11 March 2003

VG07437

Rapid Impact Compactor Ltd.
270 – 8208 Swenson Way
Delta, BC
V4G 1J6

Attention: Mr. Joe Miller

Re: **Results of Becker Penetration Testing**
Chilliwack Fire Hall

Dear Sir;

1.0 INTRODUCTION

AMEC Earth & Environmental Ltd. (AMEC) was requested by Rapid Impact Compactor Ltd. to carry out a Becker Penetration Testing (BPT) program for a site proposed to occupy a fire hall facility in Chilliwack, BC. This brief report presents a summary of the results and interpretation of the BPT results.

AMEC was retained to provide geotechnical consultant services for design and construction of a fire hall and office building with a relatively rectangular footprint of approximately 40 m by 80 m. A site plan of the proposed development is shown on Figure 1. The fire hall will be approximately two storey's high with five apparatus bays and an approximately three-storey hose tower, while the office building will be four storeys.

Based on the results of geotechnical investigations carried out by AMEC in the Fall of 2002, it was assessed that ground improvement works would be required to remediate liquefaction susceptible soils. The chosen ground improvement method was Rapid Impact Compaction (RIC), which was completed by Rapid Impact Compactor Ltd. in the end of January 2003. Quality control BPTs was carried out immediately after completion of the ground improvement works, which confirmed the success of the RIC in densifying the granular soils. A revised construction schedule allowed for additional BPTs to be carried out towards the end of February 2003, which could provide indication of an increase in density of the granular soil due to ageing effects that is typically observed after completion of ground improvement works.

The scope of work described in this report comprised advancement of the additional BPTs in February 2003 and presentation of the BPT data to evaluate the impact of the ground improvement works.

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2.0 SUBSURFACE CONDITIONS

Geotechnical investigations carried out by AMEC for the proposed development included solid stem drilling, Dynamic Cone Penetration Tests (DCPTs), electronic Cone Penetration Tests (CPTs) and Becker Hammer testing. In summary, the results of these investigations indicated general soil conditions comprising nominal granular fill over interbedded sand and silt layers extending to about 3 m depth, which was underlain by granular soils.

The sand content in the interbedded deposit appeared greater than the silt content and the sand content was even significant in the silt zones, which resulted in a generally cohesionless deposit. However, cohesive silt zones up to about 0.3 m thick were occasionally encountered immediately below the fill at a few test hole locations. The cohesive and cohesionless zones were typically firm and loose to compact, respectively.

The granular deposit below the interbedded deposit consisted of sand with variable gravel content and minor silt content and occasional cobbles. The upper zone of this granular soil deposit was compact to very dense with typically equivalent SPT-N_{60} values of the order of 17 blows/ft or more to approximately 6.5 m depth. However, loose to compact zones up to about 2.5 m thick existed between 6.5 m and 10 m depth. Interpretation of BPT data indicated dense to very dense granular soil from about 10 m to 15 m depth over compact to dense granular soil to about 20 m depth, which in turn was underlain by very dense granular soil.

The groundwater table was estimated at about 2.5 m to 3.0 m depth based on measurement in a monitoring well and the recorded CPT data.

3.0 DESCRIPTION OF GROUND IMPROVEMENT WORKS

The RIC method was selected to densify the granular soils. Following a pilot program using different compaction frequency and pattern, the RIC method was specified as follows:

a) Each 6 m by 6 m area should be compacted with minimum two passes with each pass having a minimum of 13 RIC spots.

b) Each RIC spot should be compacted by sufficient blows to achieve a final set during the second pass of maximum 10 mm.

It was necessary to subexcavate and replace the upper soils containing significant fines due to wet weather conditions. Generally, the subexcavations extended to about 0.5 to 1.0 m depth, which were backfilled with one lift of sand with minor gravel content followed by compaction with a smooth drum ride-on compactor.

The RIC works were carried out on the entire building footprint after completion of subexcavation and replacement. Full-time monitoring services were provided by AMEC to confirm that the RIC works were in compliance with the above criteria.

4.0 QUALITY CONTROL TESTING

Advancement of BPTs to confirm the ground improvement was carried out immediately after completion of the RIC works in the end of January 2003. Typically, it is beneficial to carry out the quality control BPTs a period of about minimum 2 weeks after completion of the ground improvement works due to an observed increase in density as a result of ageing effects. Thus, the BPTs carried out immediately after completion of the RIC works could misrepresent the actual impact of the RIC works and will not be addressed in this report.

A total of five BPTs (03-11 to 03-15) were advanced to about 12 m depth on 25 February 2003 using a Becker Hammer rig operated by SDS Drilling Ltd. The approximate locations of these BPTs are shown on Figure 1. An AMEC representative monitored the field work, which included recording of the blow counts and the bounce chamber pressure of the Becker Hammer. In addition, pull-out tests were carried out to assess the friction on the BPT casing.

There are two methods to convert the recorded Becker data to equivalent SPT-N_{60} values. The method proposed by Harder[1] is a function of the recorded blow counts and bounce chamber pressure of the diesel hammer. The method proposed by Sy[2] is a function of the energy transferred from the hammer to the BPT casing, the friction along the BPT casing and the blow counts. Based on previous experience of converting Becker data to equivalent SPT data, the Harder method often tends to smooth out the data and the Sy method tends to indicate a greater variability of the equivalent SPT-N_{60} values. In addition, the Sy method often predicts generally higher blow counts than the Harder method. The Harder method was proposed many years prior to the Sy method and appears to be used more often.

The interpreted equivalent SPT-N_{60} values using both methods at BPTs 03-11 to 03-15 are shown on the attached Figures 2 through 6.

5.0 DISCUSSION

Five BPTs (02-1 to 02-5) were advanced prior to implementation of the RIC works. The approximate locations of BPTs 02-1 to 02-5 are shown on Figure 1. The equivalent SPT-N_{60} values for these five BPTs are shown on Figure 7, which is based on the Harder method. The figure generally indicates less than 10 blows/ft from the ground surface to about 2.4 m (8 ft), zones with 10 to 20 blows/ft from about 2.4 m (8 ft) to 4.0 m (13 ft) depth and between 6.5 m and 10.0 m (21 ft and 33 ft) depth and more than 20 blows/ft for the remaining depths.

Based on the results of all the geotechnical investigations including BPTs, CPTs, drill holes, water level measurement, etc., it was assessed that liquefaction susceptible soils existed in a zones between about 2.5 m and 3.7 m (8 ft and 12 ft) depth and in discontinuous zones between approximately 6.5 m (21 ft) and 10.0 m (33 ft).

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[1] Harder, L., 1997: "Application of the Becker Penetration Test for evaluating the liquefaction potential of gravelly soils", Seismic Short course on Evaluation and Mitigation of Earthquake Induced Hazards.
[2] Sy, A., 1997: "Recent developments in the Becker Penetration Test: 1986 – 1996", Can. Geotech. Jour., vol. 24.

Several ground improvement methods were reviewed and the RIC was selected to densify the upper liquefaction susceptible zone. However, the results of the quality control BPTs indicated the potential for also eliminating the lower liquefaction susceptible zones as discussed below.

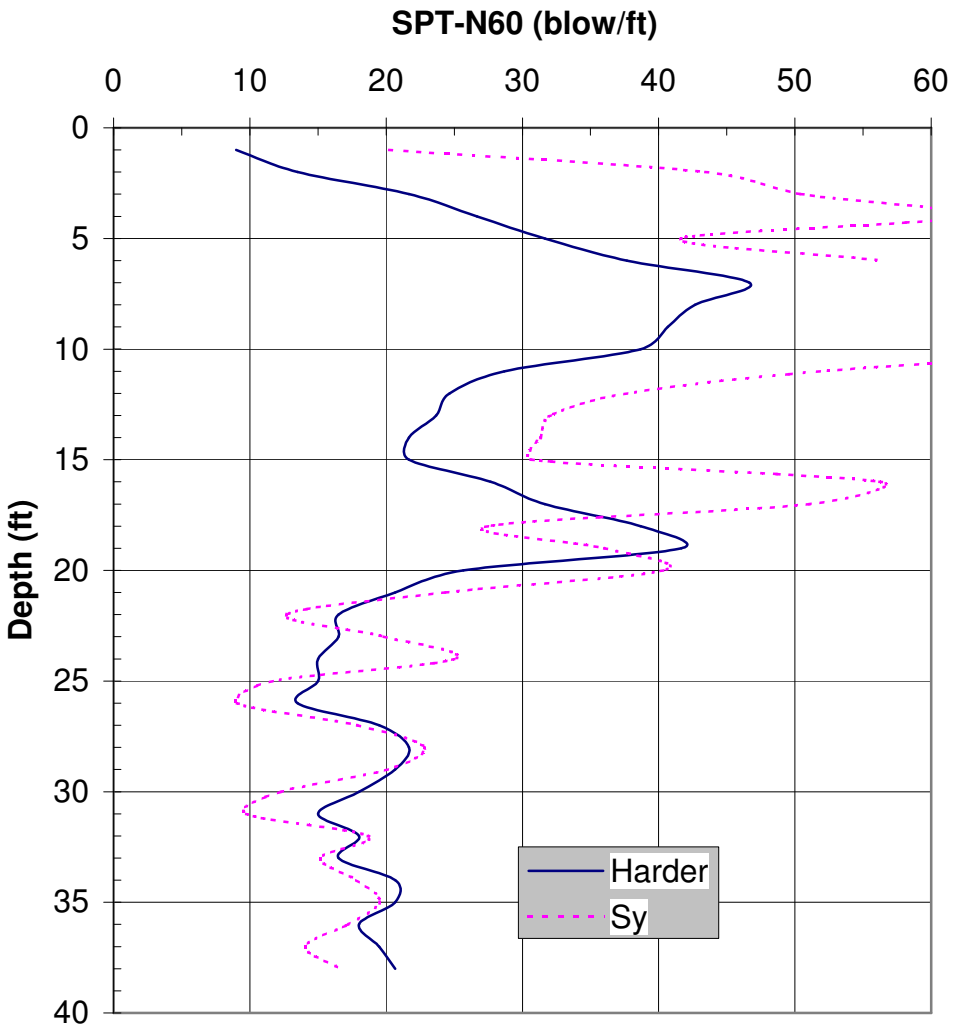
A summary of results from BPTs 03-11 to 03-15 is shown on Figure 8, which indicates the equivalent SPT-N_{60} values based on the Harder method. The figure generally shows equivalent SPT-N_{60} values of minimum 20 blows/ft below the estimated ground water level at about 2.5 m to 3.0 m (8 ft to 10 ft) depth except for zones generally between 6.5 m and 9.1 m (21 ft and 30 ft) depth at BPTs 03-11 and 03-13. Based on the results of CPTs carried out on the site, it is judged these deeper zones with less than 20 blows/ft is associated with increased fines content in the granular deposit.

Comparison of the general trends of the SPT-N_{60} values on Figures 7 and 8 indicate that RIC works densified both the upper and lower liquefaction susceptible soils. BPTs were advanced before and after the RIC works at similar locations in three areas. The pre- and post equivalent SPT-N_{60} values using the Harder method is shown on Figures 9, 10 and 11 at these three locations. Figure 9 indicates that the RIC works densified the soil to a depth of about 8.5 m (28 ft) with a minimum increase of approximately 10 blows/ft. Figure 10 shows a considerable increase in blow counts to a depth of about 5.5 m (18 ft) and a smaller increase below this depth. It is possible that this smaller blow count increase is associated with soil heterogeneity and inaccuracy with the testing method. Figure 11 shows a considerable increase in blow count to approximately 6.0 m (20 ft) depth and a negligible impact in the soils below. It should be noted that the pre- blow counts below a depth of about 6.0 m at the location shown on Figure 11 was fairly high at a minimum of 20 blows/ft.

6.0 CONCLUSION

The RIC method proved to be successful in densifying liquefaction susceptible soils on the subject site. The general trends of SPT-N_{60} values shown on Figures 7 and 8 of pre- and post-BPT data clearly indicates that the RIC method densified significantly to a depth of about 6.0 m (20 ft). In addition, it is judged that granular zones on the subject site with equivalent SPT-N_{60} values of about 15 blows/ft or less between depths of 6.0 m (20 ft) and about 9.1 m (30 ft) were densified to equivalent SPT-N_{60} values of about 20 blows/ft or more.

BPT 03-11 CONVERSION OF BPT TO SPT



NOTES:

1) SPT-N_{60} values using the Harder conversion method are based on field blow count, N, and bounce chamber pressure.
Reference: *"Application of the Becker Penetration test for evaluating the liquefaction potential of gravely soils"*, by L. Harder in *"Seismic short course on Evaluation and Mitigation of Earthquake Induced Liquefaction Hazards"*, March 13 and 14, 1997 in San Francisco.

2) SPT-N_{60} values using the Sy conversion method are based on field blow count, N, and casing friction, Rs.
Reference: *"Recent developments in the Becker penetration test: 1986-1996"*, by Alex Sy, Can. Geotech. Jour., v. 34, 1997.

3) No SPT-N_{60} values shown if input parameters not defined in the methods.

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	PROJECT: Chilliwack Fire Hall (BPTs)	
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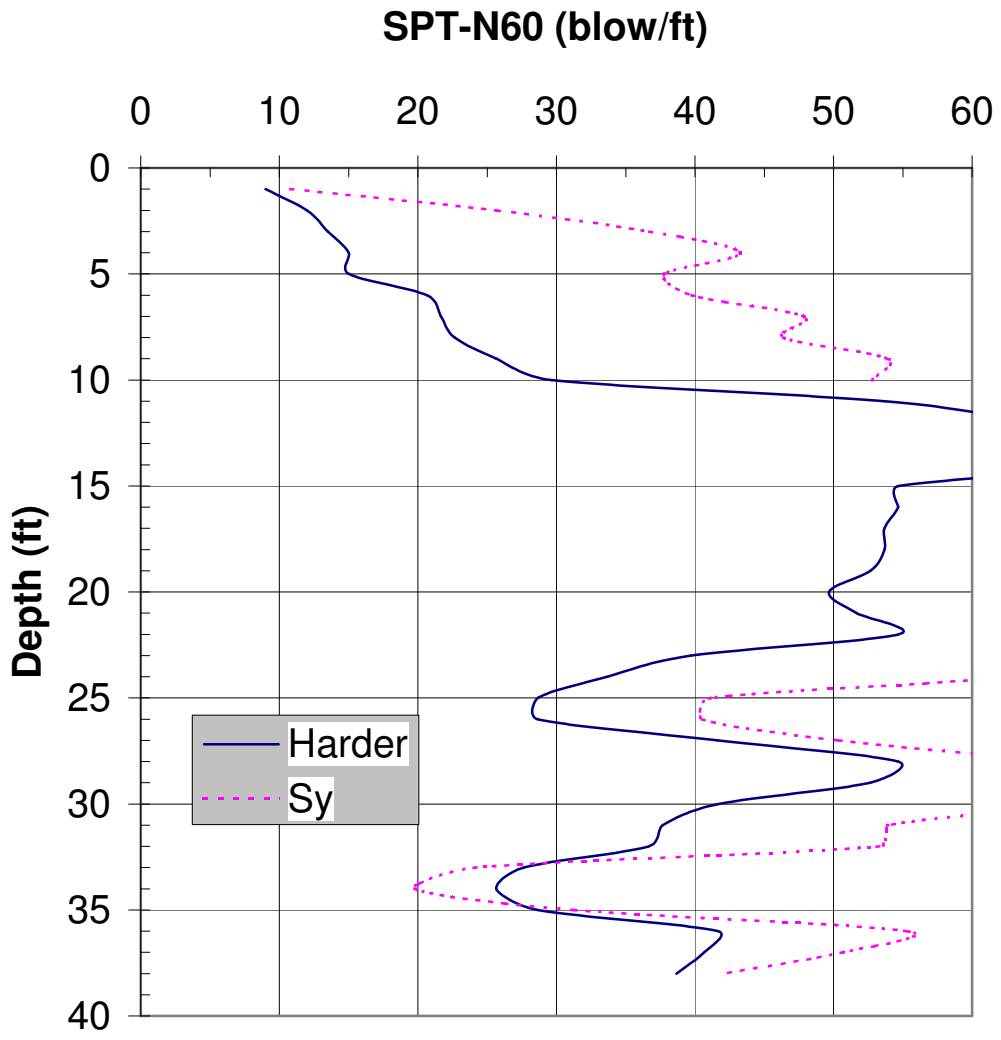
BPT 03-12 CONVERSION OF BPT TO SPT



NOTES:

1) SPT-N_{60} values using the Harder conversion method are based on field blow count, N, and bounce chamber pressure.
Reference: *"Application of the Becker Penetration test for evaluating the liquefaction potential of gravely soils"*, by L. Harder in *"Seismic short course on Evaluation and Mitigation of Earthquake Induced Liquefaction Hazards"*, March 13 and 14, 1997 in San Francisco.

2) SPT-N_{60} values using the Sy conversion method are based on field blow count, N, and casing friction, Rs.
Reference: *"Recent developments in the Becker penetration test: 1986-1996"*, by Alex Sy, Can. Geotech. Jour., v. 34, 1997.

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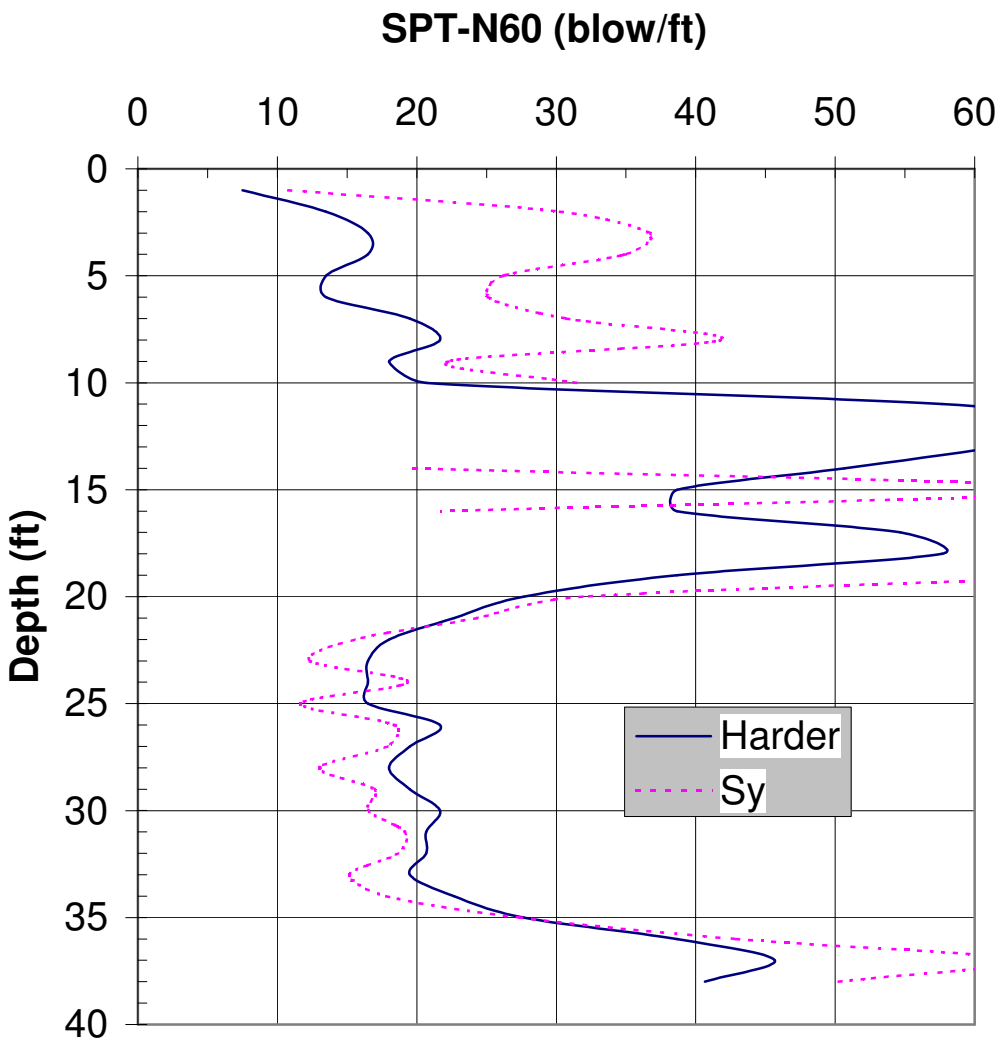
BPT 03-13 CONVERSION OF BPT TO SPT



NOTES:

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Reference: *"Application of the Becker Penetration test for evaluating the liquefaction potential of gravely soils"*, by L. Harder in *"Seismic short course on Evaluation and Mitigation of Earthquake Induced Liquefaction Hazards"*, March 13 and 14, 1997 in San Francisco.

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Reference: *"Recent developments in the Becker penetration test: 1986-1996"*, by Alex Sy, Can. Geotech. Jour., v. 34, 1997.

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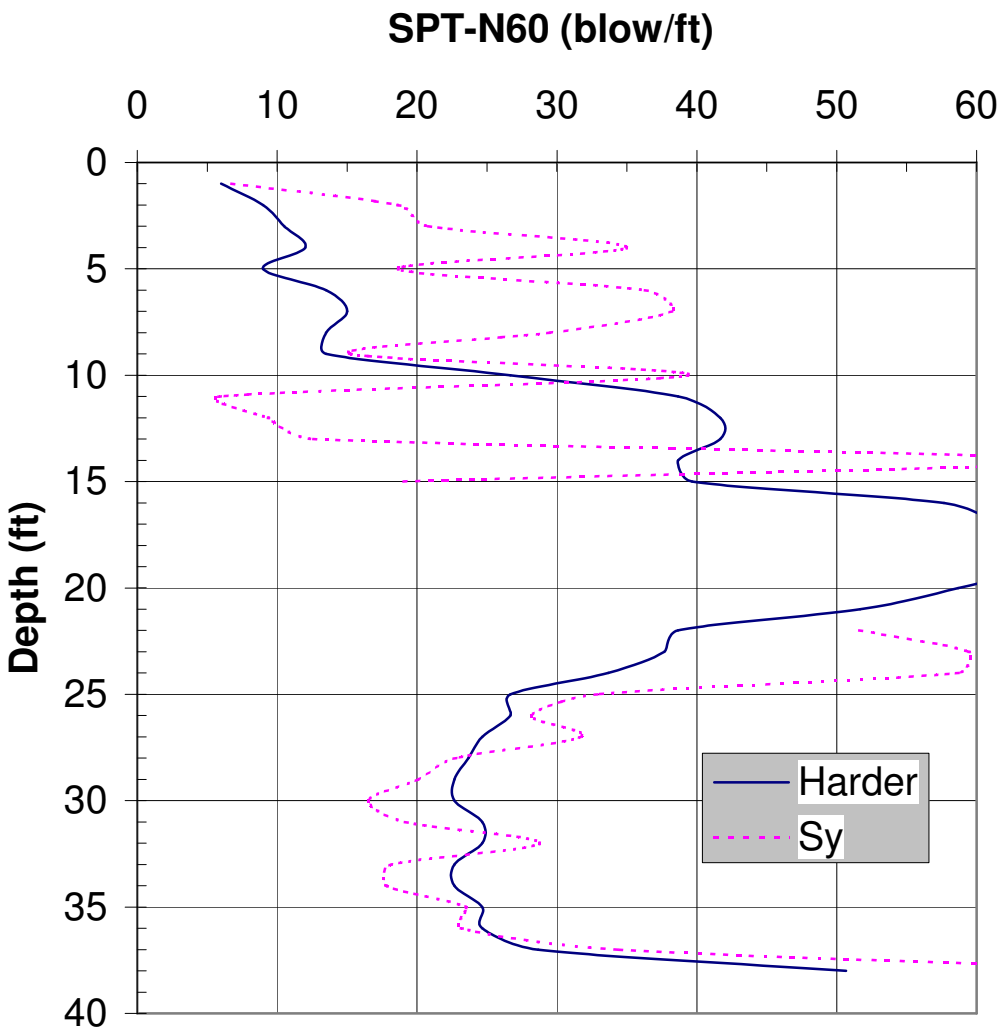
BPT 03-14 CONVERSION OF BPT TO SPT



NOTES:

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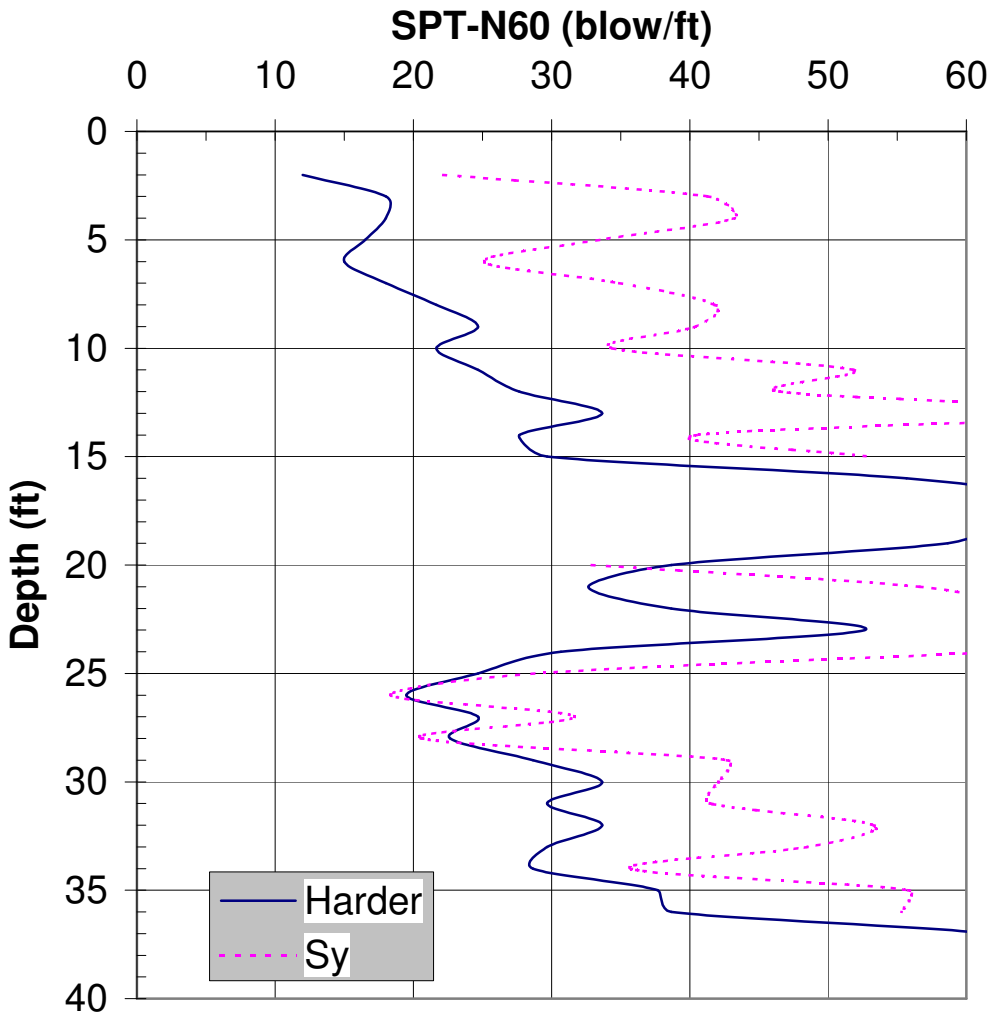
BPT 03-15 CONVERSION OF BPT TO SPT



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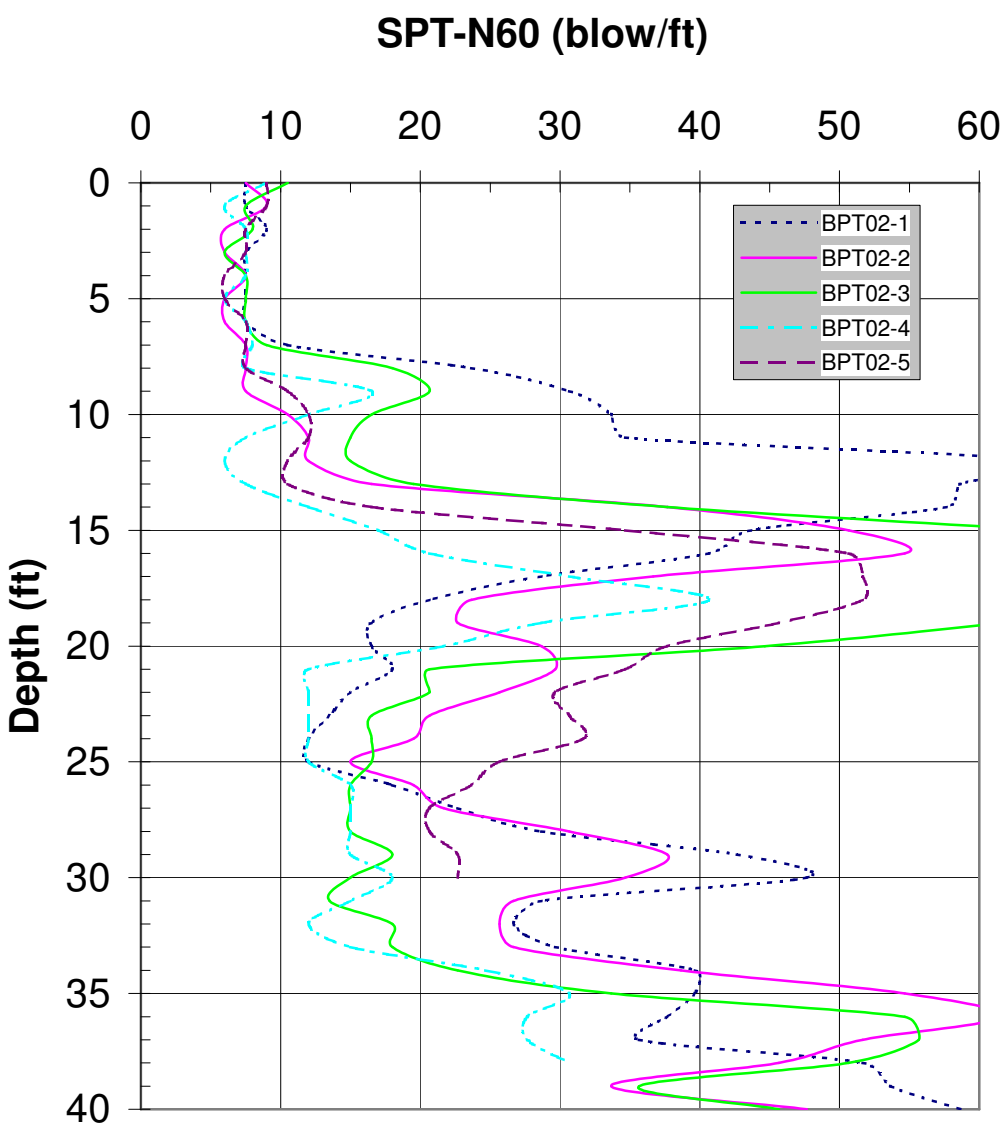
PRE-DENSIFICATION BPTs [Harder method]



NOTES:

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2) No SPT-N_{60} values shown if input parameters not defined in the Harder method.

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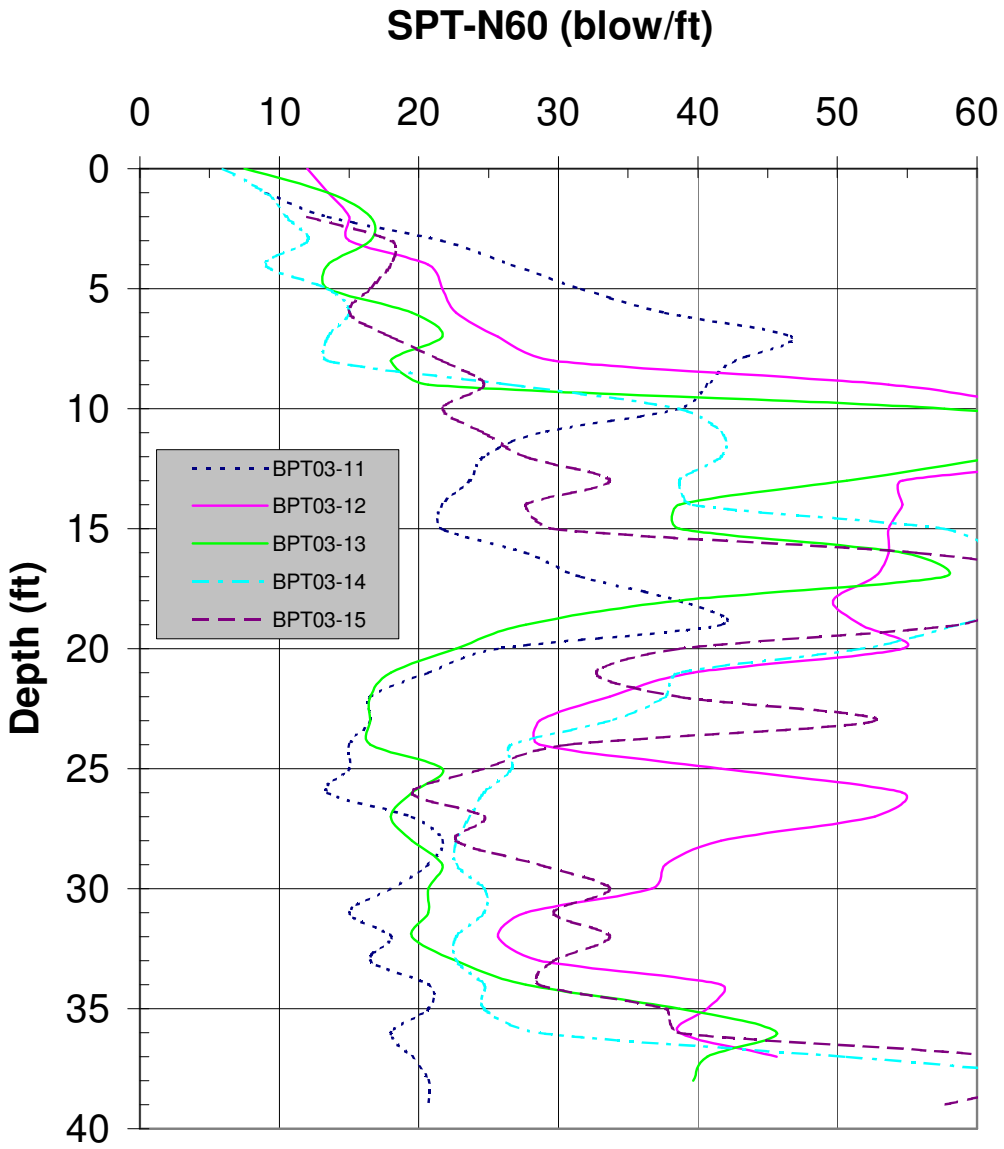
POST-DENSIFICATION BPTs [Harder method]



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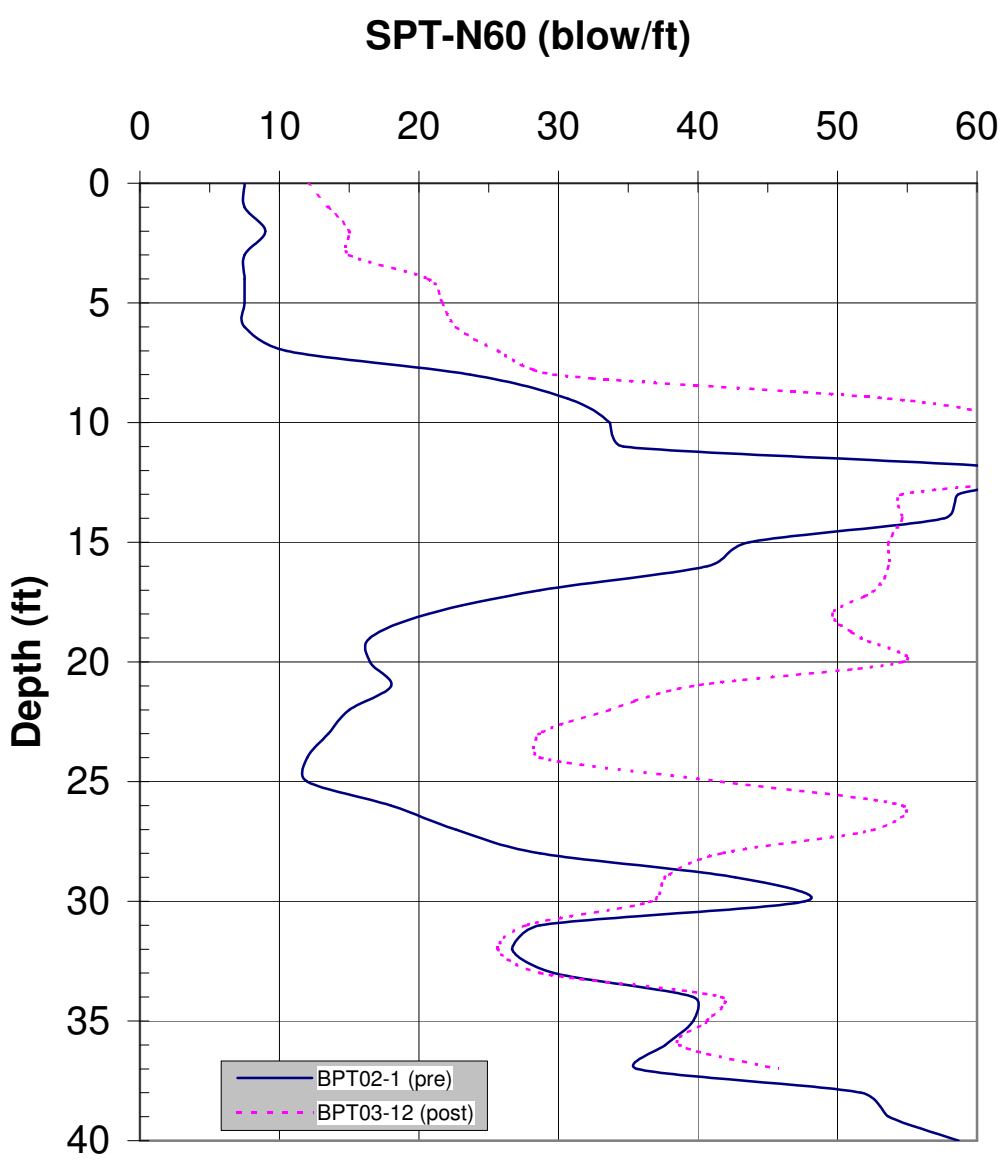
BPTs 02-1 and 03-12 [Harder method]



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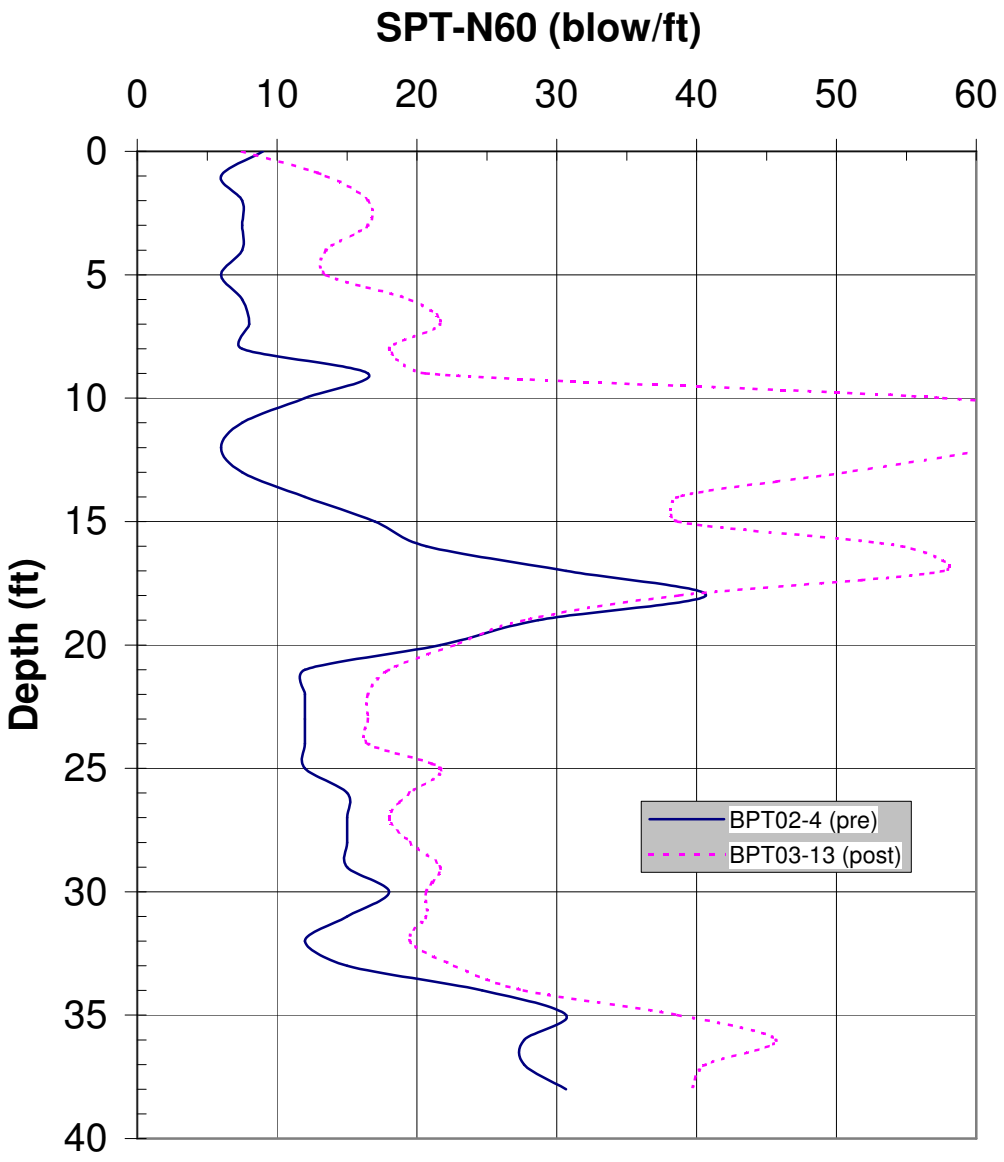
BPTs 02-4 and 03-13 [Harder method]



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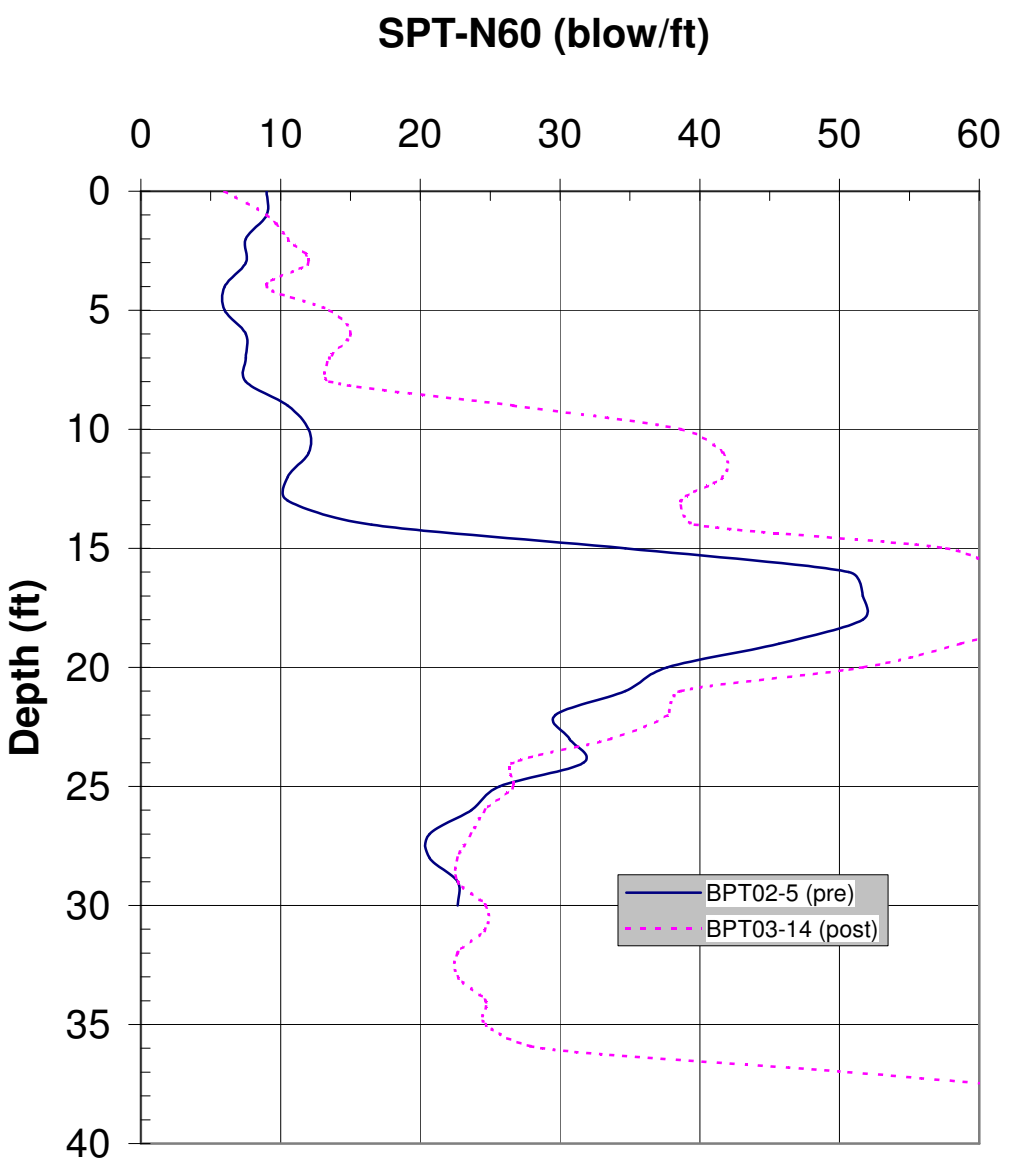
BPTs 02-5 and 03-14 [Harder method]



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