January 28, 2004

File: 19-4227-0

Rapid Impact Compactors Ltd.
270 - 8208 Swenson Way
Delta, B.C.
V4G 1J6

Attention: Mr. Joe Miller

RAPID IMPACT COMPACTOR GROUND IMPROVEMENT VIBRATION MONITORING AND DENSIFICATION ASSESSMENT DOWNTOWN SITE, SQUAMISH, BRITISH COLUMBIA

Dear Sirs:

As requested, Thurber Engineering Ltd. (TEL) conducted detailed a vibration monitoring and post-densification testing program at a site in downtown Squamish, British Columbia. The purpose of the work was to monitor and assess the vibrations generated by the Rapid Impact Compactor (RIC) and the densification effects of RIC compaction with depth and lateral distance from the area subjected to compaction.

1. BACKGROUND

The RIC was adopted to treat the loose, liquefaction susceptible soils underlying the test site after a trial densification area was successfully treated. Vibration data was collected to examine vibration/energy attenuation with distance and post-densification penetration testing was conducted to assess both the depth and lateral extent of improvement due to RIC.

2. SOIL AND GROUNDWATER CONDITIONS

In general, the soil conditions comprised about 2 m of variable, native silt and silty sand over loose to compact, clean sand to the depth investigated as shown on the attached test hole log (Figure 1). Site preparation prior to compaction comprised removal of the majority of the surficial silt layer and replacement with end-dumped granular fill, either crushed basalt or pit run

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sand and gravel. Due to the relatively high groundwater table, a sump pump was required to maintain the groundwater level at least 1 m below the surface of the working platform of granular fill.

3. METHODOLOGY

Ground vibrations were monitored on the fill pad surface and on the adjacent native ground surface at various distances from the compactor. Peak Particle Velocities (PPV) and vibration frequencies were recorded using an Instantel Blastmate II. Feedback from the vibration monitoring was used to adjust the compaction energy input to control potentially damaging off-site vibrations and settlements.

4. RESULTS

4.1 Vibrations

Figure 2 attached shows attenuation of Peak Particle Velocity (PPV) with distance from the centre of the 1.5 m diameter RIC foot recorded on the granular fill pad and on the adjacent native soil conditions for a drop height of about 0.96 m. Measured dominant vibration frequencies generally ranged from about 5 to 30 Hz with an average value of approximately 10 Hz beyond about 10 m from the compaction point.

To compare vibration/energy attenuation with distance for different energy input, equipment and/or soil type, Dowding (1996) recommends the use of scaled energy attenuation plots wherein the distance is divided by the square root of the transmitted energy as shown on Figure 3. Note that the figure also includes data points for lower drop heights or energy input that were not included on Figure 2 and that the overall trend remains the same. Dowding indicates that, on a scaled distance plot, higher PPV values are indicative of more efficient or superior coupling between the mechanism of energy transfer (RIC, vibratory compactor, etc.) and the soil being treated. Accordingly, the results suggest that the RIC is considerably more efficient than dynamic compaction and that it falls within the lower bound of the general range of conventional vibratory compaction equipment. This clearly shows the advantage of maintaining the RIC foot in contact with the ground to optimize transfer of energy during the compaction process.

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4.2 Densification

Following treatment with the RIC, confirmatory testing, comprising a series of Dynamic Cone Penetration Tests (DCPTs) and test holes, was conducted using an auger drill rig equipped with an automatic trip hammer. The DCPT cone tip is similar in size and shape to the Standard Penetration Test (SPT) split spoon sampler and is driven using the same hammer energy. Previous local experience indicates that DCPT blow counts are approximately equivalent to SPT N-values.

Figure 4 shows the improvement based on DCPT blow counts relative to blow counts obtained in the original, pre-densification test hole log (Figure 1). By inspection, treatment with the RIC has resulted in significant improvement to at least 5 m depth with both pit run and minus 50 mm crushed gravel fill.

Figure 5 shows the effect of the RIC at the edge of the treatment area. The DCPT conducted coincident with the perimeter compaction points shows significant improvement to about 6 m depth. DCPTs conducted at 3 and 4.5 m from the perimeter compaction points show some nominal improvement extending laterally beyond the zone of treatment.

We trust that this is sufficient for your present needs. Should any questions arise, please call us.

Yours very truly,
Thurber Engineering Ltd.
David J. Tara, P.Eng.
Project Principal

Paul J. Wilson, EIT
Project Engineer

Enclosures

REFERENCES

1. Dowding, Charles H. (1996), Construction Vibrations, Prentice Hall, 610 pages.

Sheet 1 of 2

TEST HOLE NO.
03-4

FIGURE 1 - LOG OF TEST HOLE

LOCATION: Downtown Squamish

TOP OF HOLE ELEV:
METHOD: Solid Stem Auger
DRILLING CO.: On-Track Drilling Inc.
INSPECTOR: JMS

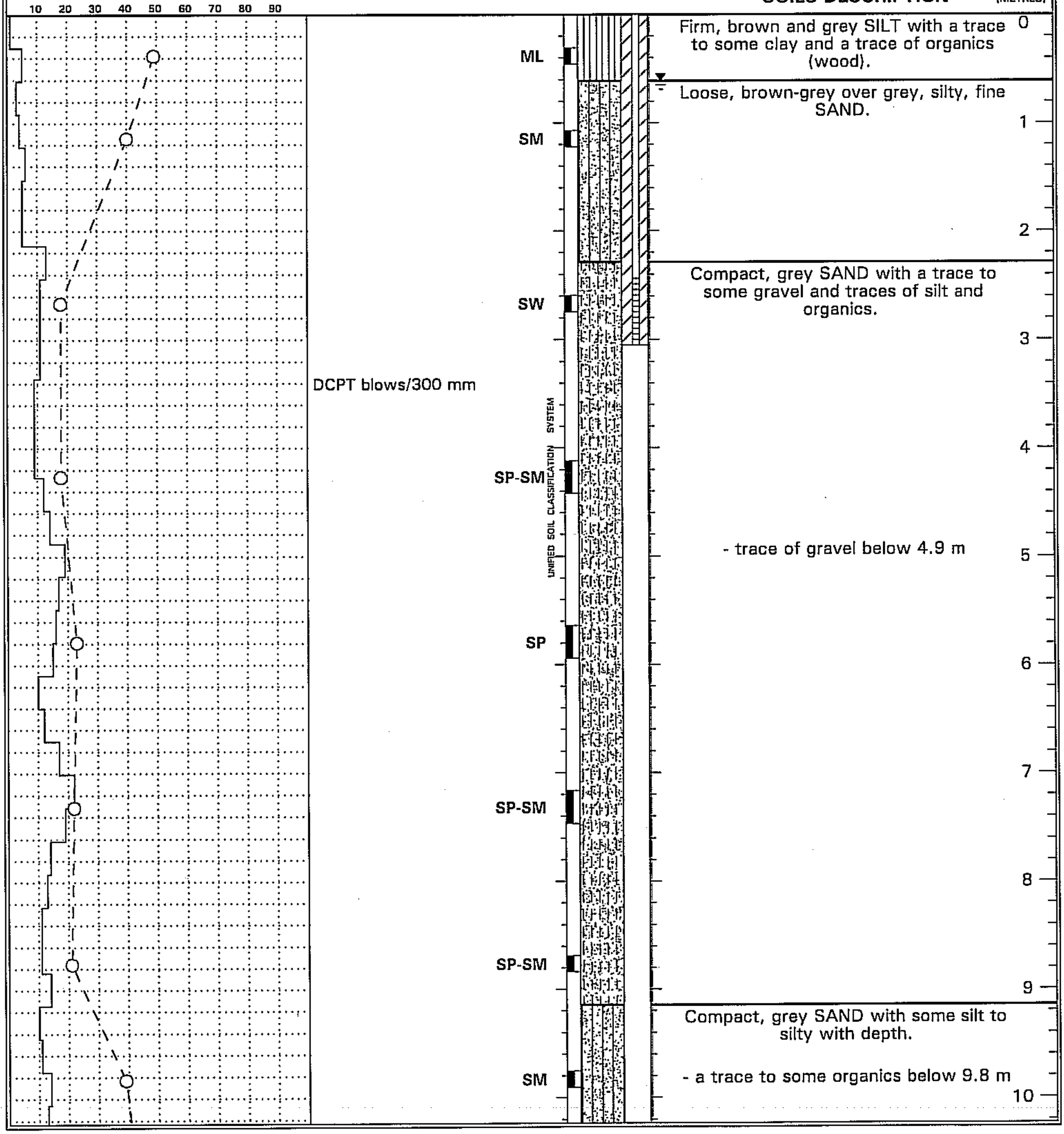
THURBER

CLIENT: Rapid Impact Compactors Ltd.
PROJECT: Downtown Squamish
British Columbia
DATE: Oct. 20, 2003
FILE NO.: 19-4227-0 **SCALE:** 1:50

PENETRATION (blows per 300 mm)
WATER CONTENT (%) ○ Disturbed ● Undisturbed
WATER LEVEL Plastic Limit Liquid Limit
SAMPLES ◧ Disturbed ■ Undisturbed ☒ No recovery
UNDRAINED SHEAR STRENGTH (kPa) ◆ Peak ◇ Residual
GRAIN SIZE (%) ▲ Passing #200 sieve △ Passing #4 sieve

SOILS DESCRIPTION

DEPTH (METRES)



Firm, brown and grey SILT with a trace to some clay and a trace of organics (wood).

Loose, brown-grey over grey, silty, fine SAND.

Compact, grey SAND with a trace to some gravel and traces of silt and organics.

- trace of gravel below 4.9 m

Compact, grey SAND with some silt to silty with depth.

- a trace to some organics below 9.8 m

Figure 2 - Downtown Squamish, Vibration Attenuation with Distance
0.96 m Average Drop Height

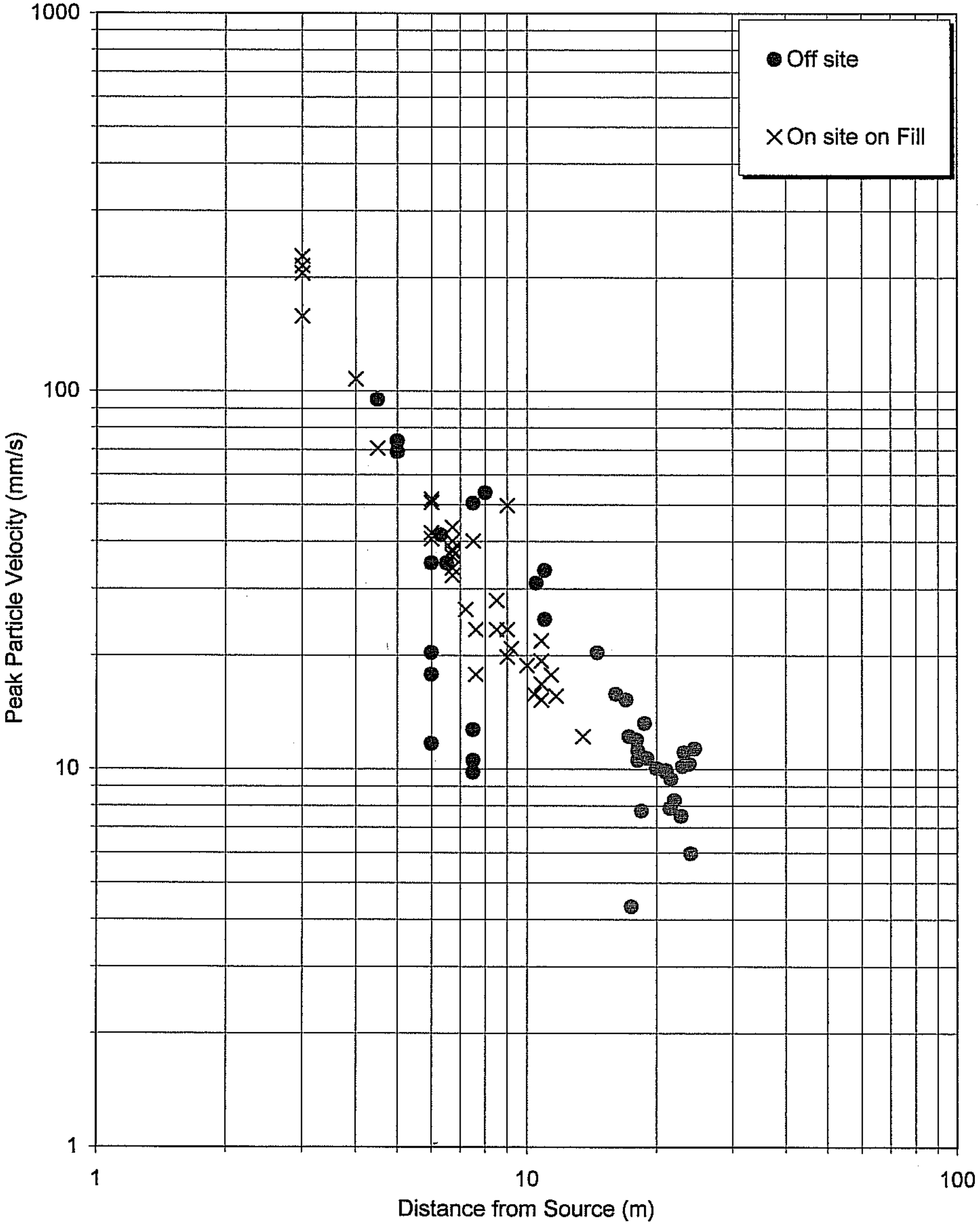


Figure 3 - Downtown Squamish
Peak Particle Velocity Attenuation with Distance

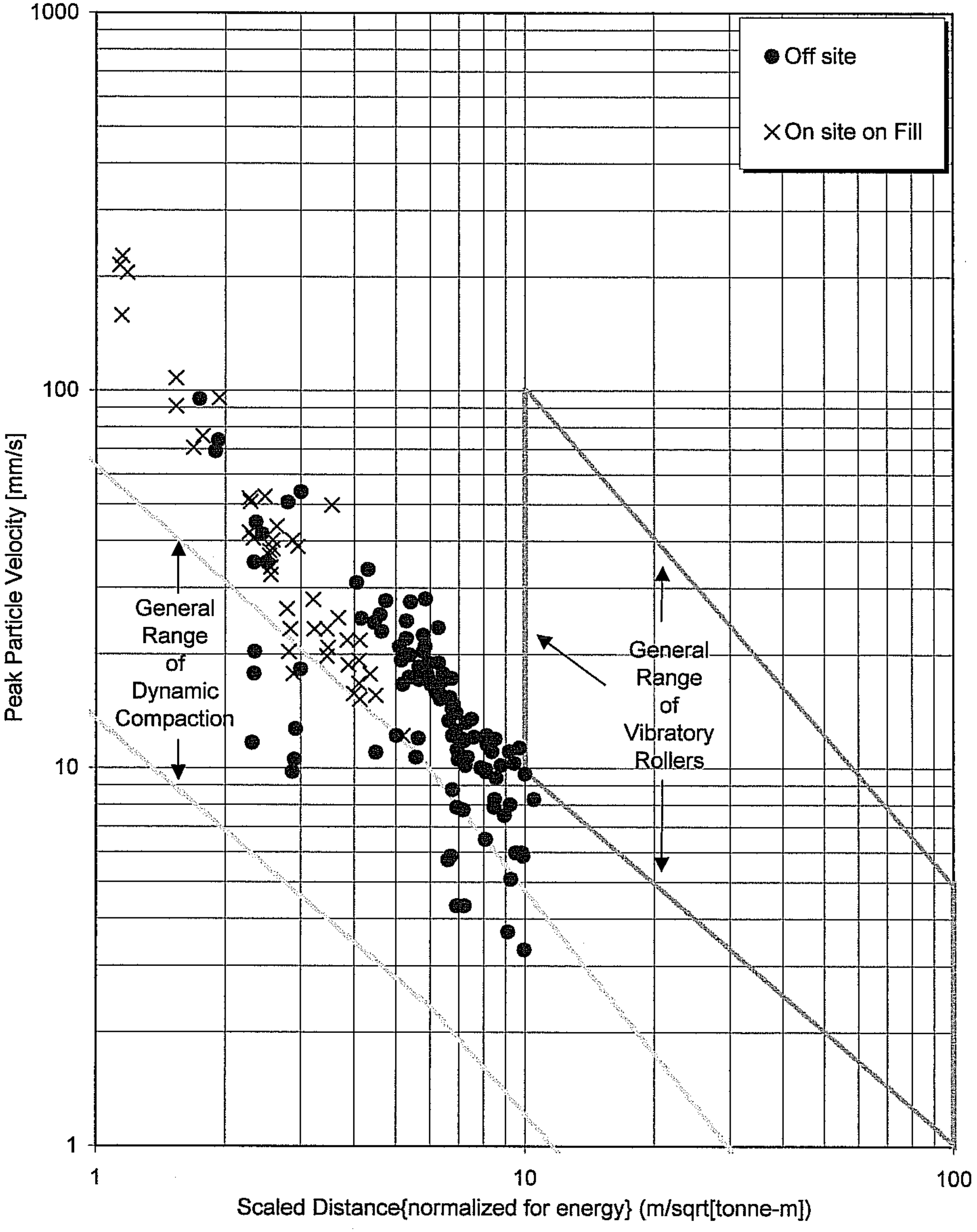


Figure 4 - Effect of Compaction Surface Material on DCPT N-value

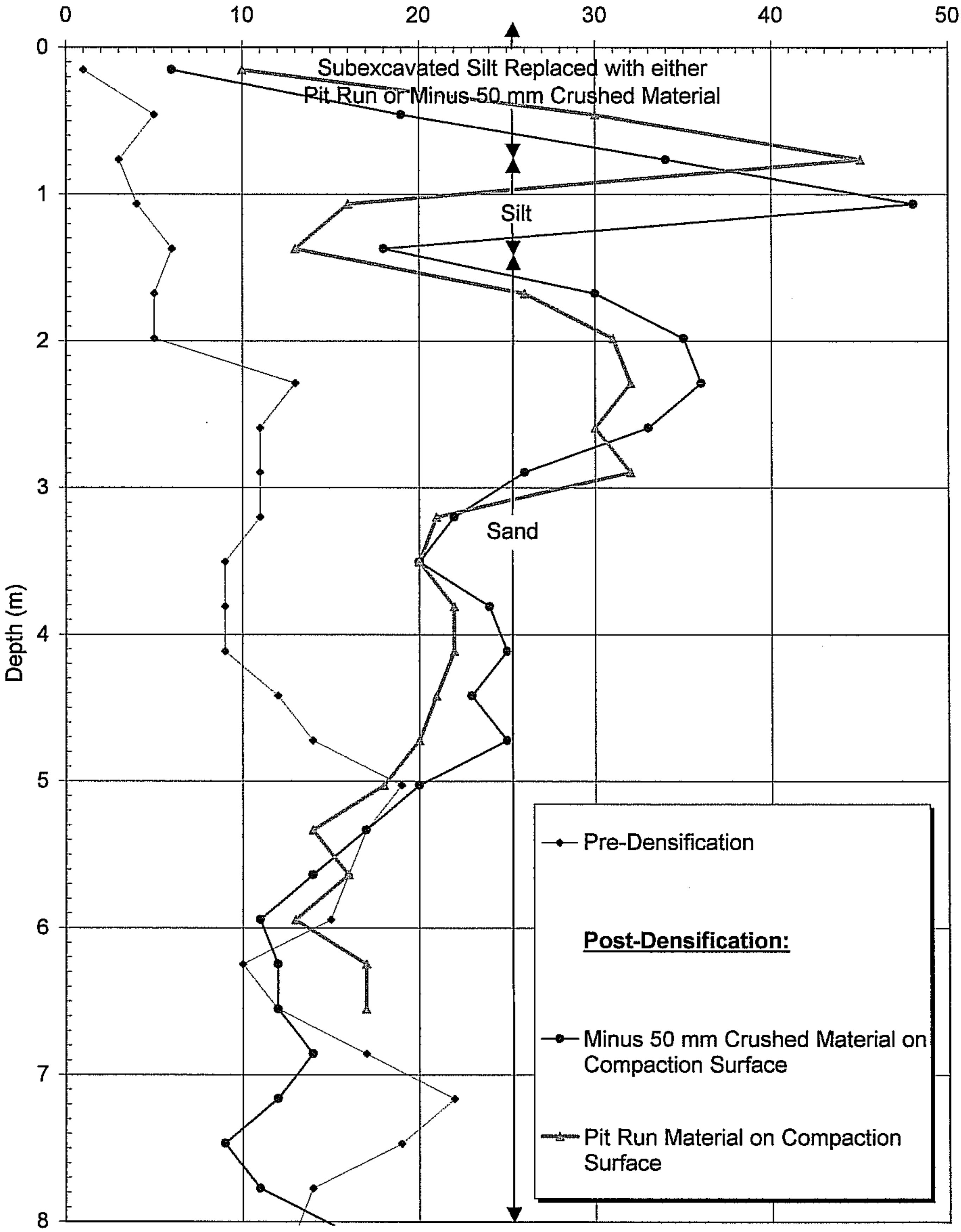


Figure 5 - Edge Effect on DCPT N-value