MD3XT – NEXT GENERATION SUBMARINE CABLE PLOUGH, LIFTING THE BAR

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Abstract: The presentation will demonstrate the recent advances in submarine telecom cable installation. The success of the MD3XT cable plough system, which incorporates high power jetting assist, has re-defined industry expectations for depth of burial and cable installation rates. The presentation will mix theory and operational feedback.
The new plough design has two new features; first adjustable burial depth to 3.3m and secondly incorporation of 530kW of water jetting. The plough is shown to be configured for 2.2m or 3.3m burial and thereby optimise its performance. Variable burial depth is supplemented by introduction of low-pressure water jets in both burial configurations. Jetting assist is shown to increase ploughing rates by factor x2 – x4 in certain soil conditions and reduce vessel bollard pull by up to 50%.
The presentation will include operational feedback to demonstrate how the technology has performed, lessons learned on its deployment and improved reliability, and finally options to extend its capability on the plough to be able to plough with jetting assist in 1500m water depth.

1. INTRODUCTION

SMD introduced their telecoms plough into the market late 1990s. This was a step change in technology from the original plough (The Standard Cable Plough or SCP) and was described in reference [1]. It had a unique ability to plough at a depth beyond the industry standard 1.1m o 1.5m without compromising the stability of the plough. It was also in a weight budget to be handled by existing 35t SWL A-Frames and towed within the limits of bollard pull available on cable lay vessels, moving up from 50t to 80t. It met the objectives of deeper burial up to 2.0m and up to 3.0m in favourable conditions.

Reece [1] highlighted to reach the maximum burial depths demanded by the market, within the weight and tow limits stated above, the introduction of jetting was required. This paper describes how jetting has been incorporated into the plough, its predicted performance improvement, operational feedback and how this has led to the next genesis of the cable plough. The paper presents a performance analysis using theory and actual data provided by KT Submarine during two long campaigns in a mix of complex seabed conditions.

2. BASELINE JETTING PREDICTIONS

Figure 1 shows the performance envelope of the original plough. Dark Green section shows the original Standard Cable Plough 1.5m performance. Light Green section above shows improvement in using the Multi-Depth capability. Performance is limited by the maximum tow force.

Figure 2 shows the predicted improvement in performance by adding jetting (Light Green Shading). Note the improvement is focused in two sediment types; soft clay and dense sand, minor improvement predicted in coarse sand, medium and stiff clay.

The performance predictions were based on low pressure jetting theory, as defined by Reece and Grinsted [2] and from experimental data collected by SMD at several test sites.

Jetting was intended to be deployed in three ways; a forward and deployable jetting leg, through the main share forward leading edge and through the main share under heel, see Figure 3 and 4. Jetting was considered passive so is additive to the performance of the plough.

Operational feedback indicated mixed results and the sudden downturn in the submarine cable installation market led to a pause in the development of plough and jetting technology for more than a decade. In the last few years, SMD reconsider what are the next steps in plough technology, revisit the operational feedback, and develop the next generation plough system.

Many of the early adoption operators, (Subcom, NTT, KCS & Global Marine) reported a lack of consistency in achieving 3.0m burial. Applying under heel jets did weaken the soil beneath the share to accelerate sinking, but at the detriment of plough control. Also, the reliability of the submersible motor and pump arrangements needed to improve to convince the market it was worthwhile to carry the extra performance afforded by jetting.

3. JETTING PERFORMANCE PREDICTIONS

Figure 5 shows the plough performance with the addition of jetting in the form of a single 265kW jet pump or a 2 x 265kW jet pumps in parallel. The analysis considers a consistent granular seabed ranging from coarse (low relative density) to fine (high relative density) on a continuous scale.

The curves show two baseline conditions, ploughing at 2.0m burial and ploughing at 3.0m burial and jet trenching at 2.0m burial and 3.0m burial using water jet only. The hypothesis is the original plough is a passive or jet assist machine so when the jetting is OFF or operates in a soil condition that is not conducive to water jet technology (e.g. medium to high strength clays) then the performance is “ploughing only”. When jetting is ON, and the soil conditions are strongly conducive (e.g. medium to dense, sands) then the performance approaches “jetting only”. Total performance is the combination of “ploughing” and “jetting” and this is shown in 2.0m burial and 3.0m burial conditions. See Figure 6 for a tabular performance summary.

4. INCORPORATING HIGH-POWER JETTING ONTO BURIAL PLOUGH

Figure 3 shows the plough is a 2.0m burial plough and Figure 4 capable of 3.0m in favourable conditions. Therefore, the challenge was to design a plough that could deliver the performance improvement indicated by Figures 5 and 6 in all complex seabed conditions within the same practical limits of A-Frames and towing winches.

The ingenious solution was an interchangeable share extension. Figure 7 shows the next generation plough in shallow burial mode (2.2m burial); Figure 8 in deep burial mode (3.3m burial). The two figures show the integration of the short and long extensions. All other parts are common.

Share extensions have been used before but they were semi-permanent additions or conversions. These extensions are easily exchanged and this can be done at sea. By careful design it is possible to unlock three benefits in both shallow (2.2m) and extension (3.3m) modes:

1. The share heel remains horizontal in all burial depths and complies with

the long beam principal and stability of the plough. This will ensure a reliable and controlled burial in all seabed conditions.

2. All other hardware is retained and the plough geometry and scaling parameters are consistent. It is easy to change the boot when deep burial is required and revert to a smaller plough when not.
3. The jetting water supply is fed from the main share through a water interface into either extension. There is no modification or re-configuration of the plough required.

Jetting on the later plough is spread between the deployable front jet leg or the share leading edge. It is possible to direct all 530kW of jetting into the share nozzles.

5. PERFORMANCE DATA

KT Submarine were the first plough operator to use new plough on CS Segero. It replaced an SMD Standard Cable Plough (SCP) after 20 years of service. The new plough air weight was 24Te including 2 x 265KW jetting. The existing 50Te tow winch was upgraded to 80Te tow winch without any changes to the vessel foundations. This met the original design intent.

First case study is APG cable route, 2015 for NEC. The campaign is characterised by three distinct seabed conditions, Figure 9 and for analysis these are summarised in Figure 10 with comments (see Figure 14).

Figure 11 shows performance data. The results have been averaged over a full campaign length 49km where there are defined seabed conditions. The target burial depth was 150cm cover over the cable and a consistent min average 170cm has recorded.

Sediment type (i-ii) is very soft, silty clay with an expected undrained sheer strength <20kPa and the minimal tension and excess burial depth suggests the plough did not require jetting to achieve acceptable progress. Sediment type (i-v) is the most interesting and challenging condition where the summary characteristic is dense silty SAND with a strong veneer of very dense SAND at the actual maximum burial depth. Sediment type (ii-iv) is the mid-range medium dense SAND.

Figure 12 is a comparison of the actual data points versus prediction (from Figure 5 and 6). Predictions are based on a 2.2m burial analysis whereas the actual average burial is defined in Figure 11, so the results have been normalised using [1] and the formula progress (speed) is inversely proportional to the square of burial depth.

Performance data was not available with no pump scenario on these operations. However, KT Submarine have much experience in APG cable route and in burial with SMD standard cable plough over 20-year service. Recommendation is performance is similar in sediment type (i-v) and (ii-iv), and can be defined as tow tensions 30~40Te, burial depth is <100cms and speed is 600m/hr.

Second case study from KT Submarine is AAE-1 project in 2016, for NEC. Figure 13 shows summary performance in a variety of seabed strengths.

This second case study provides further assurance of the performance of the plough in a 170km singular campaign in a range of conditions. Note the performance data is an average over the campaign length for the sediment types. Some conclusions can be drawn from the above:

1. Max target burial depth, 150cms was exceeded in all seabed conditions;
2. Client stipulated plough with jetting, so no base data for new plough only;

3. With exception of ultra-soft condition (i-ii), switching from one jetting motor to two shows reduced speed and tension. This may be a reaction to increased seabed strength, turning the second motor on, to maintain an acceptable progress speed whilst reducing tow tension. Further analysis of the reduction in speed may be necessary;
4. In ultra-soft condition (i-ii), introducing a small volume of low-pressure jetting will improve performance but adding more will not. Plough speeds are already accelerated and acceptable;
5. Averaged tow tensions range from 20Te – 32Te, a reduction of around 10Te from historic base data;
6. Averaged burial depths range from 170cms – 278cms, a step change in the performance relative to SCP;
7. Averaged ploughing speed range 320m/hr – 1500m/hr, an improvement in historic data.

The improvements in tow tension, burial depths and ploughing speeds are all additive so all performance indicators are positive.

6. SUMMARY

Operational data from two case studies has shown that the introduction of jetting has made a significant improvement in the performance of the new plough.

Though the data is not definitive, as would be expected in a real operational situation, it is possible to draw some clear conclusions. These confirm the base assumption that the introduction of high volume, low pressure flow is particularly effective in medium to dense granular conditions and the presence of different strength stratified soils that weaken the bulk conditions can further accelerate progress. The original hypothesis that x2-x4 improvement in ploughing speeds remains consistent with the performance data in a wide range of granular materials.

7. CONCLUSIONS AND OPERATIONAL LESSONS FOR THE FUTURE

KT Submarine’s operational feedback has been extremely helpful and it has confirmed the improved reliability and performance as expected. It is now possible to have a passive 3.0m plough and boost performance with the introduction of jetting in water depths up to 1500m. Further improvements to the reliability of the water jetting system, to increase the time between maintenance services, have been developed in partnership with KT Submarine and developed further and these will be tested in 2019. These focus on drawing water and minimum seabed into the pump inlets and strengthening the sealing around the submersible motors. Further improvements in how the 530kW of power is transmitted subsea are also to be tested in 2019.

APPENDIX

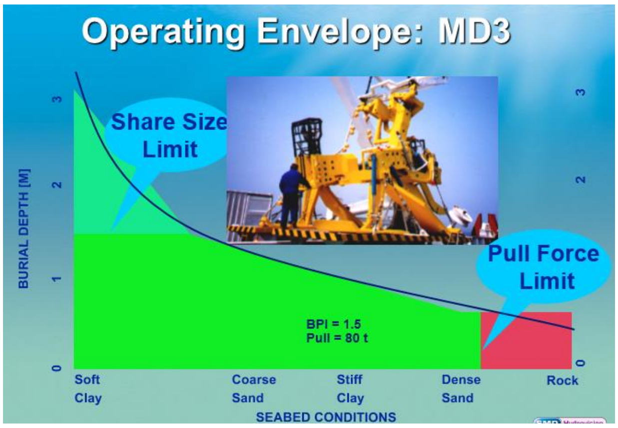


Figure 1 - Performance Envelope of MD3

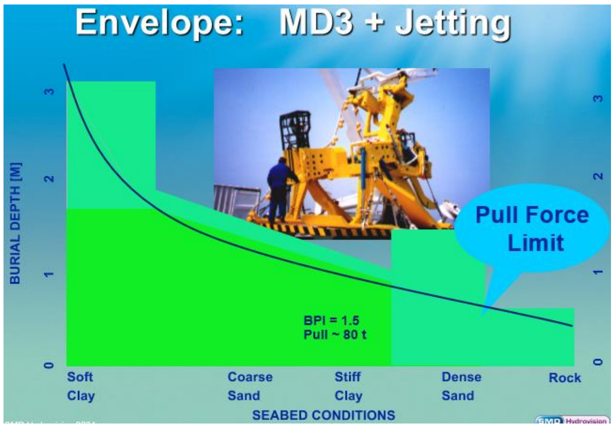


Figure 2 - Performance Envelope of MD3 with Jetting Assist

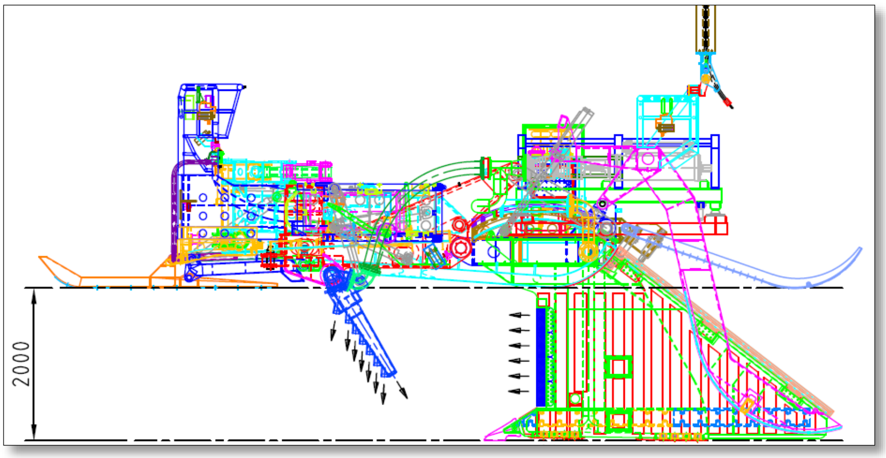


Figure 3 - MD3 shown in 2.0m burial mode; front jet tool deployed and jetting through share leading edge

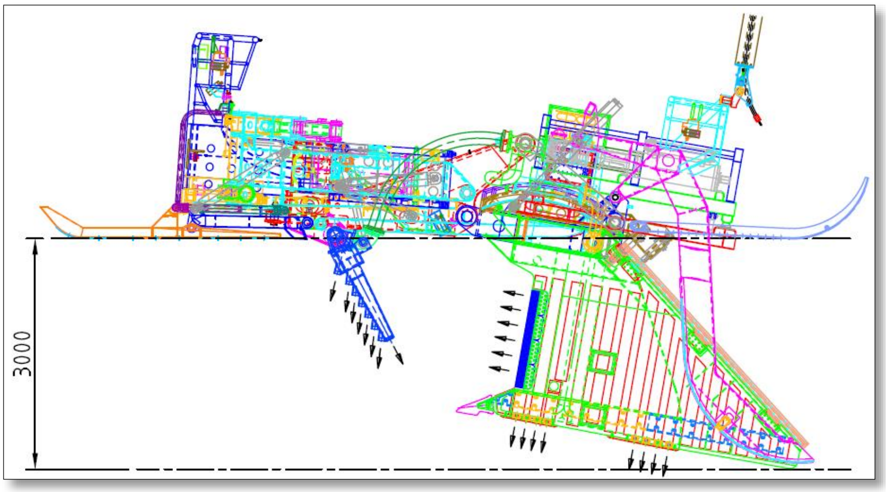


Figure 4 - MD3 shown in 3.0m burial mode; front jet tool deployed and jetting through share leading edge and under heel

Figure 5 - MD3 Plough Speed (m/hr) vs Sand Relative Density

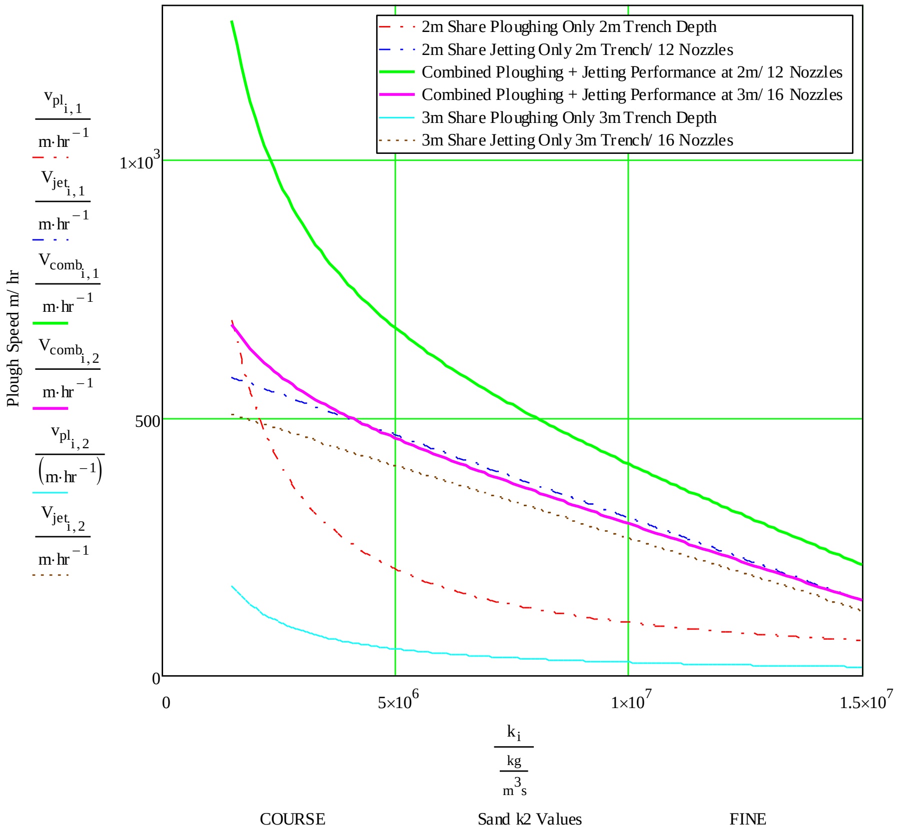


Figure 6 - MD3 Plough Speed (m/hr) for 3 Sand Relative Density Conditions

	Coarse Sand (25% RD)	Median Sand (50% RD)	Fine Sand (75% RD)
2m Plough Only – No Jetting	410	140	85
2m Plough – Jet Pump 1 (265kW Jetting)	680	335	210
2m Plough – Jet Pump 1 + 2 (530kW Jetting)	940	475	320
3m Plough Only – No Jetting	100	40	25
3m Plough – Jet Pump 1 (265kW Jetting)	325	140	125
3m Plough – Jet Pump 1 + 2 (530kW Jetting)	575	390	215

Figure 7 - MD3XT in 2.2m burial mode

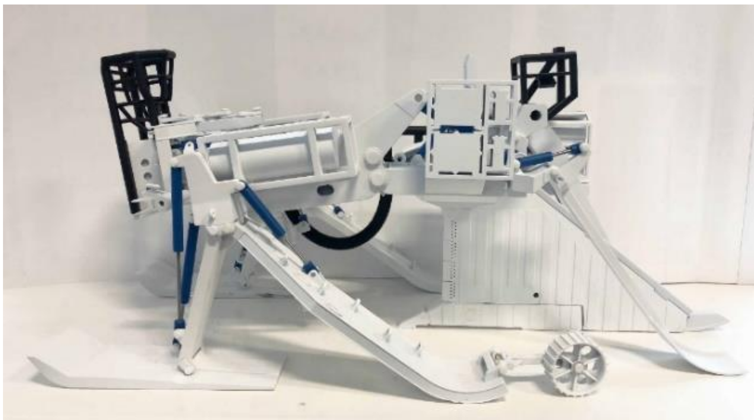
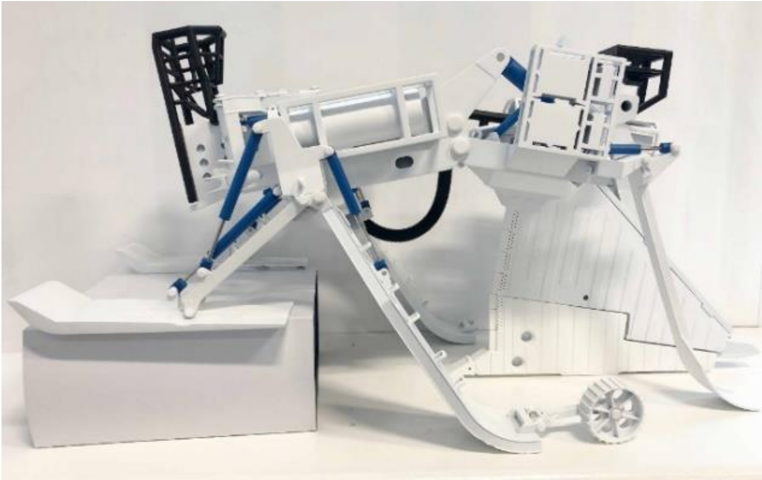


Figure 8 - MD3XT in 3.3m burial mode



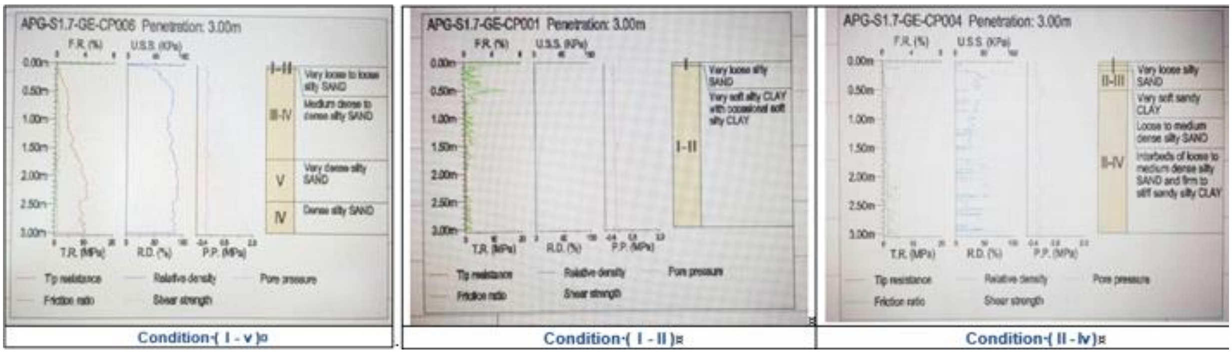


Figure 9 - Geotechnical Analysis of Three Seabed Conditions

Figure 10 - Summary Characteristics for Three Seabed Conditions

Condition	Characteristic	Summarised Characteristic	Comment
(i-v)	(i-ii) - Very loose to loose silty SAND	Dense Silty SAND	Ultra thin layer
	(iii-iv) Medium Dense to Dense Silty SAND		
	(v) Very dense silty SAND		Lower range of burial target
(i-ii)	(i) - Very loose silty SAND	Very soft silty CLAY	Ultra thin layer
	(i-ii) Very soft silty CLAY with occassional soft silty CLAY		
(ii-iv)	(i) - Very loose silty SAND	Medium Dense SAND	Ultra thin layer
	(i) - Very soft sandy CLAY		Ultra thin layer
	(ii-iii) Loose to Medium Dense Silty SAND		
	(ii-iii) Interbeds of Loose to Medium Dense Silty SAND and firm to stiff sandy silty CLAY		Consistent Medium Dense Sand with some stiffer clay

Figure 11 - MD3XT Performance Summary

Sediment Type	Jetting	Average		
		Speed(km/h)	Tension(T)	Burial Depth(cm)
i - ii	None Jetting	1.70	4.52	219.57
	One Motor	No Reference		
	Both Motors	No Reference		
i - v	None Jetting	No Reference		
	One Motor	1.34	22.53	170.00
	Both Motors	1.58	16.29	181.37
ii - iv	None Jetting	No Reference		
	One Motor	1.12	7.57	186.19
	Both Motors	1.35	11.79	169.51

Figure 12 - Comparison of MD3XT ploughing speeds (m/hr) with jetting pumps

	1 Pump (265kW)			2 Pump (2 x 265kW)		
	Actual	Predicted	Normalised	Actual	Predicted	Normalised
Medium dense SAND	1120	470	660	1350	660	910
Dense silty SAND	1340	210	290	1580	320	470

Figure 13 - MD3XT Performance in Mixed Seabed Campaign, AAE-1, 2016

Sediment Type	Jetting	Average		
		Speed(km/h)	Tension(T)	Burial Depth(cm)
I -II (3m)	None Jetting	No Reference		
	Single Motor	1.53	20.50	277.86
	Both Motors	1.04	25.35	244.86
I -III (3m)	None Jetting	No Reference		
	Single Motor	0.36	31.87	210.01
	Both Motors	0.32	27.57	174.93
I -IV (3m)	None Jetting	No Reference		
	Single Motor	0.95	26.27	205.71
	Both Motors	0.40	21.79	204.92
I -IV (1.5m)	None Jetting	No Reference		
	Single Motor	0.87	27.83	198.14
	Both Motors	0.81	21.51	175.07
II -IV (3m)	None Jetting	No Reference		
	Single Motor	0.37	32.06	239.12
	Both Motors	No Reference		
II -IV (1.5)	None Jetting	No Reference		
	Single Motor	1.01	23.96	170.20
	Both Motors	0.59	24.23	180.43
II -III	None Jetting	No Reference		
	Single Motor	1.42	23.16	225.04
	Both Motors	0.71	22.92	225.04

Figure 14 - Sediment Classification

Sediment Type	Strength / Density Description	Strength –Cu (kPa)	Density – Dr (%)	Description
I	Very soft / Very loose	< 20	<15	Typically very loose silty SAND, or very soft silty CLAY generally with a high organic content
II	Soft / Loose	20 – 40	15 – 35	Typically loose silty SAND, or soft silty CLAY generally with some organic content
III	Firm / Medium dense	40 – 75	35 – 65	Typically medium dense silty SAND, or firm clayey SILT, or silty CLAY
IV	Stiff / Dense	75 – 150	65 – 85	Typically dense silty SAND, or stiff clayey SILT, or silty CLAY
V	Very stiff / Very dense	150 – 300	85 – 95	Typically very dense silty SAND, or very stiff clayey SILT, or silty CLAY
VI	Weathered bedrock	>300	>95	Weathered Bedrock