SLAC-CN--267

DE84 011887

SINGLE PASS COLLIDER MEMO

AUTHOR: G.E. Fischer, K. Werner

DATE: 5/9/84

TITLE: Ground Motion - Some relative phase measurements
in the PEP Tunnel.

INTRODUCTION:

The spatial as well as the temporal characteristics of ground motion are of interest when one attempts to evaluate orbit distortions resulting from time varying quadrupole displacements. In other words, one needs to know the spatial correlations of quad displacements along the orbits path. A correlation with the betatron wavelength would be, for example, potentially more dangerous than from say purely statistically uncorrelated quad motions.

The space versus time relationship of ground motion is, of course, related by the effective velocity of sound in the supporting medium. The medium consists of the ground itself, the tunnel floor and the magnet support structure - the latter two having perhaps transmission line characteristics of their own. The question therefore is: What values of velocity should one use for the various types of disturbances that will be encountered in practice?

This note describes the results of a minimal experiment designed to answer two questions:

(a) Is it at all possible to measure correlations in an existing tunnel with simple equipment?

(b) Are the results consistent with the "known" geophysical characteristic of the site?

The answer to both questions, we believe, is surprisingly, yes.

METHOD:

MASTER

Two vertically sensing geophones (A, B,) of matched gain were connected to a two channel FFT (Nicolelet 660) Analyser used in the Transfer Function mode. See Figure 1. In this mode the analyser measures the complex ratio B/A of the Fourier transforms from which is derived the relative phase angle of the disturbances at any particular frequency within a selected band.

ExB

As a driving source we chose the two 75 HP vertical piston air compressors located in Bldg.023 whose sharp 6.00 Hz signal is ubiquitous over the site. Fig 2. depicts the geometry of the source in relation to observers in the PEP tunnel.

Test site #1 was chosen such that the time of arrival of say a cylindrically spreading wave train should be nearly independent of relative sensor separation in the tunnel. Test sites #2 and #3 are nearly in line with the direction of the propagation vector, albeit they are closer to the source.

DATA:

Figure 3 depicts the relative phase angle between the signals from sensors A and B versus their physical separation in the tunnel.

As expected there is little phase shift at PEP region 3. In fact, although sensor A was geometrically slightly closer to the source, the signal arrived later than at B, indicating a velocity anomaly in the flight path! The data from PEP regions 1 and 11 show distinctive and almost linear slopes.

Figure 4 depicts the measured ratio of amplitudes $|B|/|A|$. This data is not readily interpretable by us at this time since this ratio should theoretically be less than 1.

DATA REDUCTION:

Relative flight paths lengths are corrected for geometry as shown in Figure 5.

If we write, for the vertical amplitude:

$$Y(z,t) = Y_0 \sin(2\pi/\lambda)(z - vt)$$

then the local wavelength is :

$$= (z_1 - z_2) / (\phi_1 - \phi_2) \text{ in units of } 2\pi.$$

and the local velocity of propagation is: $v = f\lambda$.

RESULTS: PEP Tunnel elevation is 211 ft. above m.s.l.

	Separation between AB	Phase Shift	Proj. Dist.	Wave- length	Velocity ft/sec Km/sec	Depth below surface
Region1	64m	320°	157'	177'	<u>1059</u> .32	16'
Region11	64m	397°	189'	171'	<u>1028</u> .31	60'

Since both the source emitted and the sensors received in the vertical direction and the line of propagation is primarily in the horizontal, the velocities measured must be looked upon as shear wave velocities. If theory is valid, velocities are frequency independent.

INTERPRETATION & Speculation

The rather low values of velocity encountered struck us at first glance, as somewhat peculiar. For PEP region 11 we had expected values up to twice as high. However an examination of the geotechnical data provided for PEP (Ref.1) and later for SLC (Ref.2) reveals the following.

PEP Region 1 is in a "cut and cover" tunnel and seemingly passes through a valey of recent "aluvial" material of the so called Santa Clara formation.

PEP Region 11 is considerably deeper underground and should therefore have been in more competent myocene sandstone. Bore holes PEP 11-2 and DH-5 show layers of "clayey silt" and "sandy silt" at PEP depth and a thin layer of "clay" passes through the tunnel adjacent to hole 11-7. Sandy silt has a compressional strength of less than say 40 psi. The velocity measured is therefore not inconsistent with shear wave velocities of 1000ft/sec. normally found nearer the surface.

On the other hand, it appears suspicious that the two velocities are so similar. We may be measuring characteristics of the tunnel or floor and not of the surrounding ground. A further experiment in a location of "known" myocene sandstone would answer that question. In either case we are measuring a relevant quantity since the tunnel floor supports the magnets.

It is amusing to recall that the length of one SLC achromat (whose betatron phase shift is exactly $3 \times 2\pi$) is 170 ft. long. That means that if the SLC tunnel were to pass through similar material and behave in the same manner, at some direction of the tunnel parallel to the velocity vector our friendly 6.00 Hz compressor would exactly resonate with the third multiple of the betatron wavelength! One then recognizes that by changing the direction of the tunnel to some other angle, the lattice will pick out any periodic local source of frequency f . This may not be serious for the single pass SLC unless its repetition frequency is locked to f . A storage ring is not so lucky.

REFERENCES:

1. Dames and Moore Geotechnical Report June 1977
2. Title I Geotechnical Report for the SLAC SLC North and South Tunnel. Earth Science Associates, Palo Alto, Sept 1982.

Fig. 1

EXPERIMENTAL SET-UP

PHASE EXPERIMENT IN PEP

Figure 2

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

MAGNITUDE RATIO
VS
DISTANCE APART

BY: K.L.W

Fig. 4

note:

- TEST 1
- TEST 2
- △ TEST 3

FIG 5

$$\lambda = \frac{Z_{proj}}{(\phi_H - \phi_B) \text{ in units of } 2\pi} \quad , \quad v = \lambda f$$