New Plymouth CBD Site Subsoil Class: Results from ground investigation

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ABSTRACT

The geological profile of a site and hence the determination of a site subsoil class can have a significant influence on the selection of a design peak ground acceleration (PGA) as derived from NZS 1170.5 (2004). At the New Plymouth Central Business District (CBD), various practitioners have historically held different views of the site subsoil class. These have been presented as being either Class C or D. This has come about when the underlying Quaternary Lahars or the Late Miocene-Pliocene sedimentary Matemateaonga Formation have been considered as bedrock.

Results of ground investigations comprising three deep cored boreholes put down in the CBD, unconfined compressive strength testing and shear wave velocity testing are presented. An assessment of the site subsoil class based on a strict interpretation from NZS 1170.5 (2004) is presented in this paper. The results show that neither the Lahars nor the Matemateaonga Formation meet the criteria of bedrock in accordance with NZS 1170.5 (2004). This means that the site in the CBD should have a subsoil class of Class D based on a strict interpretation of NZS 1170.5 (2004, Amendment 1, 2016). These findings may have implications on the selection of site subsoil class for other parts of New Zealand which are underlain by weak and variably cemented rock, and wider debate is encouraged.

1 INTRODUCTION

Beca was commissioned by the New Plymouth District Council (NPDC) to undertake ground investigation over a period from January 2016 to August 2016 in the New Plymouth Central Business District. The Ministry of Business, Innovation and Employment (MBIE) provided funding for the shear wave velocity testing component of the investigation. The purpose of the investigation was to obtain data to assist with the assessment of the site subsoil classification in terms of NZS 1170.5 (2004).

The scope of works included the drilling of three deep cored boreholes up to 162.5m depth to determine the depth to and nature of rock, and the stiffness of the Laharic deposits above. Unconfined compressive strength (UCS) testing of recovered core samples were undertaken and PVC access tubes were installed to allow for shear wave velocity testing.

The boreholes were drilled at three Council owned sites within the New Plymouth CBD (as shown on Figure 1 and described in Table 1).

2 GEOLOGY OF THE NEW PLYMOUTH CBD

The relevant published geological map for the area, Geology of the Taranaki Area (Townsend et al. 2008) shows the New Plymouth CBD to be underlain by Quaternary Beach Deposits overlying Undifferentiated Quaternary Lahars which are in turn underlain by Late Miocene - Pliocene sedimentary rock (Matemateaonga Formation).

The Quaternary beach deposits typically comprise planar to cross-bedded sands, and may include gravel and boulders. The undifferentiated Quaternary Lahars comprise gravelly sand, with cobbles and boulders of andesite, while generally competent and suitable for founding structures, the origin of this material implies that it is laterally and vertically discontinuous. The Matemateaonga Formation consists of muddy sandstone, with beds of siltstone, mudstone, limestone or shellbeds, and locally coal and conglomerate.

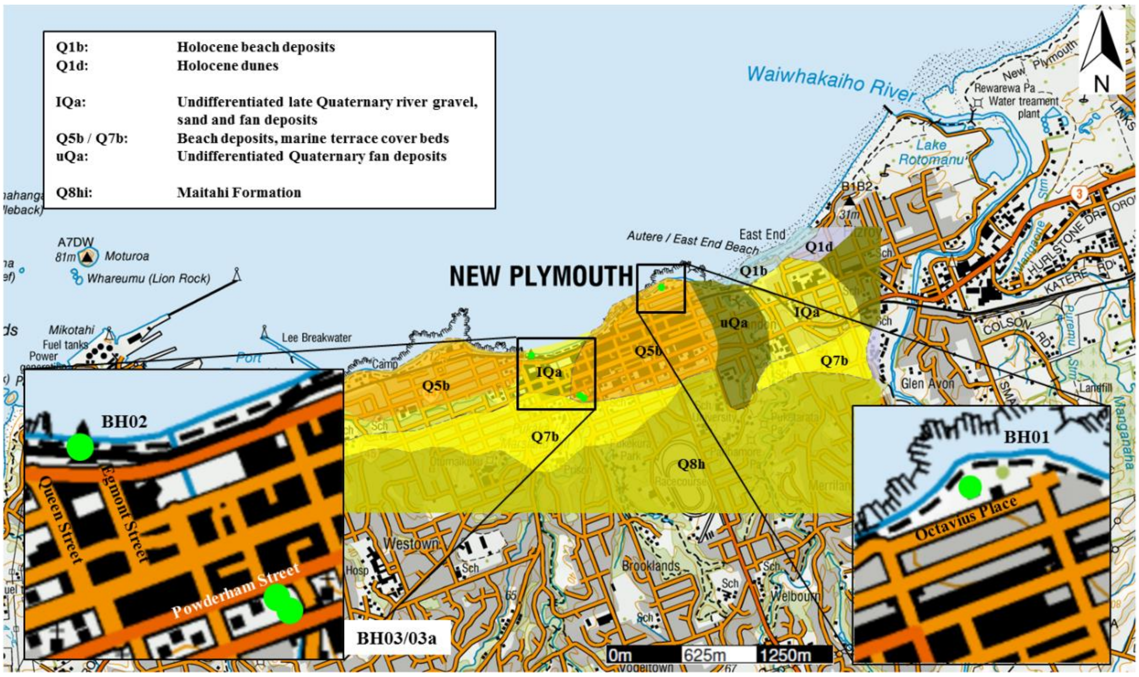

Figure 1: Borehole locations, NZ topo50 Gridless Maps (Land Information New Zealand (LINZ)) and geological layers as per Townsend et al. (2008)

3 RESULTS OF GROUND INVESTIGATION

3.1 Borehole Drilling

Machine boreholes were drilled at 3 CBD locations, triple tube cored (to 'H' size) to depths of between 92.0m and 162.5m. The upper soil profile included ~5m thickness of andesitic ash (cohesive), overlying Quaternary beach deposit sands (~8.5m thick, found at the coastal BH01 only), overlying gravelly sandy undifferentiated Quaternary lahar deposits (~22m to 31m thick), with muddy sandstone/mudstone rock of the Matemateaonga Formation beginning at 33m to 45m depth. BH03 also included uncemented marine sand between the lahars and Matemateaonga Formation rock (~8.5m thick).

Target drilling depths of 110m to 130m were proposed, to drill sufficiently beyond the expected rock interface to prove strong/cemented intact rock. However, rock strengths and cementation remained variable with depth.

Core samples of sandstone/mudstone of varying strengths and depths were collected from all three boreholes for UCS testing.

3.2 Shear Wave Velocity Testing

Shear wave velocity testing was initially proposed to be undertaken at 1.0m intervals, in two directions in each borehole. However, a number of borehole obstructions and equipment damage occurred during testing which prevented the tests to be completed to the full depth of Boreholes

1 and 3. Testing was initially undertaken in June 2016, and re-testing in August 2016. A summary of the shear wave testing undertaken is shown in Table 1 below.

Table 1 – Summary of Shear Wave Testing

Bore ID	Location	Depth (m)	Direction (s)	Test depth achieved (m)	Comments
BH01	Mt Bryan (near Octavius Place)	162.5	N-S E-W	136.0 94.0	Shear wave probe was accidentally dropped at 136m and the cable damaged, preventing further testing.
BH02	Wind Wand (Egmont St)	92.0 (88.0)	N-S E-W	88.0 88.0	The borehole was drilled to 92m, however the PVC tube was installed to 88m due to drilling complications.
BH03	Carrington St carpark	131.0	N-S E-W	108.0 119.0	Testing encountered an obstruction at 119m depth.

Comparisons of measured shear wave velocities in two directions for a given borehole were carried out. Results of shear wave velocity profiles, soil and rock profile together with UCS test results at respective depths are summarised in Figure 2, Figure 3 and Figure 4.

Except for some differences in BH02 at -39.5mRL and in BH03 at -15mRL and -65mRL, the shear wave velocity measurements in two axes for each borehole were generally close to each other. The average of the differences of shear velocity expressed as a percentage for the two axes down each borehole ranged from -3% to 5% for the three boreholes.

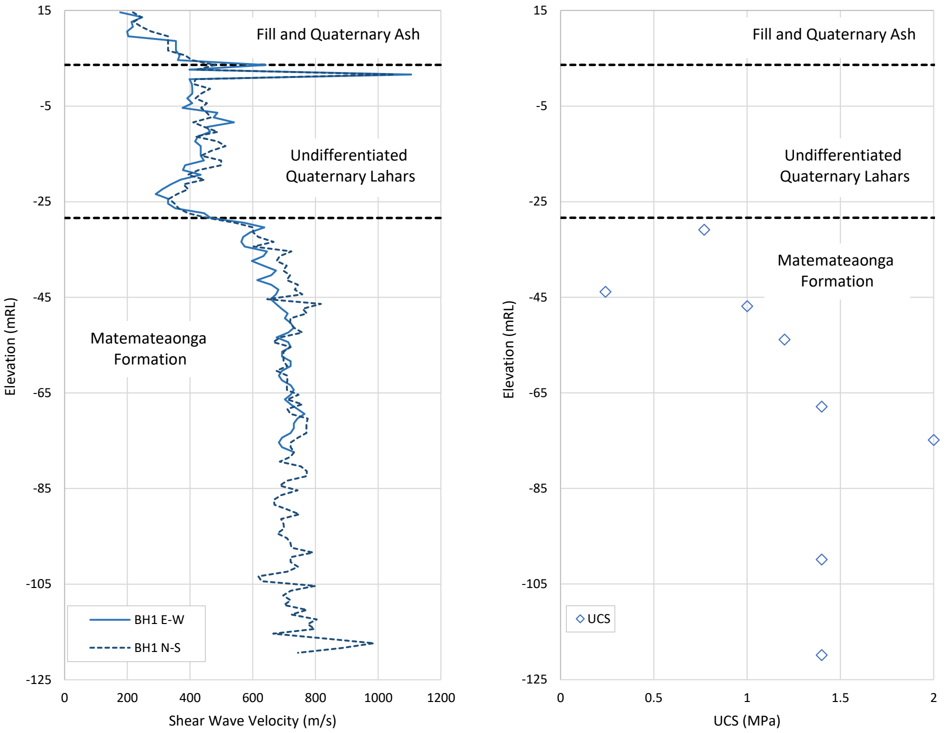

Figure 2: Shear wave velocity profile and relevant UCS results for BH01

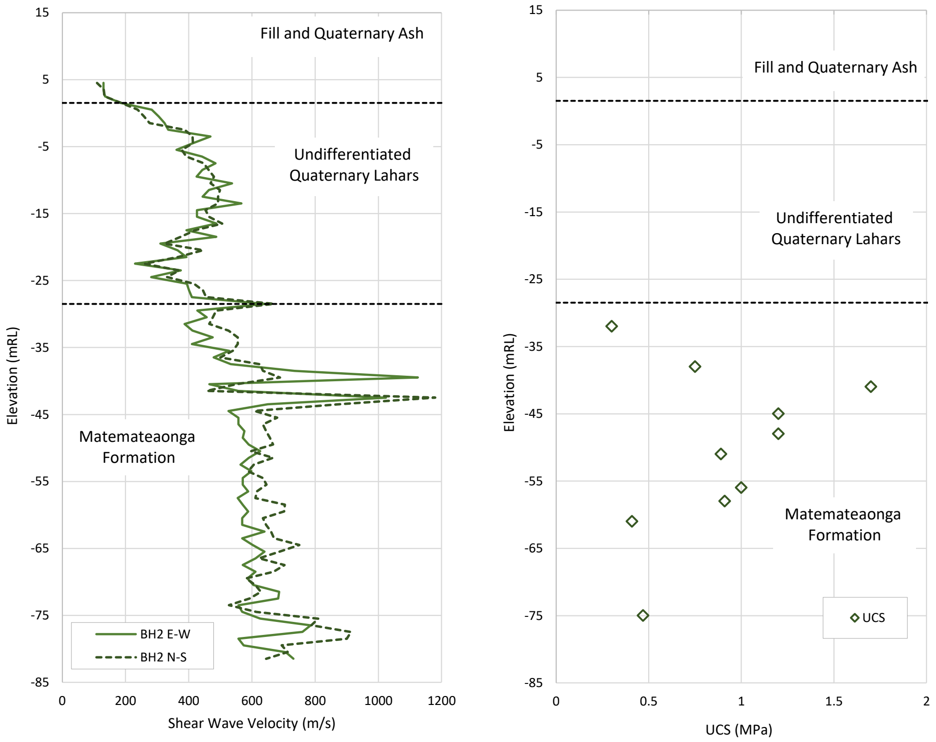

Figure 3: Shear wave velocity profile and relevant UCS results for BH02

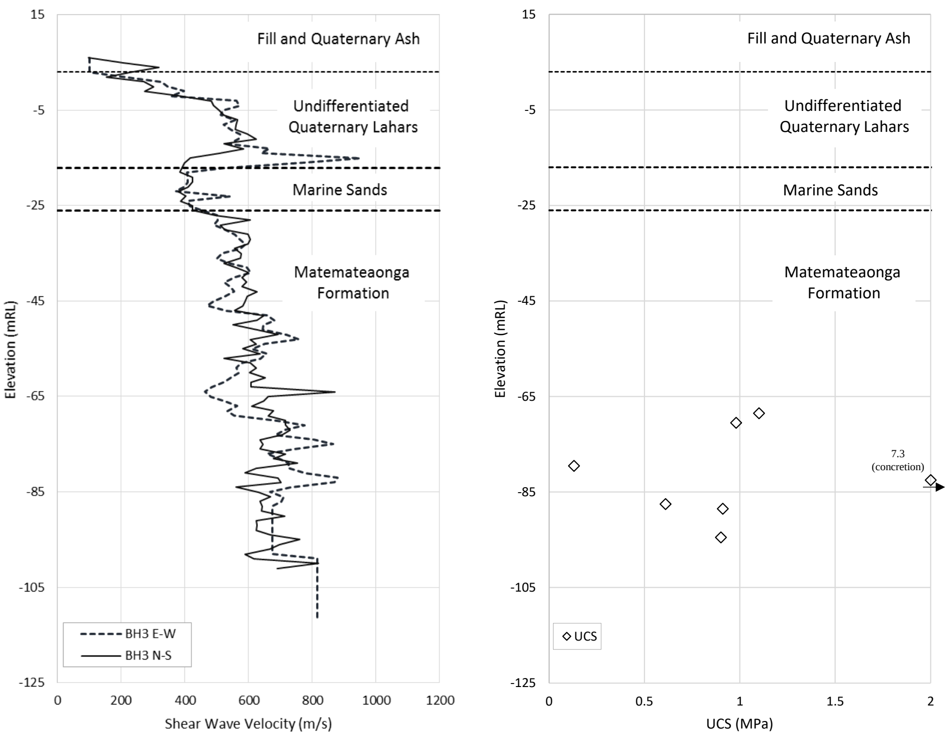

Figure 4: Shear wave velocity profile and relevant UCS results for BH03

4 ASSESSMENT OF SITE SOIL-CLASS

NZS 1170.5 Clause 3.1.3.1 (Amendment 1, September 2016) specifies a number of methods to assess the site class in the following order of preference:

(a) Measurements of shear-wave travel times or shear-wave velocities;
(b) Shear-wave velocities obtained by inversion of geophysical measurements, where the inversions are constrained by information from site profiles developed from geotechnical logging at the site or nearby;
(c) Shear-wave velocities calculated from empirical correlations for the relevant soil materials;
(d) Borelogs including measurement of geotechnical properties;
(e) Evaluation of site periods from Nakamura (horizontal/vertical) spectral ratios or from recorded earthquake motions;
(f) Borelogs with descriptors but no geotechnical measurements; or
(g) Surface geology and estimates of the depth to underlying rock.

For sites with layered soils, NZS 1170.5 (Clause 3.1.3.7) allows the natural period of the site to be estimated by summing the contributions to the natural period of each layer. The contribution of each layer may be estimated by multiplying 0.6s by the ratio of the layer's thickness to that for its soil type in Table 3.2 of NZS 1170.5 (2004). However, Larkin and Van Houtte (2014) provide evidence that the NZS 1170.5 method calculates smaller (and unconservative) site periods when compared with other established methods such as closed form solutions (e.g., Dobry & Madera in Madera (1971) as reported in Larkin and Van Houtte (2014)) or lumped mass solutions. Given the soil layering observed in this site, the closed form solution (Dobry & Madera) was adopted for the determination of site period.

5 FINDINGS

Descriptions of the Matemateaonga formation below are confined spatially to the locations of the boreholes and results should not be extrapolated beyond these locations.

5.1 Strict Interpretation of NZS 1170.5

The Matemateaonga formation encountered in the three boreholes comprised alternating layers of extremely weak to weak, moderately to slightly weathered mudstone, extremely weak to very weak, moderately to slightly weathered sandstone, and layers of uncemented dense, fine to medium sand at interspersed depths in all three boreholes. NZS 1170.5 (2004) defines rock as having:

- A compressive strength between 1MPa and 50MPa; and
- An average shear-wave velocity over the top 30m greater than 360m/s; and
- Not underlain by materials having a compressive strength less than 0.8MPa or a shear wave velocity less than 300m/s.

The following were observed from the investigations:-

- UCS of the Matemateaonga formation ranged generally between 0.24MPa to 2.1MPa, with one rock sample identified as a concretion tested at 7.3MPa. This range falls outside (less than) the 1MPa minimum threshold to be considered as a rock.
- Rock with interbedded sand layers is expected to have different spectra from rock without sand layers. The Commentary to NZS 1170.5 with respect to the definition of rock clarifies that "…the spectra and peak ground accelerations for the soil sites that were formerly combined with rock sites were statistically significantly different from rock spectra, and similar to spectra from other shallow soils." It further states that "Very

> stiff or very dense soils or gravels that may have shear-wave velocities in this range are excluded on the basis of the studies referred to earlier."

Based on the above findings and on carrying out a strict interpretation from the definitions in NZS 1170.5 (2004) with respect to rock strength and soil inter-layering, we conclude that the Matemateaonga formation should not be considered as bedrock.

5.2 Interpretation from Site Period

Using shear wave velocity measurements obtained from this study, calculations of site periods were undertaken based on Dobry & Madera (as reported in Larkin & Van Houtte (2014)). Assuming that the maximum depth of the Matemateaonga Formation was equal to the proven depth of 136m BGL and that bedrock is immediately below 136m bgl, calculated site periods based on maximum and minimum measured shear wave velocities ranged from 0.73s to 0.94s respectively. Based on averaged shear wave velocities from all borehole measurements, the calculated site period was 0.82s.

As the Matemateaonga Formation is understood to be deeper than 136m bgl, the site period is therefore expected to be greater than the above. Given that the calculated site period exceeds 0.6s, it can be concluded that the site subsoil class should be Class D.

6 CONCLUSIONS

The above study concludes that based on a strict interpretation of NZS 1170.5 (2004) for the area tested, the site should have a subsoil class of Class D. This conclusion hinges on whether the Matemateaonga Formation should be classed as a rock. On the basis of its low strength (< 1MPa in many instances) and soil inter-layering, this Formation falls outside of the interpretation of rock as provided by NZS 1170.5 (2004). In addition, calculated site periods from measured shear wave velocities exceed the 0.6s threshold which defines the site subsoil class as Class D.

This conclusion has implications for other areas in New Zealand which are underlain by weak and variably cemented rock. It is, perhaps, timely that the current formal definition of rock for site subsoil class determination is debated and a revised set of criteria developed.

7 ACKNOWLEDGEMENTS

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