SPIN DYNAMIC CONE PENETRATION TESTING EXPERIENCE IN THE LOWER MAINLAND

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Recent experience with a new Dynamic Cone Penetration Test method in the Lower Mainland is reviewed. The Dynamic Cone Penetration Test is fast and economical, and provides a continuous profile of resistance versus depth. However, it has long been recognized that rod friction effects measured dynamic penetration test results at depth. Past efforts to minimize the effect of rod friction include the use of a disponsable cone, performing the test through an outer follower casing or by drilling out and recommencing the test at depth. The new method minimizes rod friction by spinning the AW rods at 60 revolutions per minute during penetration. The resulting data is compared to Standard Penetration Test N_{60} values, interpreted equivalent N_{60} values from the Cone Penetration Test, and traditional Dynamic Cone Penetration Test methods. The data shows that the new method significantly reduces the effects of rod friction and produces repeatable N_{60} values to depths of 30 m or more in deltaic sand and silt deposits.

INTRODUCTION

Penetration testing, including the Standard Penetration Test (SPT), Dynamic Cone Penetration Test (DCPT), Cone Penetration Test (CPT) and Becker Penetration Test (BPT), is commonly used for in situ profiling or logging of the physical and mechanical properties of soils in the British Columbia. Each of these methods has relative advantages and disadvantages as summarized in the Canadian Foundation Engineering Manual (CFEM) (1992). The SPT, introduced in 1902 and standardized between the late 1920s and early 1930s, has the largest historical data base for assessing in situ properties of granular soils and is still in relatively wide use. Due to the nature of the SPT method, testing is generally conducted at discrete depths. To obtain continuous resistance versus depth profile, the DCPT, CPT and BPT were developed and are generally calibrated and/or corrected to obtain equivalent SPT N_{60} values. As noted in the CFEM, dynamic cone size is not standardized and typically ranges from 50 to 100 mm in diameter and may be short or sleeved.

As described in the CFEM, it has long been recognized that the effect of rod friction tends to mask the cone tip resistance. Considerable effort has gone into the elimination of the effect of friction on the measured resistance in the development of the CPT and BPT (CFEM, Sy (1997)). Efforts to eliminate the effects of rod friction with the DCPT include the use of a disposable, oversized cone, the use of a follower casing and drilling mud, and periodic drill out. In comparing the DCPT to the SPT, Naesgaard (1988) recognized frictional effects

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and produced emperical correlations based on soil type and depth to correct DCPT blow counts to equivalent N_{60} values.

A common observation by drillers has been the difficulty in extracting the rods or casing on completion of a penetration test. To overcome this difficulty, drillers sometimes rotate the rods to reduce the friction and thereby facilitate rod extraction. SDS Drilling Division of Boart Longyear (SDS) of Burnaby, B.C. took this one step further and rationalized that rod friction could be largely eliminated if the rods could be rotated during penetration. From this idea, the Spin Dynamic Penetration Test (SDPT) was developed. This new method has been tested at several Lower Mainland sites underlain by deltaic deposits. Comparative plots of SDPT and equivalent N_{60} values from SPT and CPT versus depth are presented.

THE NEW METHOD

The new SDPT method is similar to SPT and DCPT methods wherein the blows required to advance the sampler or cone a distance of 305 mm is recorded and, where necessary, converted to an equivalent N_{60} value. The hammer mass, drop height and rods are identical to the SPT. For the SDPT, an automatic trip hammer has been modified to facilitate rotation of the rods at about 60 revolutions per minute (rpm) during penetration. The trip hammer is rated at about 95% efficiency and produces about 47 drops per minute. After some initial experimentation with cone sizes, SDS selected the current model of the SDPT disposable cone which measures 73 mm in diameter by 200 mm long. The tip has a 19 mm blunt end and a 60° cone angle, resulting in an 154 mm long sleeve.

SOIL CONDITIONS AT THE TEST SITES

The locations of the four Lower Mainland test sites are indicated on Figure 1. Criteria for site selection included uniformity of subsoil conditions, accessibility and availability of existing geotechnical information. The soil conditions at the test sites are summarized on Figure 2. In general, the subsoil conditions typically comprise up to 3 m of variable fill over silt and/or loose to dense sand underlain by relatively soft silt at depth. Apart from the potential for near surface variability, the sites are all underlain by reasonably uniform deltaic deposits. Due to the presence of underground utilities at several of the sites, it was necessary to hand auger to depths of up to 3 m prior to commencement of penetration testing. The test sites near Knight Street, Oak Street and Port Mann Bridges have SPT and CPT data. The Hopcott Road site was selected due to the presence of a relatively thick, uniform, loose sand deposit in which the effect of rotational speed could be assessed.

THE TEST PROGRAM AND RESULTS

To evaluate the effect of the rate or speed of rotation, a series of tests were conducted at the Hopcott Road site. The test pattern comprised a series of SDPT profiles conducted along the perimeter of a 2.4 m diameter circle. The profile at the centre of the circle was conducted at 60 rpm and the others at speeds ranging from 40 to 120 rpm. Figure 3 shows the measured blow count for the penetration test profiles. By observation, rotational speeds below about 100 rpm yielded relatively consistent results. A rotational speed of 60 rpm was selected for use for the remainder of the test program.

Testing was then undertaken at the other test sites. Plots of uncorrected SDPT blow counts versus depth for the Knight Street, Oak Street and Port Mann sites are shown on Figures 4, 5 and 6, respectively. Also shown on the plots are SPT N_{60} values and equivalent CPT N_{60} values. All CPT data and SPT data for the Knight Street and Port Mann sites was provided by the Ministry of Transportation and Highways (MoTH). At Oak Street, the SPTs were conducted by SDS in a mudded hole. All SPT data was corrected for energy using the method described in the CFEM. The CPT data was converted to equivalent N_{60} values using the method described by Lunne, Robertson and Powell (1997).

At several locations, where it was necessary to hand auger through the fill, the SDPT profiles commence below existing grades. As indicated, several of CPT profiles were also started below the ground surface to avoid obstructions and/or damaging existing underground services, or the risk of damaging the sensitive cone.

Measured SDPT and DCPT blow counts are plotted versus depth on Figure 7 for the Knight Street, Oak Street and Port Mann sites. The DCPTs were conducted by SDS. Details of the SDS DCPT method are described in Naesgaard (1988).

DISCUSSION

Figures 4, 5 and 6 indicate that the uncorrected SDPT blow counts correspond reasonably well with both the SPT and equivalent CPT N_{60} values. Of particular interest at the test sites is the relatively close correlation between the SDPT and equivalent CPT N_{60} values below the sand layer at depths ranging from about 20 to 40 m. Rotation of the rods during penetration, although not completely understood, appears to be effective in reducing, if not eliminating, the negative effects of rod friction to depths of 30 m or more based on the results presented above.

To evaluate the effect of rod friction, measured SDPT blow counts are compared with DCPT blow counts and plotted versus depth for 3 sites on Figure 7. It appears that, depending on the site, rod friction on the DCPT becomes significant below depths of 8 to 16 m. For comparison, the CFEM indicates that rod friction tends to mask the measured resistance at depths of 15 to 20 m.

At the Knight Street site, the 2 equivalent CPT N_{60} profiles show considerable variability to a depth of about 30 m. While the range of the results are broadly similar, precise correlation between the various methods at a specific depth should not be expected in soils such as those tested. However, close correlation exists below 30 m depth where the deposit is uniform.

At Oak Street, the 2 equivalent CPT N_{60} profiles show much less variability and quite closely match the available SPT data. The SDPT profile quite closely tracks the available data except in the silty zone between about 2 to 6 m depth.

At Port Mann, the SDPT and CPT data show close correlation except below about 39 m depth where the SDPT is consistently higher. SPT N_{60} values are typically higher at this site. As indicated on Figure 6, the CPT at Port Mann refused twice and required drill out at about 35 and 40 m depth whereas the SDPT advanced through the dense layers.

Rotational velocity above 100 rpm may have an impact on the measured output as illustrated at the Hopcott Road site. For this reason, 60 rpm was selected for the test program. Further work will be required to evaluate the effect of rotational velocity on measured output and possible correlations for energy and rod length. This test method should also be evaluated in a broader range of soil deposits.

CONCLUSIONS

The new SDPT method appears to be promising. Uncorrected SDPT blow counts appear to closely match SPT N_{60} and equivalent CPT N_{60} values at the test sites to depths of 30 m or more. Due to the robust nature of the dynamic testing equipment, the SDPT can penetrate relatively dense or hard layers including gravelly deposits. The SDPT is relatively inexpensive to perform and appears to give repeatable results. Deviation from measured SPT N_{60} or equivalent CPT N_{60} values may be due to site variability and requires further investigation.

From comparison with DCPT results, one can conclude that the SDPT significantly reduces frictional effects that plague conventional dynamic penetration testing equipment below 8 to 16 m depth.

ACKNOWLEDGEMENT

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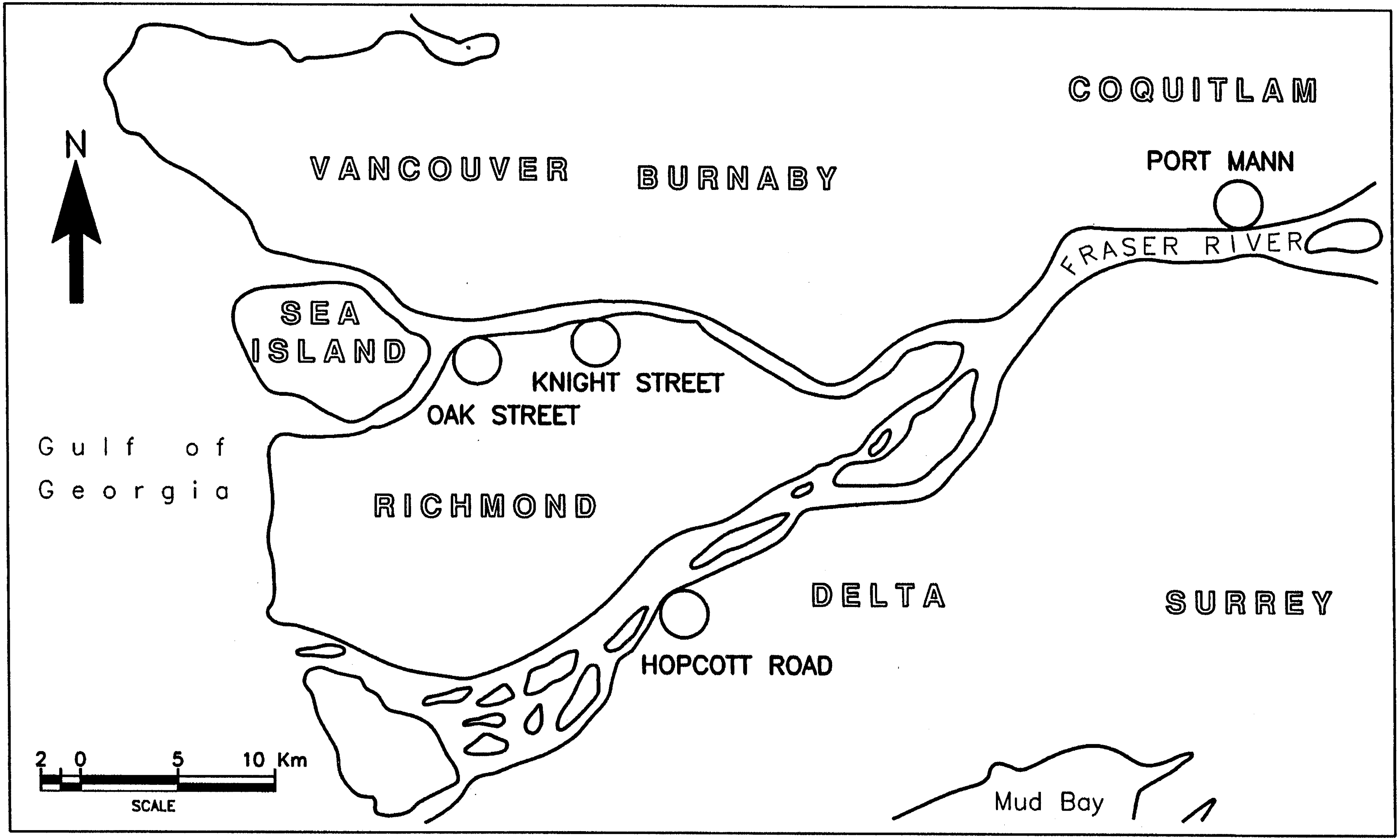

Figure 1. Test Site Locations.

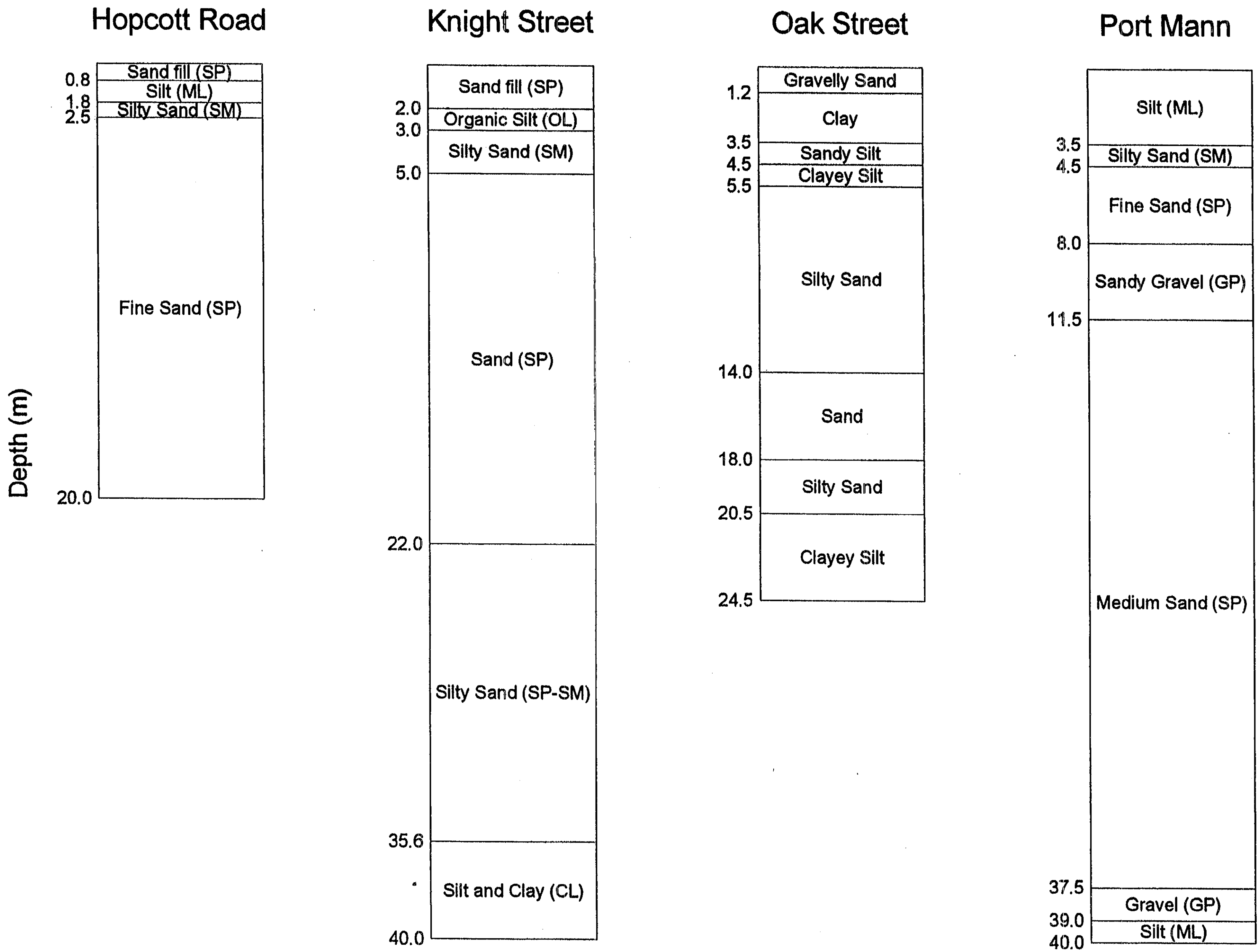

Figure 2. Soil conditions at the test sites.

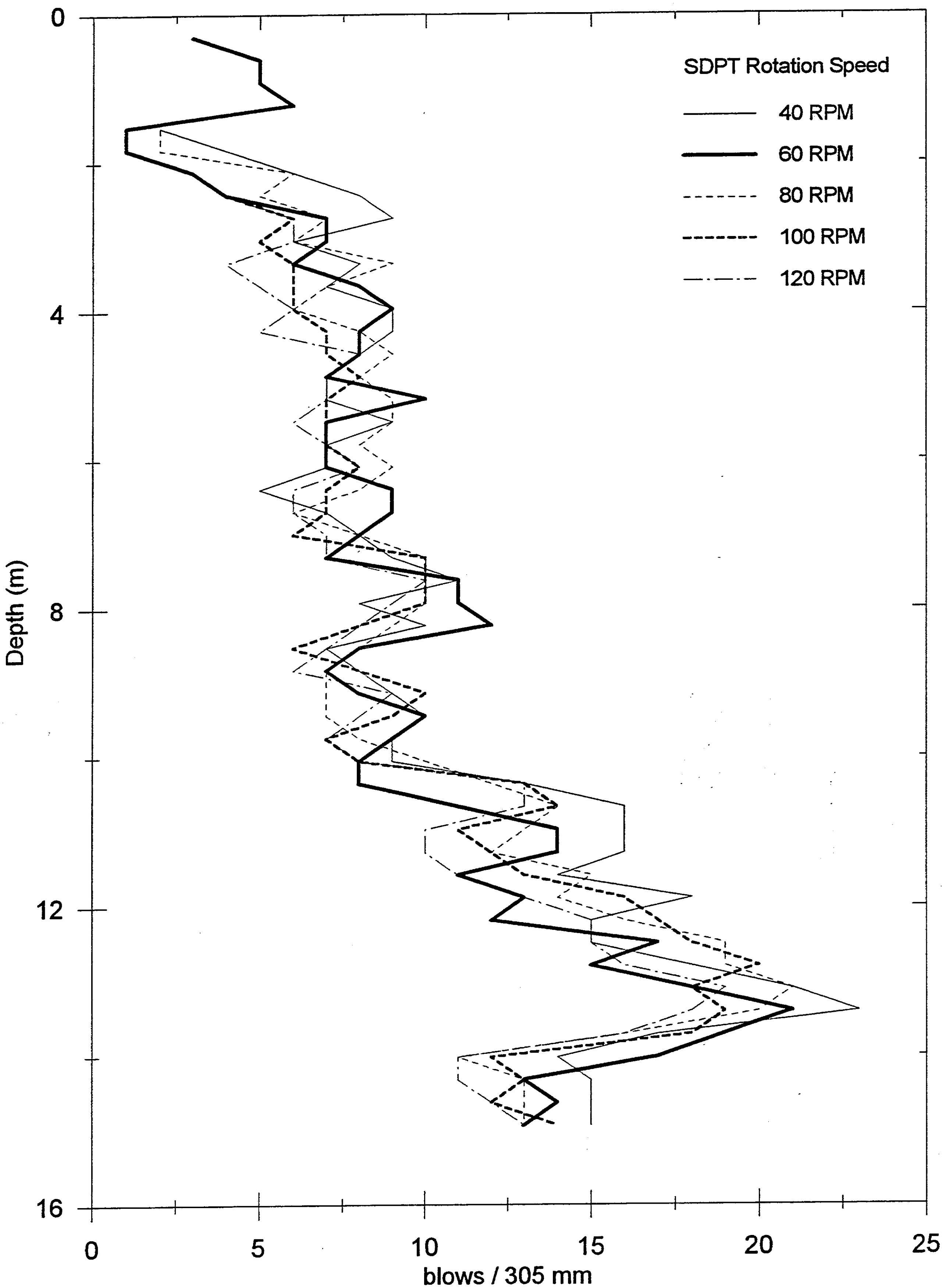

Figure 3. SDPT test data at Hopcott Road Site.

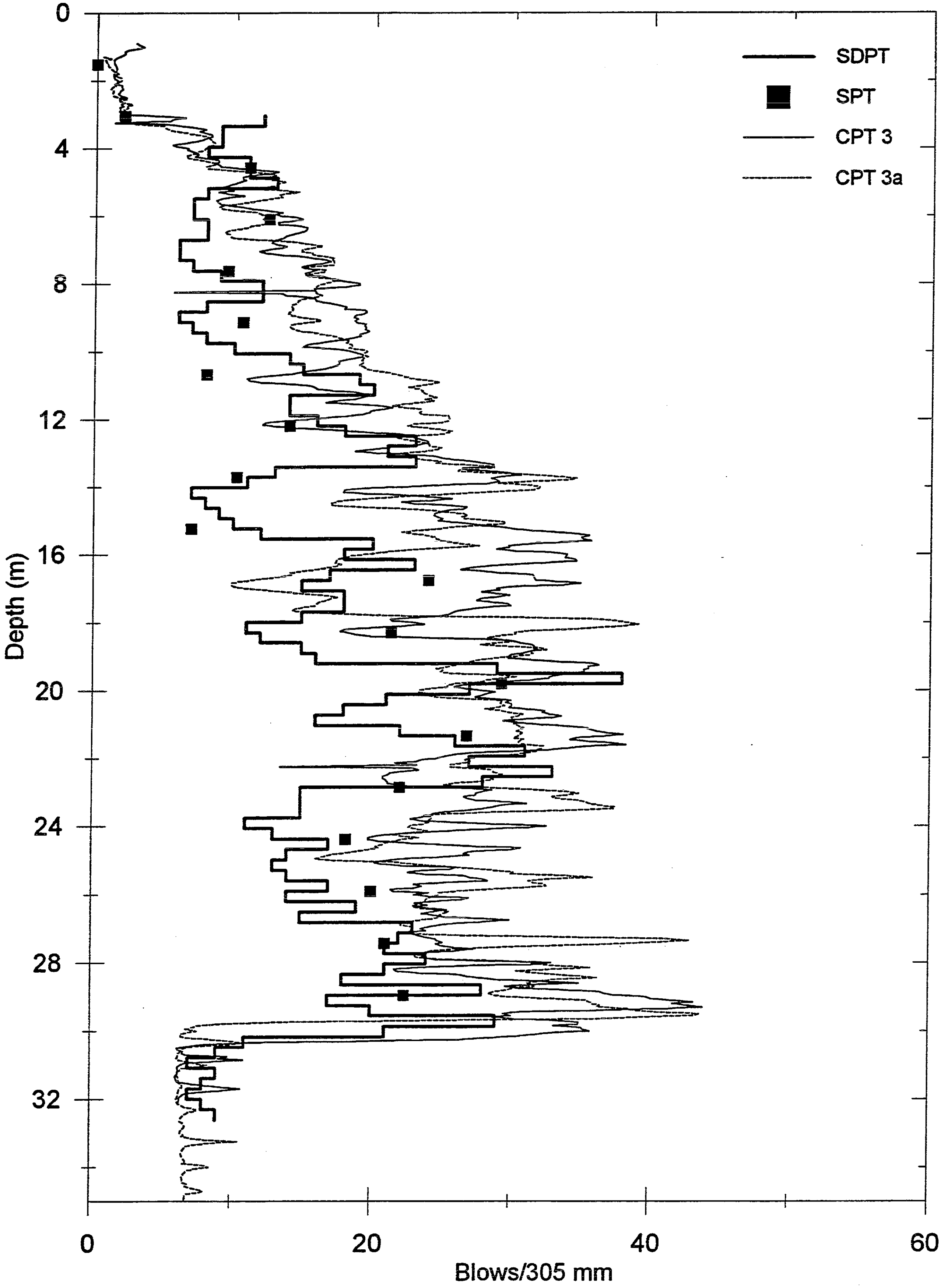

Figure 4. Uncorrected SDPT, corrected SPT N_{60} and equivalent CPT N_{60} test data at Knight Street Site.

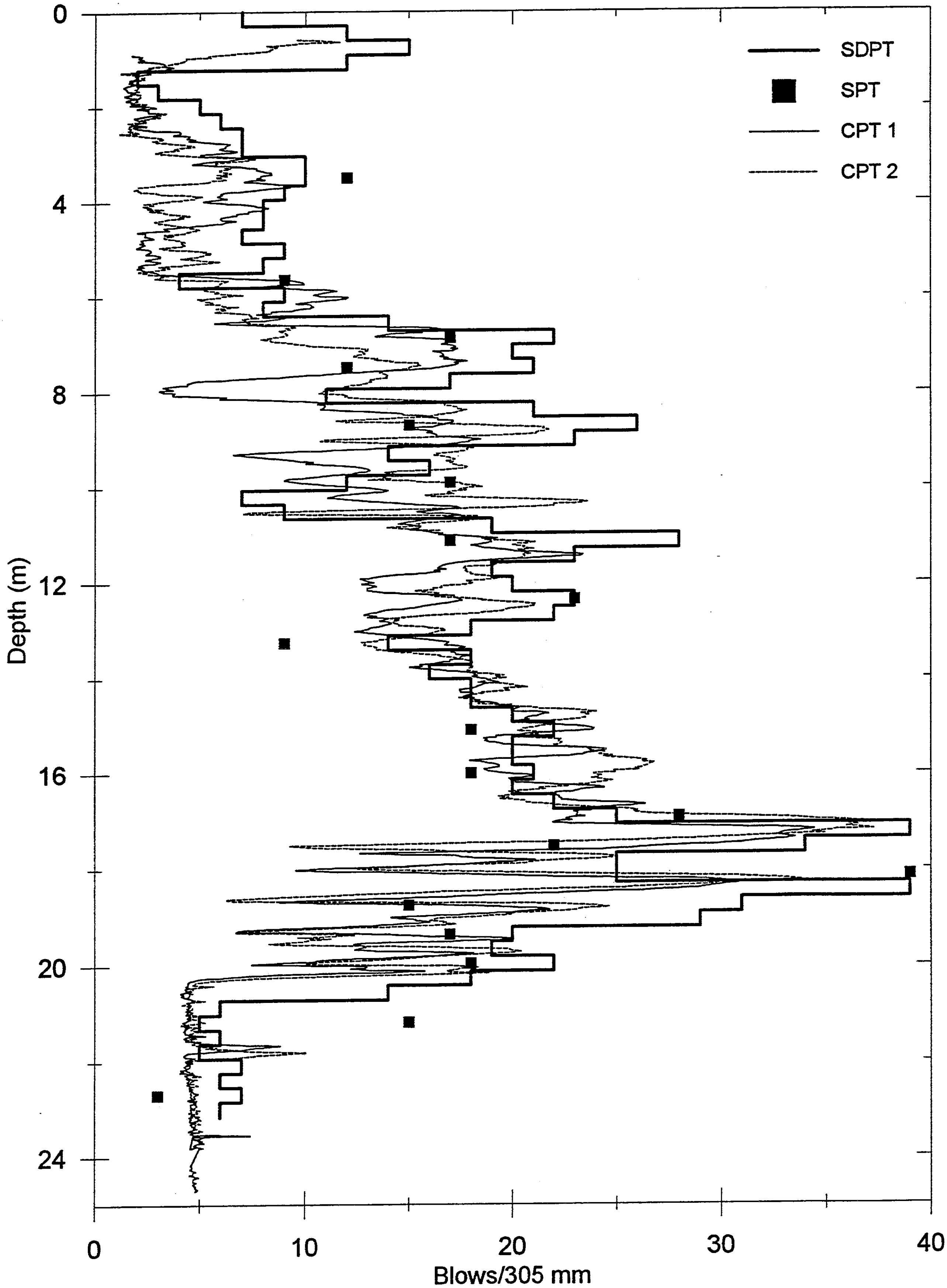

Figure 5. Uncorrected SDPT, corrected SPT N_{60} and equivalent CPT N_{60} test data at Oak Street Site.

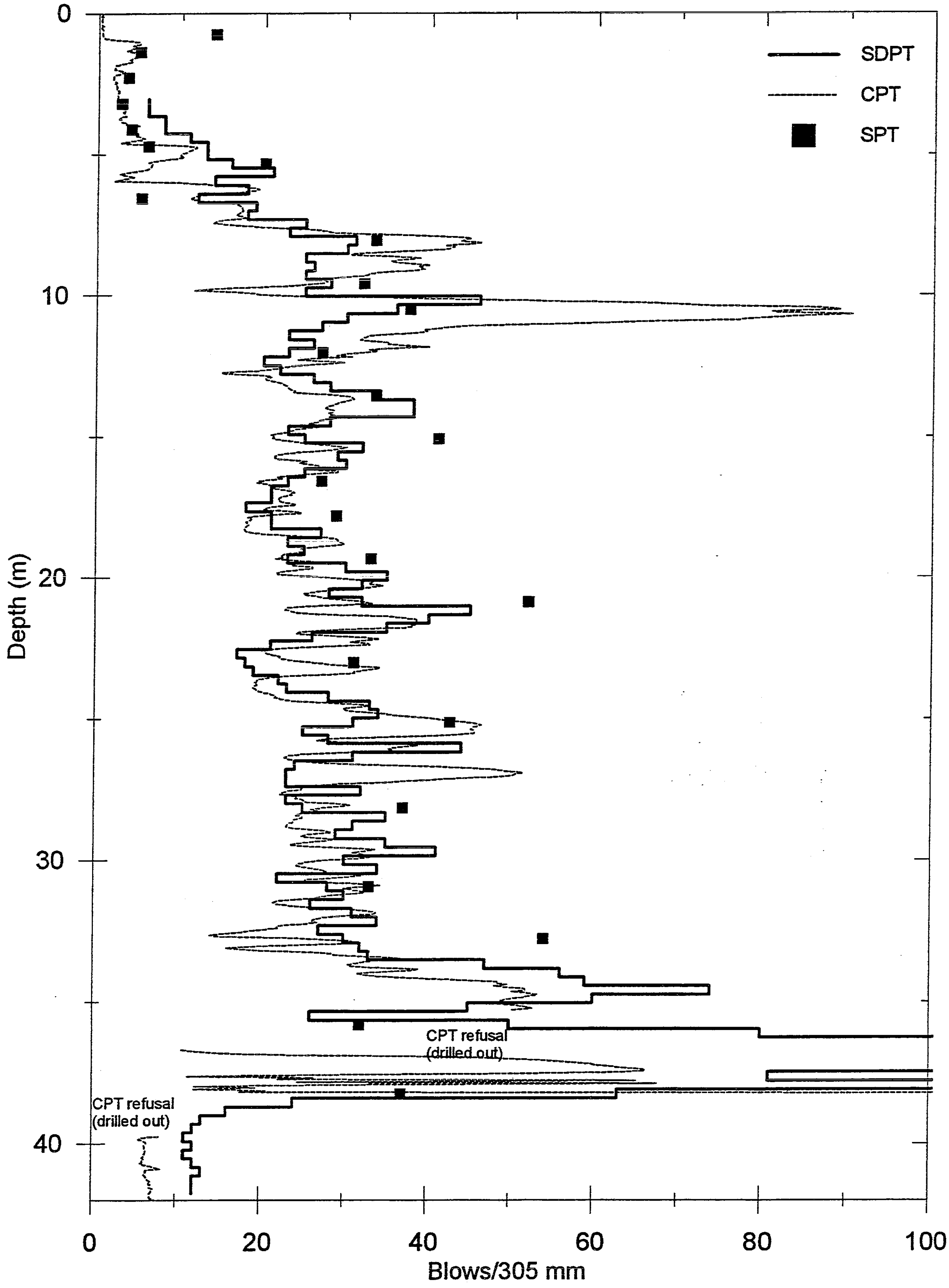

Figure 6. Uncorrected SDPT, corrected SPT N_{60} and equivalent CPT N_{60} test data at Port Mann Site.

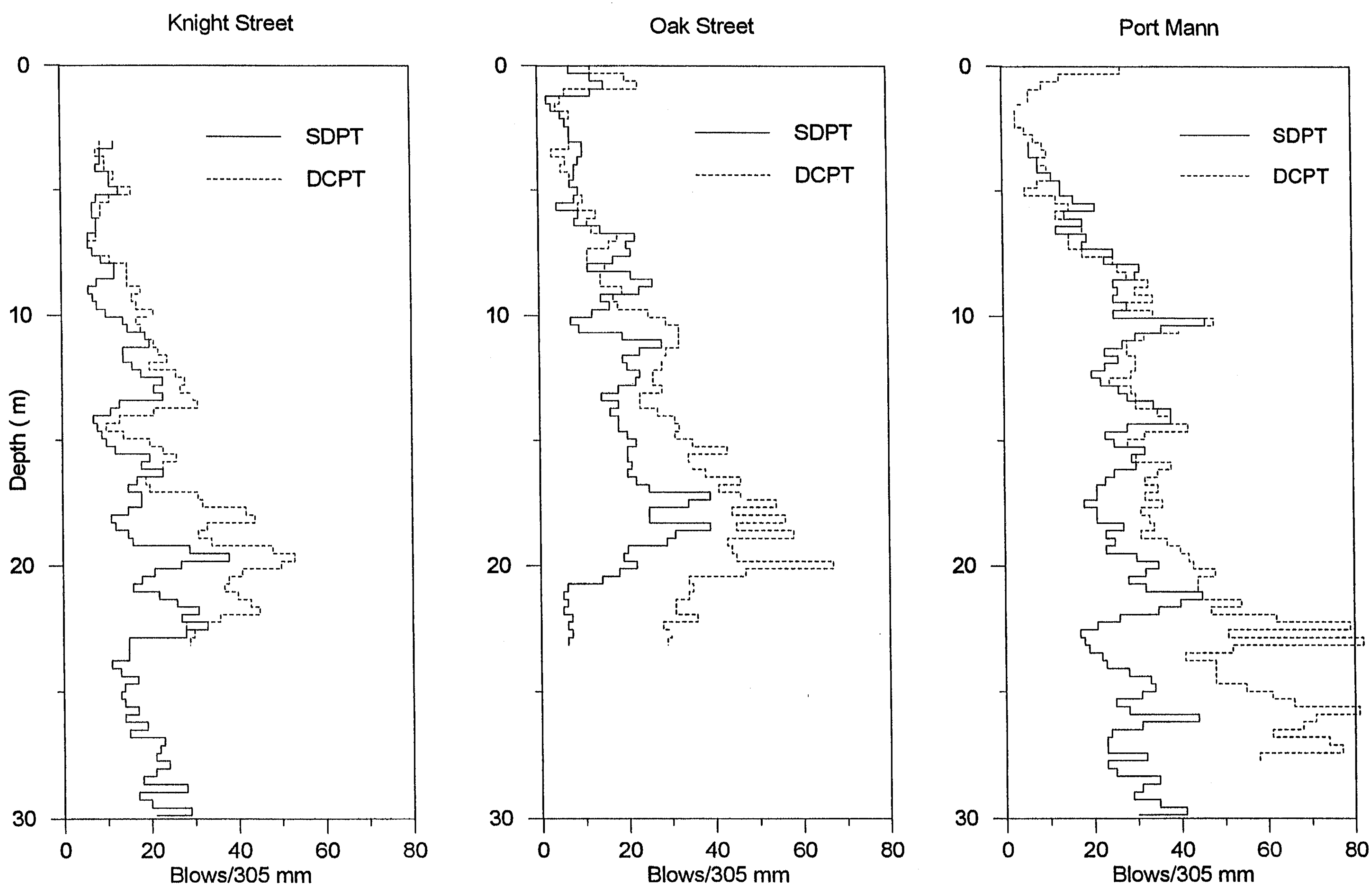

Figure 7. Comparison of SDPT and DCPT for 3 test sites.