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Application of seismic shear wave refraction for subsurface soil dynamic investigation at Bukit Changgang, Banting, Selangor

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Abstract: A seismic shear wave refraction survey was carried out to examine subsurface profile of the shear wave velocities. The information of the shear wave velocities were required to investigate the dynamic shear wave characteristic of the ground for foundation design of a vibrating machine. A 24-channel Abem Mark III signal enhancement seismograph and shear wave geophones were used in the survey. The field setup for the survey was similar to the conventional P-wave seismic refraction with close geophone spacing of 1 metre. The seismic source was a weighted timber plank spike to the ground and hammered from opposite direction in order to record two sets of traces having opposite shear wave polarity. A computer programme was used to analyse the reverse polarity records and pick the first shear wave arrival times.

A maximum of three layers were recognised from all the spread lines interpreted. The result shows that with the exception of seismic line 1, the range of shear wave velocity for the first layer was found to be in the range of 102 to 379 m/s. Second layer velocity ranges from 182 to 556 m/s and the third layer was found to be in the range of 330 to 774 m/s. The result indicates that the shear wave velocity of the layers are high and this can be attributed to the presence of a fill material (crusher run) that was common for most of the profiles except for spread lines 2, 7 and 8. The range of shear wave velocity layers for these three spreads were as follows:

Layer	Velocity (m/s)	Thickness (m)
1	114–255	0.1 to 5.9
2	186–281	0.4 to 6.9
3	330–339	

The shear wave velocities for these spread lines appear to be low and correlate well with SPT values from adjacent bore holes and agreed well to empirical correlations established by previous researchers. These velocity values were therefore recommended to be adopted for design purposes of the foundation and could be used to determine the critical soil deformation below the proposed vibrating machine in the study area.

INTRODUCTION

In engineering design for foundation of railways, roads, offshore structures as well as foundation for vibrating machinery on which vibration load are dominant, it is necessary to have knowledge of the dynamic properties of the ground. The dynamic properties of the ground is very important for the prediction of various kinds of vibrational effects and its prevention (Imai *et al.*, 1976).

The evaluation of the dynamic properties of the ground can be made through measurement of P and S-wave velocities. The S-wave velocities provides useful information on the properties of the dynamic shear modulus of shallow earth materials. In engineering practice, the methods commonly employed in evaluation of the dynamic characteristics of the site through S-wave velocity measurements are the seismic refraction, downhole, crosshole and the surface wave surveys. The S-wave velocities are normally controlled by the structural strength of the soil matrix rather than the degree of saturation. This is because the induced shear strain of the propagating S-wave particles are much less affected by the presence of water than the effect of dilational P-wave.

This paper describes the result of a seismic shear wave refraction survey to examine the dynamic characteristics of the ground for the foundation design of vibrating machine at Sanyen

Paper Mill factory at Bukit Changgang, Banting, Selangor.

DESCRIPTION OF SITE

The site for seismic refraction survey is located just adjacent to the existing Genting Sanyen Paper Mill factory. The factory generally lies on a relatively flat lowland area of coastal alluvium. Piling works have just been completed and crusher run filled material of about 0.2 metre thickness has covered most part of the site. Borehole data indicates that the crusher run filled material is underlain by a relatively thick layer of firm to stiff silty clay with thickness ranging from 10 to 14 metres. Below this layer is a medium dense sand layer of thickness varying from 6 to 8 metres. This sand layer is underlain by a firm to hard sandy silty clay and the most bottom layer, at a depth of about 26 metres, is a hard sandy clayey silt.

MACHINE FOUNDATION VIBRATION

The dynamic loading arises from a unbalanced mass m_0 rotating with an eccentricity r_0 at the operational circular frequency $\omega = 2\pi f$. The forces and moments acting on the soil foundation interface and transmitted into the ground are of the form $m_0 r_0 \omega^2 \exp(i\omega t)$, i.e. they vary harmonically with time. Much of the energy imparted to the foundation is diffused by various outward and downward spreading waves such as reflections, refractions and transformation into surface waves, while a small portion is dissipated by inelastic action in the soil.

As a result, the soil-foundation interface, and with it the foundation block, undergoes harmonic oscillations of the form $u_0 \exp[i(\omega t + \phi)$ with frequency dependent amplitude and phase lag, $u_0 = u_0(\omega)$ and $\phi = \phi(\omega)$. The basic goal of the geotechnical design is to limit the amplitudes of all possible modes of oscillation to levels small enough neither to endanger the satisfactory operation of the machine nor to cause disturbance to people working in the immediate vicinity. Chart like the one depicted in Figure 1 (based on information from Richart *et al.*, 1970) may guide the selection of an appropriate upper limit for satisfactory foundation performance.

FIELD AND INTERPRETATION PROCEDURE

The shear wave seismic refraction survey was conducted using Abem Mark III-24 channel seismograph and the horizontal shear wave geophones from Mark Products. The field procedures and setup adopted were similar to the conventional P-wave seismic refraction survey which has been described by Whiteley *et al.* (1990). The seismic source was a weighted timber plank spiked to the ground to ensure better coupling and transfer of the shear wave force (Fig. 2). For each short point, the timber plank was hammered from opposite directions in order to record two sets of traces having shear wave of opposite polarity (Fig. 3) similar to the method employed by Whiteley *et al.* (1990).

For this study only 9 seismic spreads were established and their location are shown in Figure 4. Geophone spacing of 3 metres was only adopted for spread line 1 and a spacing of 1.5 metres adopted for spread lines 2, 3 and 4. For the remaining five spread lines, a spacing of 1 metre was adopted in order to obtain clear records of S-wave first arrivals. A configuration of two offset shots and five inspread shots was employed and the seismic records were saved into 3.5 inch. Diskette for further processing and interpretation at the office.

The computer programme Firstpix (version 4.1) was used to analyse and pick the first shear wave arrival times from the records. The shear wave velocity (Vs) obtained from field measurements may be used to calculate the shear modulus (G) which is critical in foundation design for vibrating machinery. Dynamic elastic theory relates to the shear modulus, G, the soil density, ρ, and the S-wave velocity Vs i.e. $G = \rho Vs$. The normal superimposed manual picking technique from records of different polarity was used to countercheck the firstpix results and was found to be in fairly good agreement. The seismic data was interpreted using a seismic refraction software.

RESULTS AND DISCUSSION

A summary of the shear wave velocity for all the nine spread lines is given in Table 1. The result indicates that for spread line 1, a considerably higher velocity for the first and second layers was obtained as compared to all other spread lines. This may be caused by the 3-metre geophone spacing adopted at the site which is close to the spacing of the piles and may have caused the shear waves to be diffracted from the pile groups which are of very high density causing false higher velocity layers.

A maximum of three layers were detected from the nine spread lines. With the exception of seismic line 1, the range of shear wave velocity for the first layer was found to be 102 to 423 m/s. Second layer velocity was found to be 182 to 556 m/s and the third layer was found to be in the range of 330 to 774 m/s. It is important to note that a lower velocity profile has been obtained for the data processed for

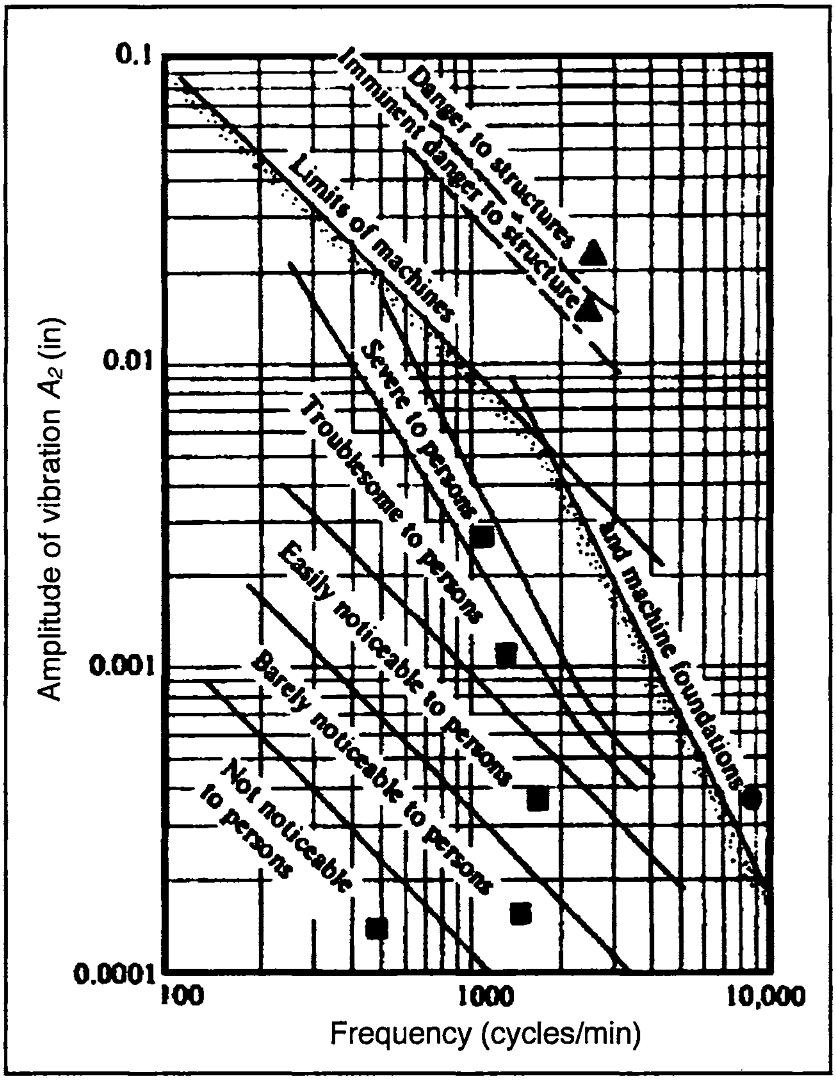

Figure 1. Allowable vertical vibration amplitudes (after Richart, 1962).

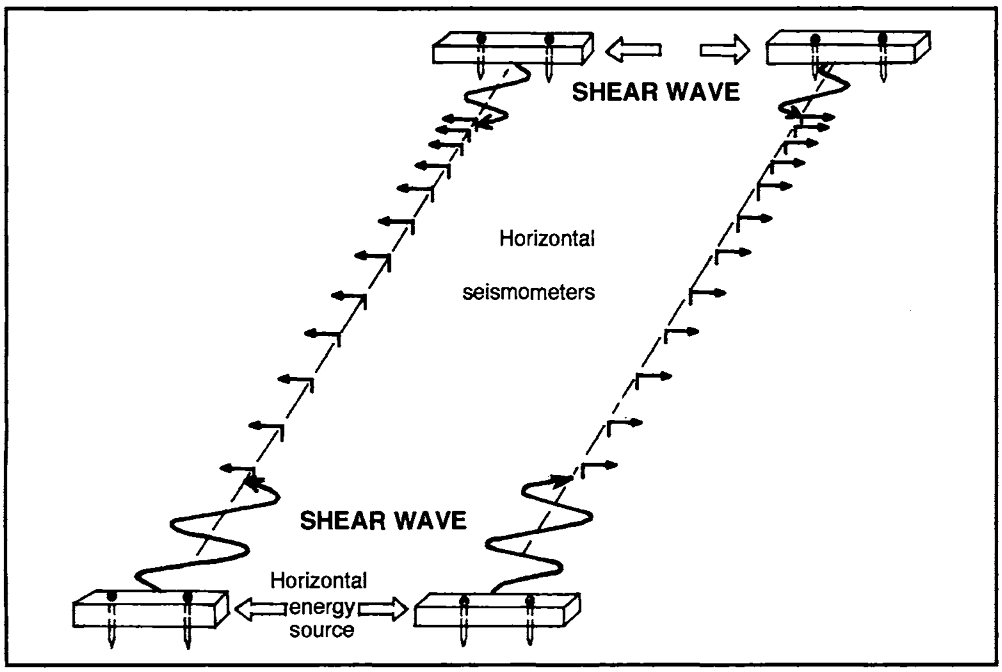

Figure 2. Source/receiver configuration for surface refraction shear wave measurements.

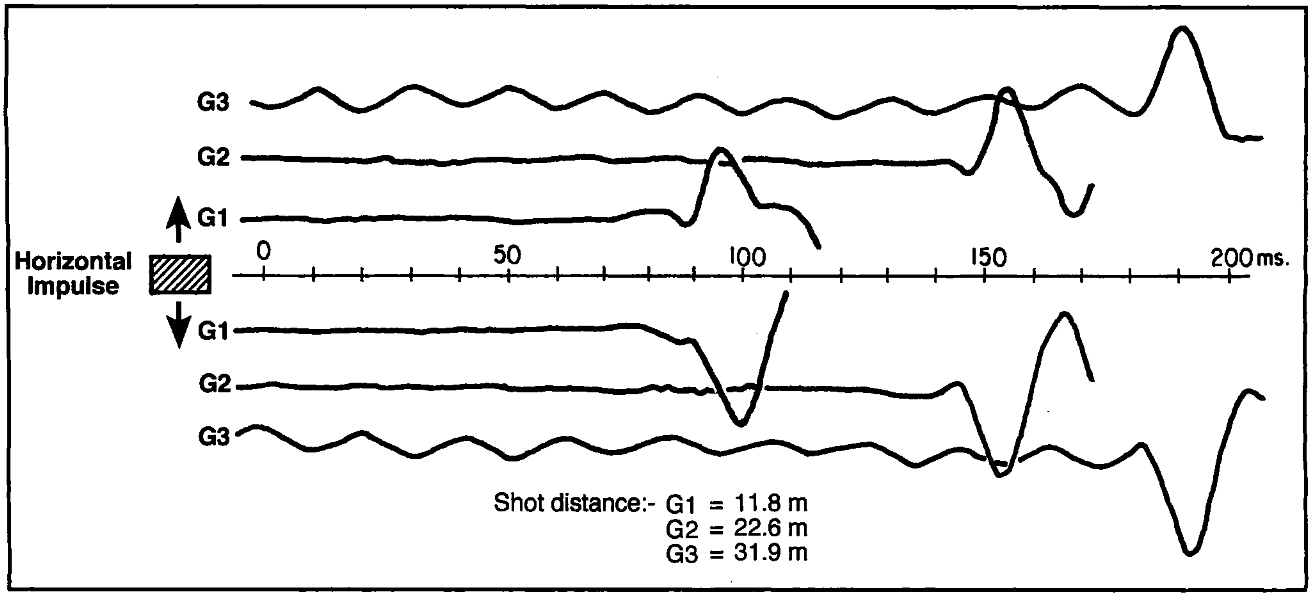

Figure 3. Seismic shear wave records to illustrate polarity reversal effects.

Table 1. Summary of interpretation of seismic profiles.

Profile	Layer	Velocity (m/s)	Thickness (m)	Depth to Interface (m)
L1	1	214–580	4.3–9.0	4.3–9.0
	2	1,031–1,213	–	–
L2	1	150–255	0.6–5.9	0.6–5.9
	2	217–246	0.4–6.9	1.0–12.8
	3	330	–	–
L3	1	190–423	0.2–11.5	0.2–11.5
	2	384–467	–	–
L4	1	135–379	0.5–8.3	0.5–8.3
	2	367–490	2.6–9.9	3.1–18.2
	3	774	–	–
L5	1	102–258	0.8–2.9	0.8–2.9
	2	222–263	1.9–4.1	2.7–7.0
	3	557	–	–
L6	1	114–338	0.4–2.1	0.4–2.1
	2	310–404	–	–
L7	1	114–189	0.3–4.1	0.3–4.1
	2	186–240	–	–
L8	1	119-242	0.1–1.8	0.1–1.8
	2	211–281	1.8–6.9	1.9–8.7
	3	339	–	–
L9	1	221–345	0.8–5.0	0.8–5.0
	2	182–556	–	–

the spread lines 2, 7 and 8. This can be attributed to the absence of a crusher run fill material that was common for all the other spread lines. The crusher run is a high velocity material which has probably caused the first layer to be higher and subsequently refracted at higher velocities for the second and third layers.

For foundation design purposes, it was recommended that the velocity values from spread lines 2, 7 and 8 be adopted. The range of S-wave velocity layers for these three spreads can be summarised as follows:

Layer	Velocity (m/s)	Thickness (m)
1	114 to 255	0.1 to 5.9
2	186 to 281	0.4 to 6.9
3	330 to 339	–

Empirical correlations of shear wave velocity (Vs) to standard penetration tests has been established by Imai (1976) on a wide range of soils in Japan (Fig. 5). At the interpreted depth of shear wave velocity of this site the SPT value was found to be at the value of 4, on back substitution the shear wave velocity found from Imai's correlation correlates well with the shear wave velocity obtained at the site.

CONCLUSION

The shear wave seismic refraction survey should be conducted prior to foundation design. The P and S-wave velocities have very important significance as the most basic data for the evaluation of dynamic properties of the ground

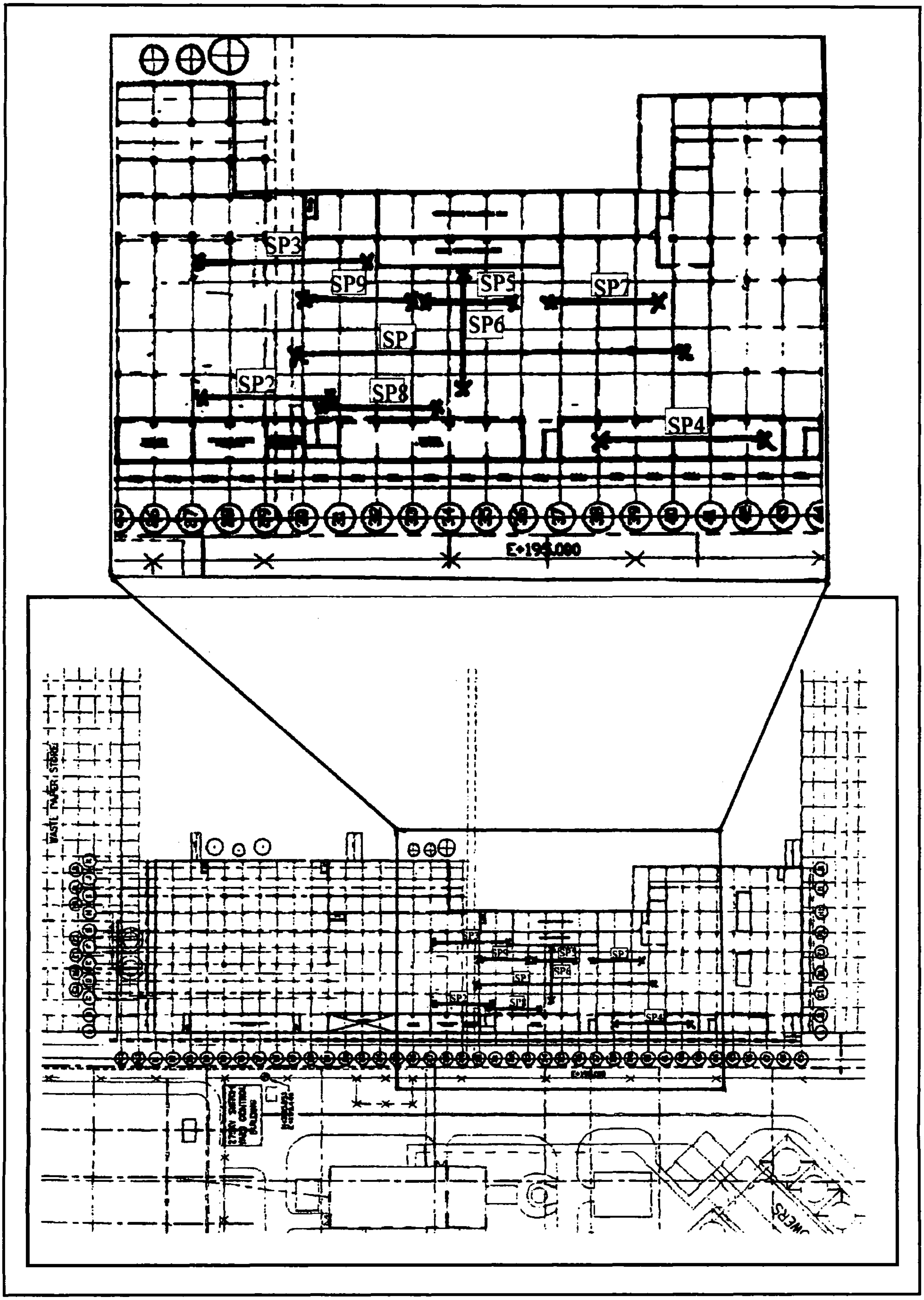

Figure 4. Location of seismic lines.

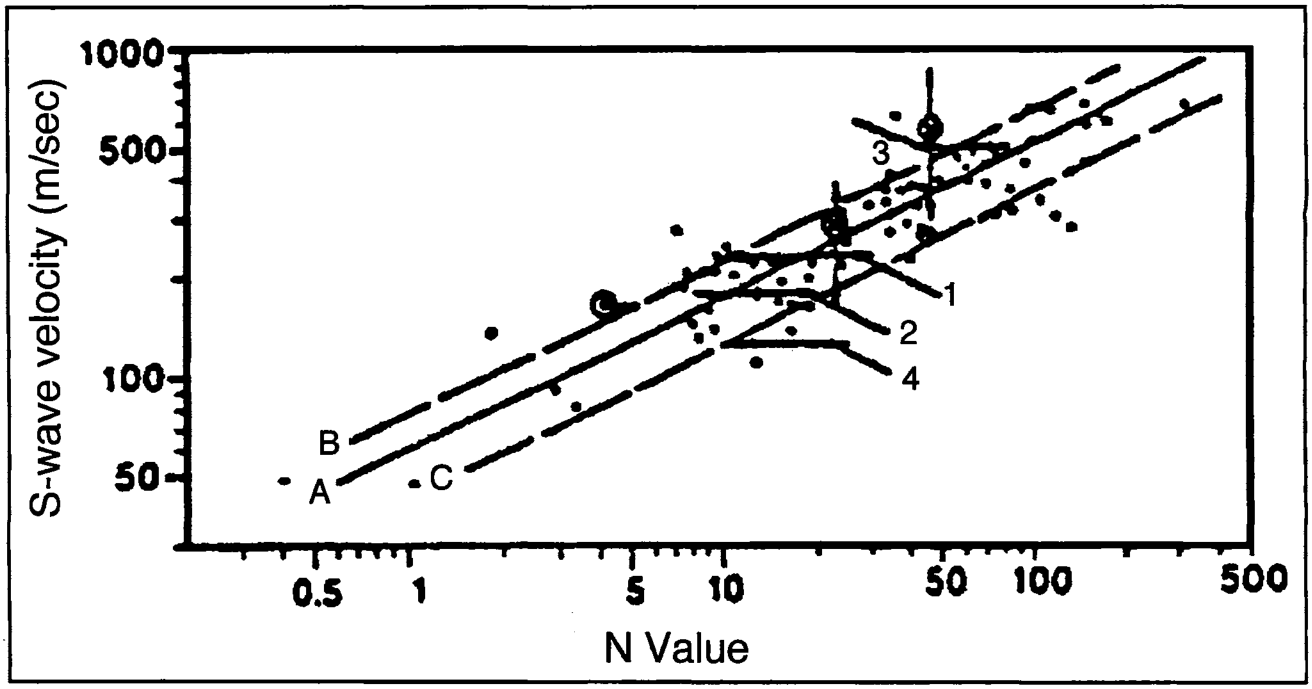

Figure 5. SPT, N values versus S-wave velocity in soils from Japan.

and its engineering application. The field wave velocity obtained was found to be the lower shear wave velocity range of soil deposits that is critical to the displacements of vibrating machines and should be carefully noted in the design.

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REFERENCES

IMAI, T., FUMOTO, H. AND YAKOTA, K., 1976. P and S-wave velocities in subsurface layers of ground in Japan. OYO Corp., Urawa Res. Inst., RP-460.

RICHART, F.E., JR., 1962. Foundation Vibration, Trans. *ASCE 127 (Part 1)*, 863–898.

RICHART, F.E., JR., HALL. J.R. AND WOODS, R.D., 1970. *Vibrations of soils and foundations*, Prentice-Hall, Inc.

WHITELEY, R.J., FELL, R. AND MACGREGOR, J.P., 1990. Vertical seismic shear wave profiling (VSSP) for engineering assessment of soils. *Exploration Geophysics, 21*, 45–52.

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