GSS GEOPHYSICS TECHNICAL NOTE

Integration of P – S Wave Tomography Imaging and Geotechnical Data for Geo-Engineering Site Characterization

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As part of an integrated site characterization project at a proposed power plant located in North Texas, P (compression) and S (shear) wave seismic data were acquired to delineate geologic structure and stratigraphy to a depth of 100 feet (30 m), and to determine the 2-dimensional dynamic modulus properties without having to drill seismic test holes. In addition to the seismic surveys, geotechnical borings were drilled to obtain core samples for lab analysis to determine the soil and rock types and physical properties. Based on geotechnical analysis of boring cores, the general stratigraphy of the site consists of an overburden soil of mainly silty to sandy clays, sandy lean clays, followed by sandstone or siltstone, and conglomerate layers within the sandstone rock units. Hard siltstones with interbedding of either sandstone or shale seams are found at borehole depths below 50 feet (Dockum Group). The variability of soil and rock compositions indicates complex depositional characteristics, and it is likely that the various layers are not continuous across the site.

A common geophysical method for deriving soil and rock modulus properties is with the use of crosshole or downhole seismic testing to acquire P and S wave velocity as a function of depth. However, much like the geotechnical investigation, the crosshole and downhole seismic testing techniques will only provide velocity and physical properties information within the local region of the boreholes. What happens when we suspect that the subsurface stratigraphy and geologic structure is highly variable, and that the modulus values are likely to change significantly across the site? Moreover, what if core samples from a geotechnical investigation can't achieve the full depth of investigation required, or boreholes cannot be drilled at the site?

GeoSurvey Systems uses P and S wave seismic tomography to obtain detailed structural and stratigraphic information, and to derive soil and rock modulus values at multiple locations along a seismic survey line. Figure 1 presents the tomography images for both the P and S wave seismic acquired along a single 240 ft (70 m) line. The processed tomography sections represent the horizontal and vertical distribution of P and S wave velocity, derived from advanced seismic tomography processing that uses finite element and full waveform inversion techniques. Because velocity varies as a function of soil and rock type, and physical properties change, the stratigraphy and general geologic structure can be interpreted on the basis of P and S wave 2-dimensional velocity distribution. Although there are close similarities between the P and S wave tomography sections shown in Figure 1, a large low velocity zone is observed in the center of the S wave tomography section (between 50 and 170 horizontal distance, and 30 to 60 ft depth). The low S wave velocity zone indicates the possibility of lower shear strength within the rock material structure.

Both the P and S wave seismic tomography sections are useful for understanding the general subsurface geologic structure, but can also be useful for planning geotechnical investigations to obtain soil and rock property information at locations where anomalous conditions may exist. The combination of geotechnical data from strategically placed boreholes and the P and S wave tomography information give us opportunity to develop a more precise site geologic model, and to derive more accurate soil and rock physical property information. In addition to the development of a geologic model based on the interpretation of P and S wave tomography sections, discrete velocity information as a function of depth is extracted from the P and S wave tomography model files.

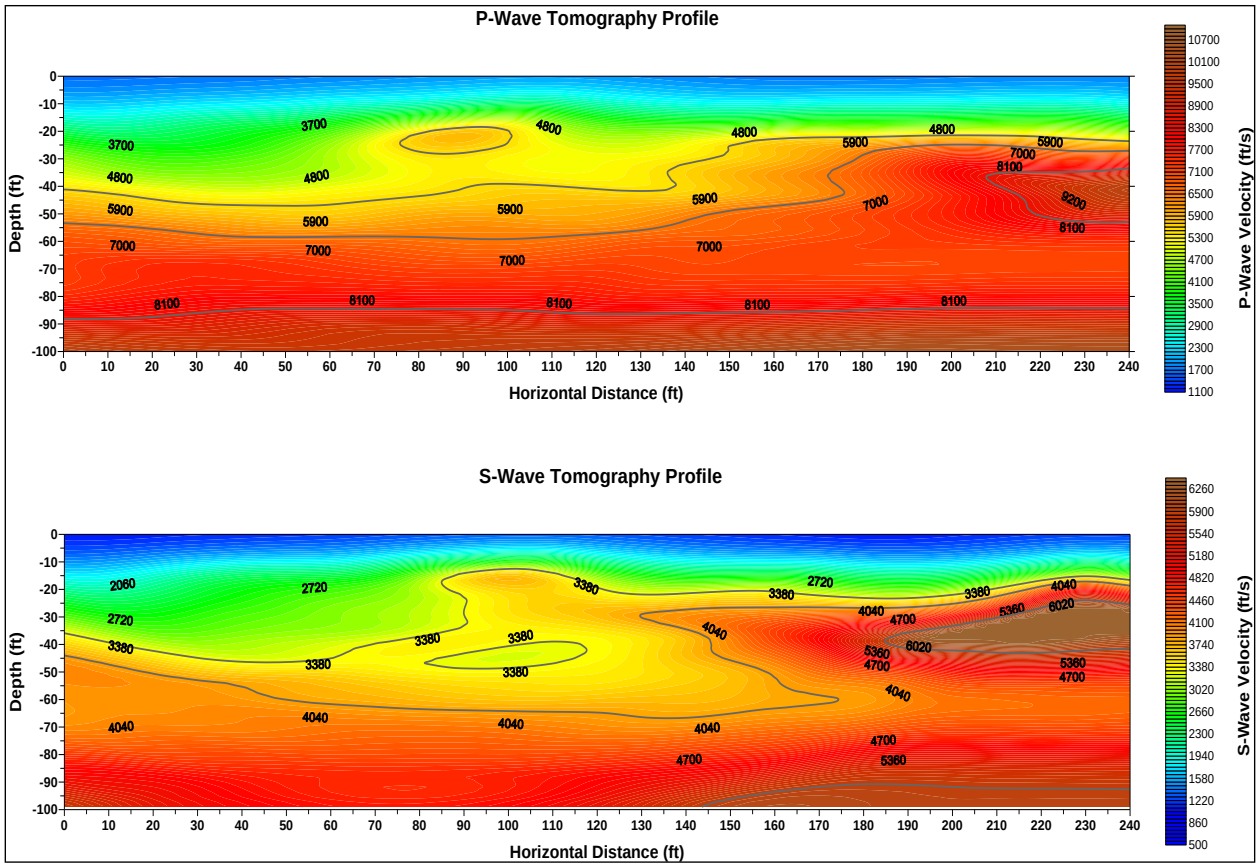

Figure 1 – Two-dimensional P and S wave tomography profiles showing site geologic structure and stratigraphy across 240 ft (70 m) seismic line. The tomography sections represent the horizontal and vertical distribution of P and S wave velocity.

Using the soil and rock density values from available geotechnical data, and the P and S wave velocity versus depth (5ft depth intervals) from multiple points along the seismic line, Shear Modulus, Young's Modulus, Bulk Modulus, and Poisson's Ratio can be derived. Table 1 gives the P and S wave velocity, and calculated modulus values as a function of 5 ft depth intervals for a selected horizontal station point on the tomography sections.

From tables of velocity and modulus values of selected vertical profiles (VP's) along the tomography profile, a shear modulus versus depth curve is plotted as shown in Figure 2.

The application of integrated geophysics and geotechnical data to develop a qualitative geologic and elastic modulus model is useful for characterization of sites where soils and hard rock geology are non-uniform and variable. The P and S wave tomography imaging technique, combined with the ability to extract velocity values as a function of depth for multiple stations along the tomography sections provides valuable information regarding stratigraphic and structural characteristics, and a more continuous indication of soil and rock physical property changes.

Depth (ft)	Density (lb/cu ft)	P-Velocity (ft/sec)	S-Velocity (ft/sec)	Shear Modulus (psi)	Poisson's Ratio	Young's Modulus
5	112	2187	987	2.35E+04	0.372	6.46E+04
10	116	2840	1336	4.47E+04	0.358	1.21E+05
15	120	3809	1798	8.37E+04	0.357	2.27E+05
20	123	4555	2250	1.34E+05	0.339	3.60E+05
25	119	6282	3172	2.58E+05	0.329	6.86E+05
30	119	6482	3451	3.06E+05	0.302	7.96E+05
35	125	6415	3366	3.05E+05	0.310	8.00E+05
40	129	6817	3316	3.06E+05	0.345	8.23E+05
45	130	6943	3522	3.48E+05	0.327	9.23E+05
50	146	7195	3695	4.30E+05	0.321	1.14E+06
55	132	7630	3868	4.26E+05	0.327	1.13E+06
60	137	7998	4125	5.03E+05	0.319	1.33E+06
65	140	8287	4369	5.76E+05	0.308	1.51E+06
70		8459	4467		0.307	
75	120	8796	4350	4.90E+05	0.338	1.31E+06
80		8798	4391		0.334	
85		9042	4707		0.314	
90	123	9527	4926	6.44E+05	0.318	1.70E+06
95		9967	5010		0.331	

Table 1 – P and S wave interval velocities extracted from tomography sections at 5 ft intervals from one vertical profile station. Using the soil density obtained from the geotechnical data, modulus data are calculated for each depth interval.

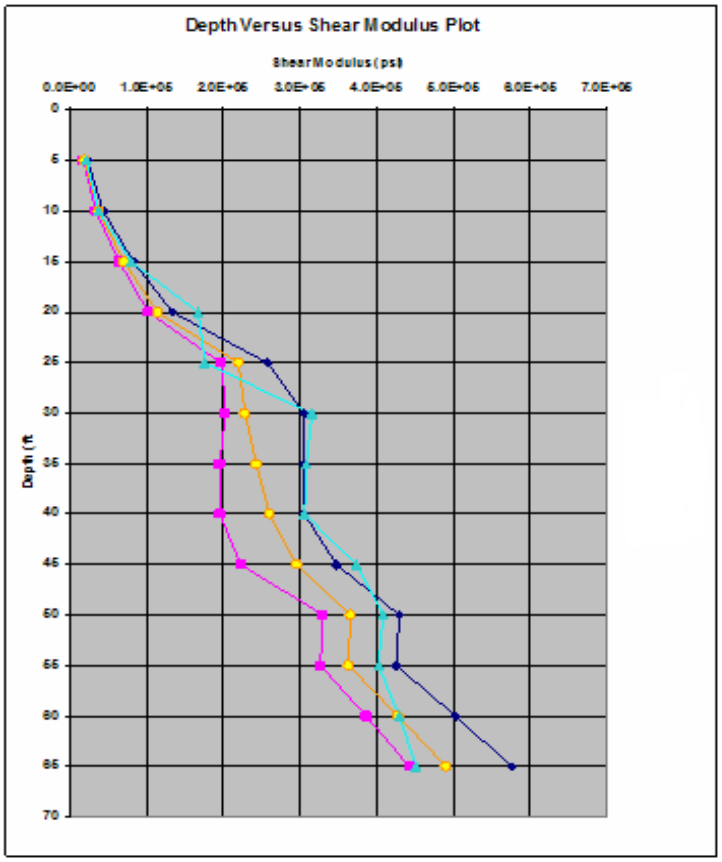

Figure 2 – Plot of Shear Modulus (pcf) versus depth for four vertical profile stations (60 ft interval) along the P and S wave seismic tomography sections. With changes in soil/rock density and P-S velocity, the low-high range of Shear Modulus versus depth is shown.

At the depth range of 5 to 20 feet the Shear Modulus values are nearly the same. At 20 to 30 ft depth the P-S velocity show a significant increase from about 3800 ft/sec to 6000 ft/sec, and the density shows a moderate corresponding increase. At the depth range 20 to 30 ft the Shear Modulus begins to show variation consistent with the geologic structure interpreted from the P and S wave tomography section. Below 30 feet the Shear Modulus indicates greater variability.

For more information concerning the application of this P-S wave

tomography imaging technique for geo-engineering and environmental site characterization projects, contact:

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