Assessing the extent of blast damage with seismic MASW methods, Clyde Wind Farm Extension.

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Introduction

Natural Power were consulted to carry out a seismic survey at wind turbine location OT229 on the Clyde Wind Farm Extension, South Lanarkshire, Scotland. Concern was raised that blasting at the neighbouring borrow pit, BP4, might increase fracturing at the turbine location. The objective of the seismic survey was to determine s-wave velocities and derived ground soil stiffness parameters and make a comparative assessment of the pre and post blast conditions to inform the foundation design.

At the time of survey overburden had been removed and medium strong to strong, lightly metamorphosed Greywacke bedrock was exposed at surface. A possible shallow fault was observed running in a north-south orientation across the OT229 foundation area.

Figure 1: Showing the location of BP4 in close proximity, 60m west of turbine OT229

Multichannel Analysis Surface Wave (MASW) Theory

The seismic MASW method was selected as the most applicable to the behaviour of the soil and rock beneath the low strain cyclical load regimes imparted by wind turbine foundations.

This method is based on seismic wave dispersion theory; longer wavelength seismic waves propagate faster than shorter wavelength hence the frequency content of the wave disperses with transit time. A dispersion analysis is carried out by plotting frequency versus phase-velocity and identifying individual dispersion curves. Computational analysis allows the derivation of a 1D shear wave velocity (Vs) profile from these dispersion curves. Vs values are used to derive geotechnical parameters for small strain stiffness (G0) and Young's modulus (Ey).

In a highly fractured subsurface s-wave velocities are slowed as they travel around the fractures, it was anticipated that increased fracturing as a result of the blast would be detected as a decrease in Vs with derived soil stiffness parameters following the same trend.

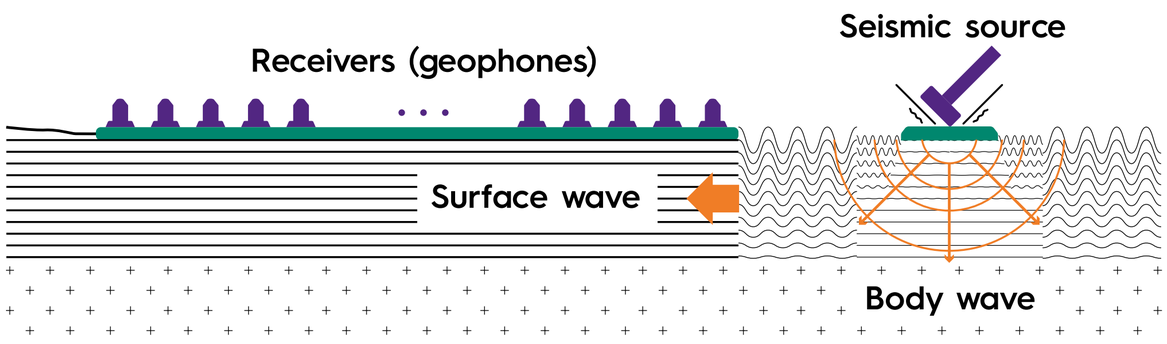

Figure 2: Schematic of field setup. Source http://www.masw.com

Survey design

The survey design incorporated 7 survey lines using a combination of roll along and symmetrical arrays (Fig. 3). The first line was positioned as close as possible to the blast area without being directly on top of the charge locations, and subsequent lines were positioned at increasing distances from the blast area to determine the effect of the blast with increasing distance. Line orientations were selected parallel and perpendicular to the faulting to provide information about the anisotropic properties of the rock.

Seismic data were acquired in two phases: phase one prior to blasting, and phase two, an identical survey, carried out after basting. All geophone and shot positions were marked with paint and a differential GPS to ensure exact repeatability in the post blast survey.

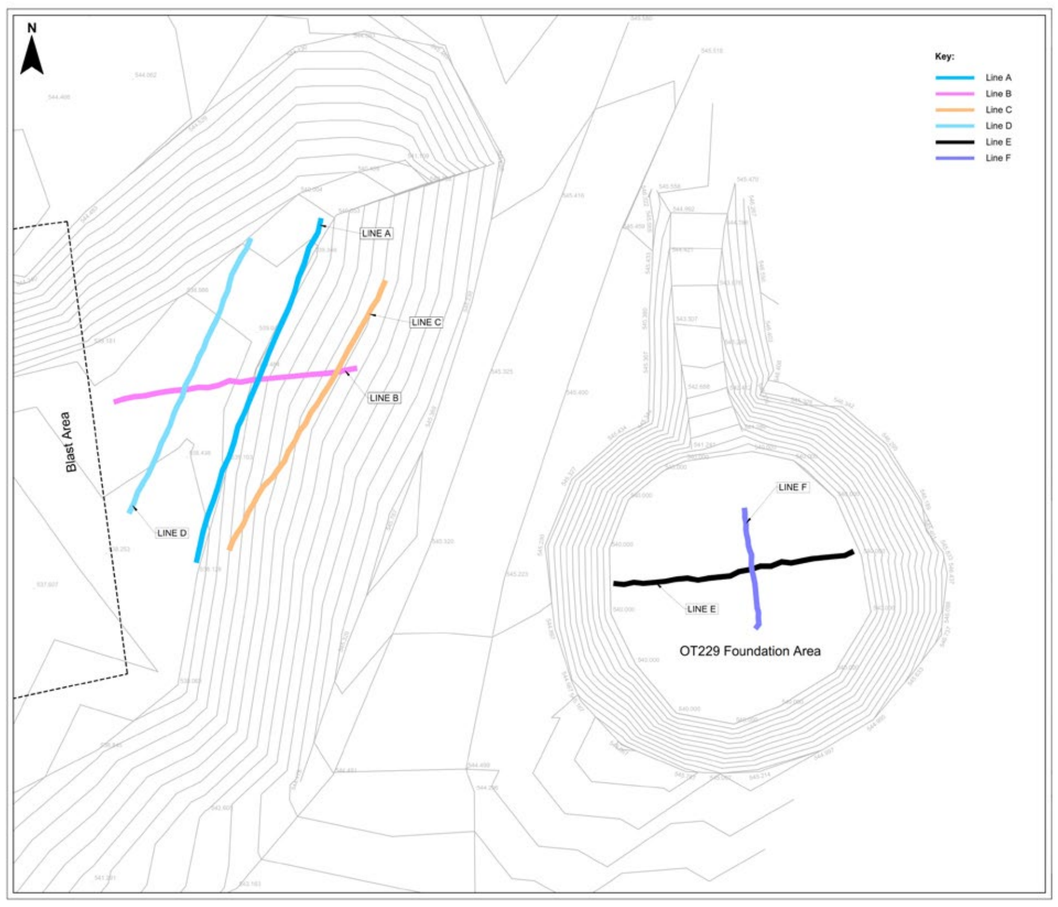

Figure 3: Seismic Survey Lines Map showing locations of 7 seismic survey lines in the context of the OT229 location and borrow pit blast area.

Site constraints

- Steep slopes limited the length of survey lines which in turn limited the maximum depth of investigation. Line orientations and positions were optimised in the field to achieve a maximum depth of investigation of 8mbgl.
- Difficulty coupling geophones and the exposed weathered bedrock surface. Flat bottomed geophones and sand were used to overcome this.
- Surface water at OT229 prevented several shots during the post blast survey. Sufficient data was acquired without these shots.

Figure 4: Steep Slopes and surface water at OT229

Data processing

Seismic data were processed using the industry standard software SurfSeis 5.3. Surfseis 5.3 uses an inverse modelling approach, evaluating the dispersion curves of possible geological models against the real life dispersion curves then iteratively improving the model fit to determine the best solution. Borehole and trial pit logs were used to constrain the modelling process for the most reliable results. Assumed values of Poisson's ratio and density were used in order to derive ground stiffness profiles from Vs.

A sensitivity analysis was carried out on survey Line E to assess the uncertainty in the results produced by the modelling process. It was noted variations of up to 5% were possible as a result of varying model fits.

Results

Comparisons between pre and post blast profiles show all lines located close to the blast area exhibit a decrease in Vs following the blast which suggests an increase in fracturing. The greatest decrease in Vs was observed in line D which is the closest line to the blast area. Lines A and C show smaller decreases with distance away from the blast.

Lines E and F located at the turbine base do not exhibit a decrease in velocity and show similar results to the pre blast survey.

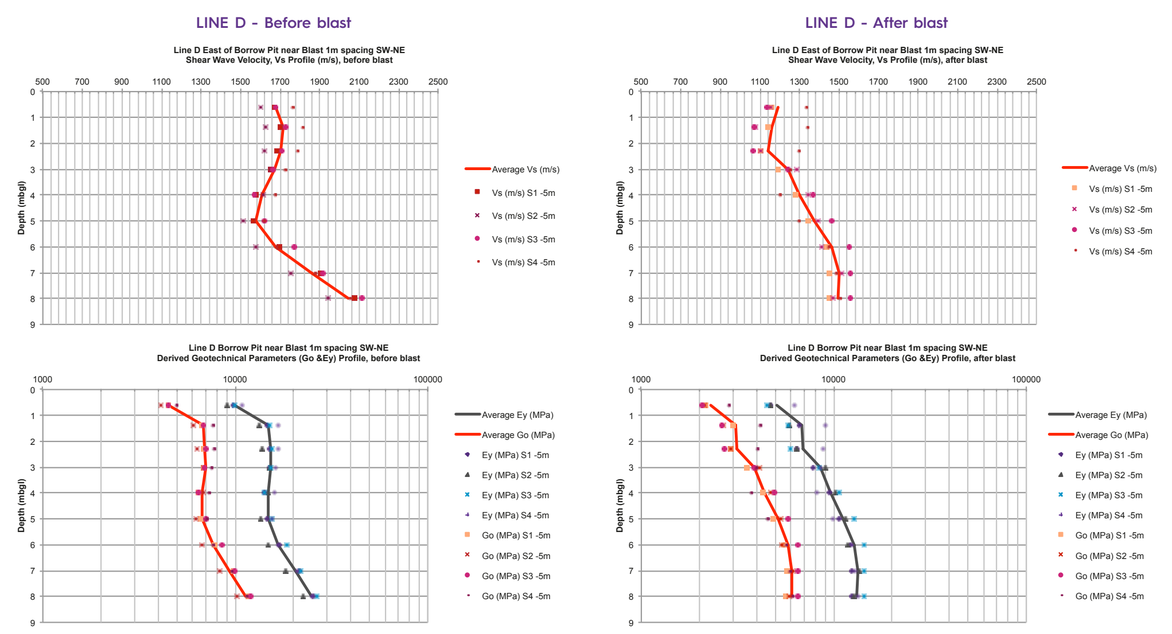

Figure 5: Comparison of pre and post blast profiles at Line D, closest to borrow pit. Significant decrease in Vs and stiffness parameters post blast.

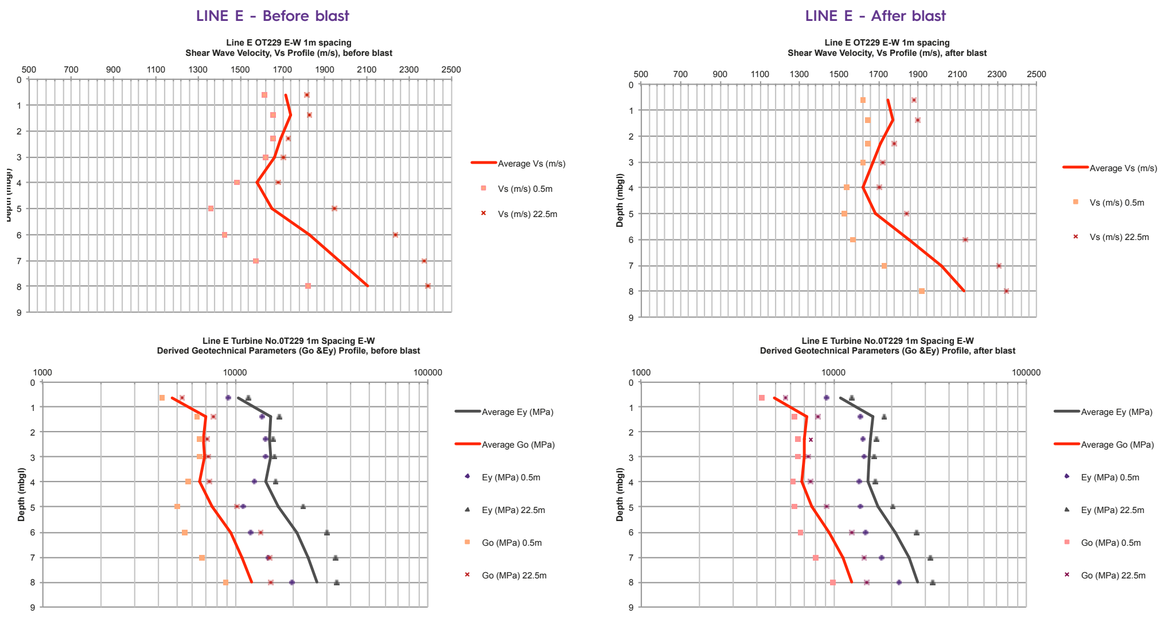

Figure 6: Comparison of pre and post blast profiles at Line E, turbine foundation centre. No significant change in results.

Survey Line	Line A	Line B	Line C	Line D	Line E	Line F
Distance from edge of blast area to line centre (m)	15.05	14.67	20.05	10.28	57.86	59.47
Average % change in Vs throughout 1D profile	-12	-3	-7	-32	+2	+2

Conclusion

1D Vs and stiffness profiles at OT229 foundation show no change post blasting indicating this area has not be significantly affected by blasting operations at BP4. Blast charges were placed at 10mbgl and this investigation is limited to 8mbgl so it is possible that below this there may be effects that have not be detected.

Seismic results were incorporated along with wider geotechnical assessment of the ground and likelihood of impact of blasting given distance from turbine base location. No design change was required for OT229 foundation.

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