Repeatability of Pre- and Post-Excavation Seismic Refraction Data at the New Benicia-Martinez Bridge Toll Plaza, Northern California

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ABSTRACT

Two seismic refraction surveys performed nearly three years apart at the same location identified a common refractor, even after the ground surface elevation had been reduced 15 meters by construction grading. Preliminary investigations for rippability and earthwork factors were performed using seismic refraction methods in November 1998 at the New Benicia Martinez Toll Plaza site (to be completed in 2002). A refractor defining unripppable bedrock was calculated at an elevation of 12 to13 meters. This refractor was approximately 17 meters below original ground surface. A second seismic refraction survey was performed at the same location in March 2001, after the site had been excavated to a subgrade elevation of 16 meters. The results identified a refractor 3.5 meters below the new grade elevation, and its seismic velocity was within 1% of the earlier survey. The calculated refractor elevation was in the same range as the original survey. Both profiles were processed using the same commercially-developed seismic processing program and were recorded using the same parameters. LOTB data identifies sandstone bedrock at this elevation. Initial excavation in preparation for tunnel construction at this location confirmed the interpretation of unripppable bedrock.

INTRODUCTION

This is a case study of the repeatability of seismic refraction surveys. In preparation for the construction of the New Benicia-Martinez Bridge toll plaza, considerable grading of Mococo Hill would be required. Figure 1 shows the location of Mococo Hill and the project site. Mococo Hill is the southern most extension of an isolated, low and rounded ridge (max. elev. 32.0m) formed from rock of the Paleocene Martinez Formation. Bedrock consists mainly of decomposed to fresh interbedded sandstone and siltstone.

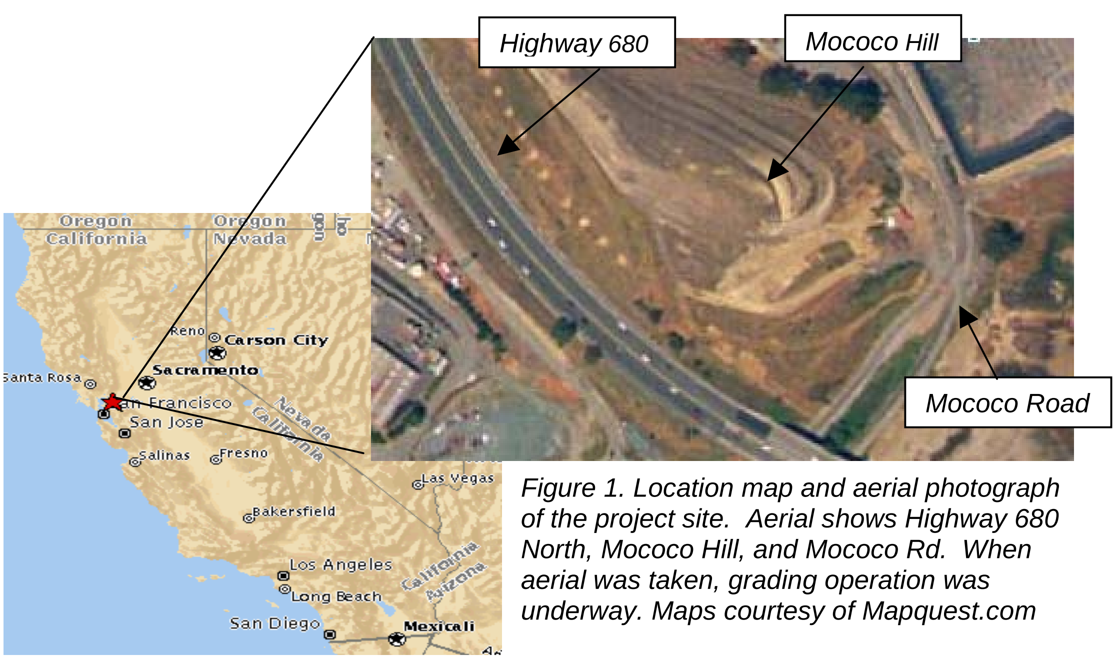

Figure 1. Location map and aerial photograph of the project site. Aerial shows Highway 680 North, Mococo Hill, and Mococo Rd. When aerial was taken, grading operation was underway. Maps courtesy of Mapquest.com

Rippability and earthwork factor data were crucial prior to letting the grading contract. A seismic refraction survey was performed in the fall of 1998 to delineate the velocity structure beneath the proposed alignment of an access tunnel, to be constructed as part of the toll plaza. The task was to define the depth to rock, assess excavation potential, and delineate structural features that might impact construction. At that time, a refractor was identified at an elevation of 13 meters that would not be rippable. Based on the information from the 1998 survey, the grading contract was let and the site was graded down 14 meters, to an average elevation of 16 meters. No excavation difficulties were encountered. Then, in the fall of 2001, prior to the letting of the underground construction contract, additional refraction data were requested to ascertain whether specialized excavation equipment would be required to construct the access tunnel (design elevation 11.0 meters). A second refraction survey was then performed at the same location as the first.

BACKGROUND

Figure 2 shows the original profile of Mococo Hill, the compiled travel time curve, velocity model, and depth section of the model. Data were acquired using a Geometrics Smartseis 12 channel seismograph with 14 MHz geophones. Geophone spacing for the profile was 3 meters. The seismic source was a Betsy downhole shotgun. Site geometry prohibited the use of long offset shots. Close proximity to Highway 680 generated substantial ambient noise and prohibited use of larger seismic sources (i.e., explosives). Short spreads, small energy sources, and noisy conditions limited imaging of the third layer and contributed to using the standard intercept-time method of interpretation (ITM) for that layer. Profile 9801 was positioned above the alignment of the planned 3.6-meter diameter access tunnel. The results of this survey identified rippable material to an elevation of 13 meters, having an earthwork factor ranging from .88 to .99 (Stephens, 1978). At 13 meters, a refractor was identified with a seismic velocity of 2000 m/sec., indicating difficult ripping or light blasting would be required. (This differs from other rippability charts commonly cited [e.g., Caterpillar, 2001] and is discussed below.) The calculated earthwork factor for this refractor was 1.13.

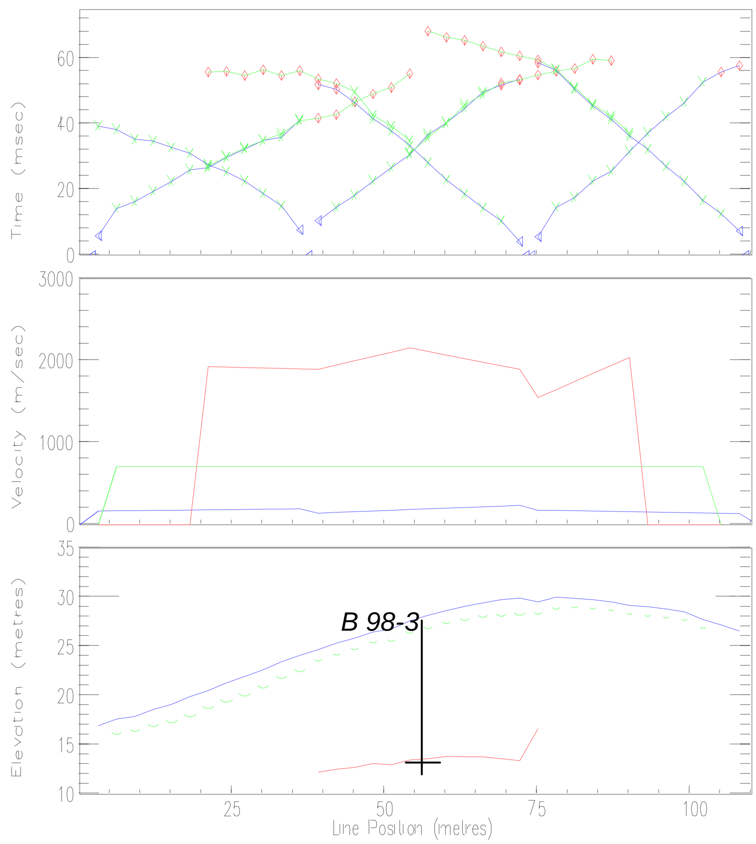

Figure 2. Seismic Refraction Profile 9801. Boring B 98-3 was drilled prior to grading operation and defined lithologic change from moderately soft sandstone to a moderately hard sandstone at 12.7m.

Data were processed using Viewseis 1.75, a commercially available processing program (Kassenaar, 1989). Where complete refractor coverage was possible, the Generalized Reciprocal Method of refraction interpretation (GRM; Palmer, 1980) was applied. The GRM calculates refractor depths for each geophone location, using overlapping refraction arrival times from both forward and reverse shots. The GRM requires the determination of the XY distance, or optimum XY. Optimum XY is defined as the distance of separation, measured at the surface, where forward and reverse seismic waves originate from the same point on the refractor. Figure 3. shows a conceptual illustration of the XY distance for refracted seismic waves. Incomplete refractor coverage was modeled using the standard time-intercept method of interpretation (ITM), (Redpath, 1973).

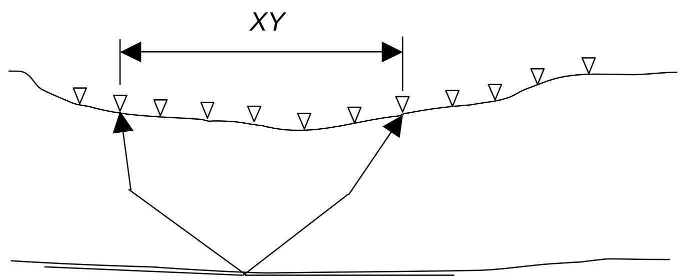

Figure 3. Graphic explanation of optimum XY (after Kassenaar, 1993)

The California Department of Transportation (Caltrans) uses their own chart correlating seismic velocity with rippability in lieu of commonly-cited references (e.g., Caterpillar, 2001). Table 1 shows Caltrans' rippability chart. Caltrans' experience is that the chart is more conservative than Caterpillar's chart, and has proven more reliable in evaluating a wide range of earth materials, limiting the number of contract change orders and reducing cost claims during construction. Earthwork factors are based on empirical correlation with seismic velocity of rock. These values are from published Caltrans studies (Stephens, 1978).

Velocity (m/s)	*Rippability*
< 1050	*Easily Ripped*
1050 – 1500	*Moderately Difficult*
1500 – 2000	*Difficult Ripping / Light Blasting*
> 2000	*Blasting Required*

Table 1. Standard Caltrans Rippability Chart

Figure 4 shows the results for Profile 2001-1, recorded at the same location as 9801, but nearly three years later and after grading had occurred. A 50 meter long profile was recorded using a Geometrics Smartseis 24 channel seismograph with 14 MHz geophones. Geophone spacing was 3 meters. Complete sampling of layer three allowed for GRM of interpretation of that layer. Profile 2001-1 indicated rippable material from the surface (approx. 16 meters) to an elevation of 13 meters. At 13 meters, a refractor was identified having a seismic velocity of 2031m/sec., indicating the need for specialized excavating equipment or blasting below that elevation. Stratigraphic data from a test boring drilled in 1998 indicate a lithologic change from a moderately soft siltstone to a moderately hard sandstone at an elevation of 12.7 meters which supports the seismic data. The design elevation for the 3.6-meter diameter access tunnel is from 9.86 to 11.3 meters, so the construction contract includes blasting specifications. Dewatering the site for underground utility installation occurred during the fall of 2001. This was achieved by trenching portions of the site's perimeter to an elevation of 11 meters. The need for pneumatic hammers to assist in the trench excavation supports the seismic refraction data. In addition, rock-breaking hoe rams were required to excavate around and under footings for PG&E tower supports for their removal prior to the grading contract (Bogdan Komorniczak, personal communication, 2002).

CONCLUSION

When properly collected and processed, seismic refraction data can be very reliable and have consistent results even under changed site conditions. Quickly and easily deployed, seismic data are often the most cost effective method of supporting drill data and can be a highly effective tool in controlling project costs by limiting potential opportunities for contract change orders. The mobility of seismic equipment enables cost effective site characterization prior to deployment of drilling equipment as well. Earthwork factors, rippability, and depth to bedrock are effectively determined in a non-destructive manner. The application of seismic refraction surveys can be utilized in any phase of reconnaissance, construction, or post-construction work.

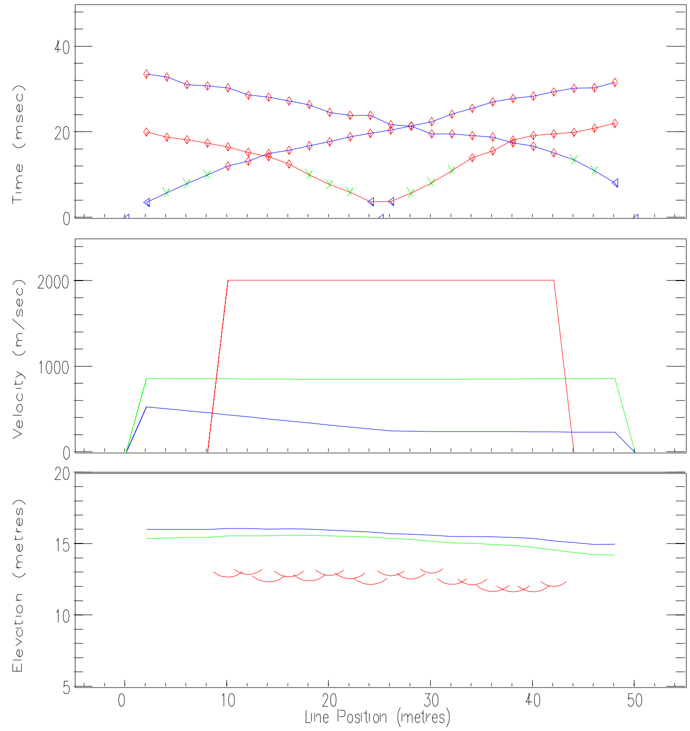

Figure 4. Seismic Refraction Profile 2001-1

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