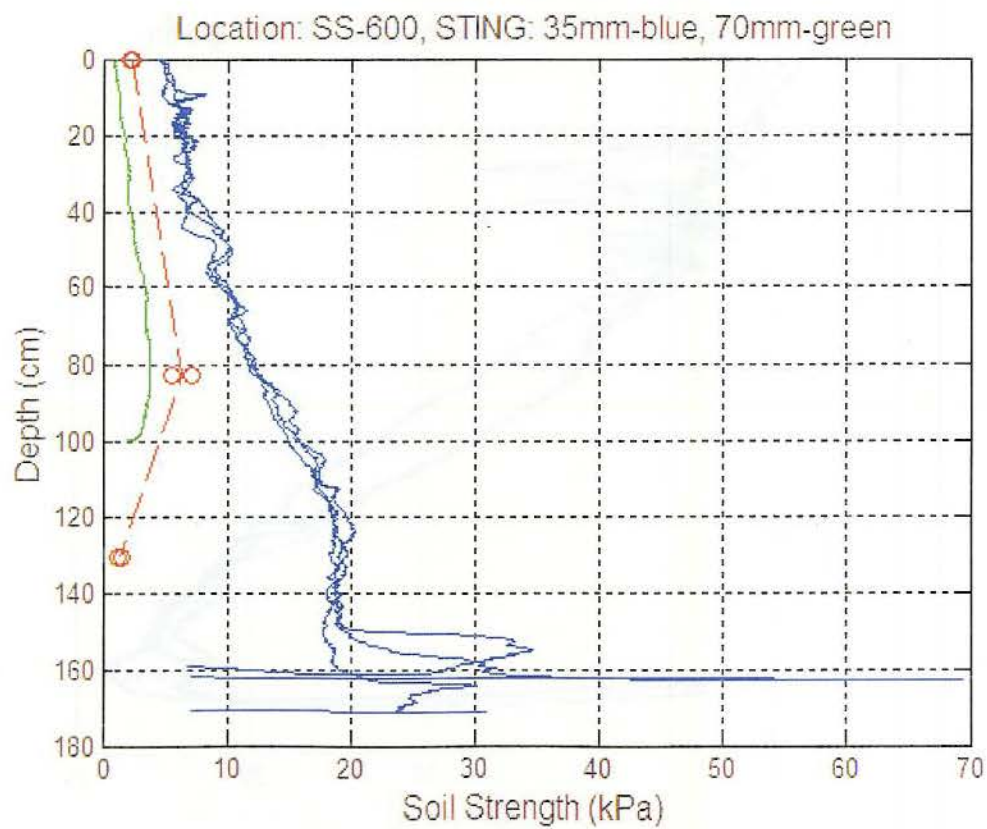
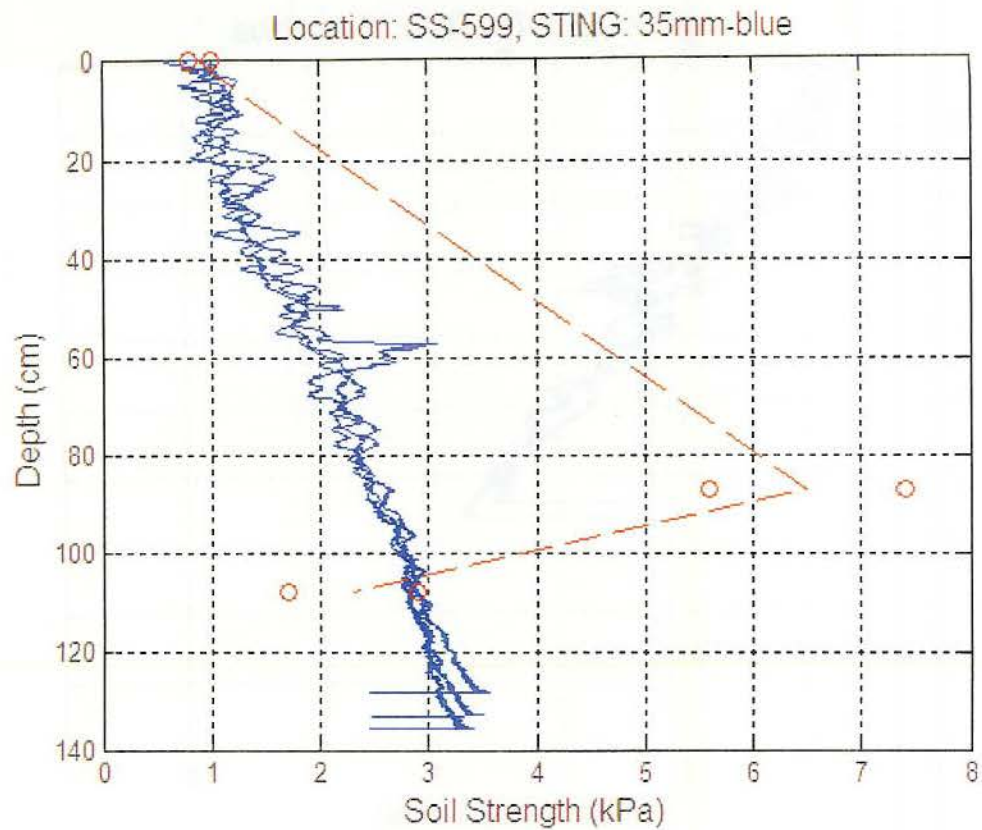












Appendix C

Processed XBP and vane tests on gravity cores for the SS location in Baltic

This appendix presents all calculated undrained shear strengths, as derived from XBP data using C. Aubeny's (TAMU) routines and compared with the vane test values obtained from analyzing the gravity cores. The vane tests were run in the vertical direction on the sub-sampled sections of the cores.

