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OPTIMIZING THE PLACEMENT OF A ROAD BETWEEN TWO RESEARCH BUILDINGS — A CASE STUDY

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1. INTRODUCTION

A problem arose during the design of major site renovations of a research campus that serves several research organizations. Prior to the site planning, two tenant organizations had progressed far into the design of new laboratory facilities. Each facility had a demonstrable sensitivity to vibration; unfortunately, there had been little coordination of the vibration requirements of the two facilities.

After considering several alternative routes for the campus' central road, practical and political issues dictated that it must pass between the two laboratories, the sites of which had already been established. The research areas of the two buildings were separated by about 120 m. The site planners recognized that traffic on the road might generate vibrations that could have an adverse impact on the research efforts of both organizations. Because the building designs had progressed so far, it was infeasible to move either building, and all of the other alternate routes were ruled out. Thus, the objective of the study discussed herein was to define a compromise route for the spine road between the two facilities that would have the *least* adverse impact on the two laboratories.

2. VIBRATION CRITERIA

Each facility has its own vibration criterion defined in one-third-octave band spectral form, stated below and shown graphically in Fig. 1.

- *Facility A* - 25 nanometers rms displacement amplitude at frequencies below 20 Hz; 3 micrometers/sec (μm/s) rms velocity amplitude at frequencies between 20 and 100 Hz.
- *Facility B* - 200 nanometers rms displacement amplitude at frequencies below 7 Hz; rms velocity amplitude of $24/f^{1/2}$ μm/s at frequencies above 7 Hz.

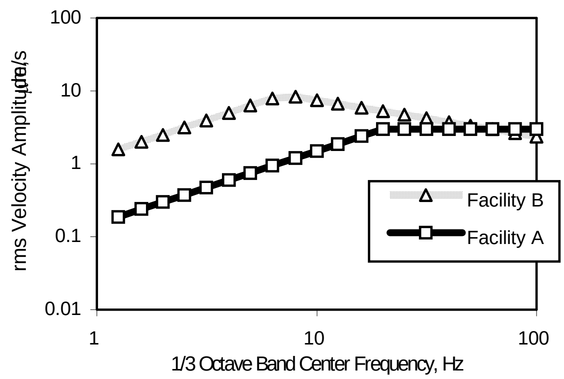

Fig. 1. Vibration Criteria

3. "OPTIMAL" PLACEMENT OF ROAD

If the road was placed midway between the two laboratories, the vibration amplitudes would be about the same in each facility. However, Facility A would be more adversely affected by this placement, since it is more sensitive to vibrations. In concept, the "optimal" placement of the road would be the one to cause an "equal" impact on each facility. Thus, the following decision parameters were established:

- If the vibrations from a particular road location exceeded both criteria, then the location would be adjusted such that both criteria would be exceeded by about the same ratio or decibel value.
- If vibrations from a particular road location did not exceed the criteria, then the location would be adjusted such that each facility had the same "headroom" in decibels.

It was decided that the "optimum" placement would be based upon the L1 metric, the envelope spectrum exceeded only 1 percent of the time. However, the scientists requested that the centile distribution of the data be produced in the form of Ln spectra.

4. MEASURED VIBRATIONS

The present campus has an arterial road that is similar in construction and vehicle usage to that of the proposed new road. Vibrations were measured at four distances from the centerline of that road several times during the day to characterize the variation of amplitude and frequency content with distance. The measured L1 spectra measured at 8, 18, 80 and 120 meters from the road are shown in Fig. 2.

The 120 m curve is representative of most locations on the campus that are well-removed from traffic sources. The predominant frequency of this "far-

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field" motion is between 6 and 10 Hz, with an rms velocity amplitude slightly less than 1 µm/s. The requirements of Facility A are easily met at this distance. The predominant frequency of the motion 8 m from the road is 16 Hz with an amplitude on the order of 10 µm/s, which exceeds the criterion of Facility B by 2.6 times. Since a distance of only 120 m separates the two research spaces, the road had to be placed at some distance greater than 8 m from Facility B and less than 102 m from Facility A.

5. INTERPOLATION APPROACH

The criterion curve for Facility A can be bracketed between the 120 m and 80 m spectra and the Facility B criterion curve can be bracketed between the 8 m and 18 m spectra. These are shown in Figs. 3 and 4.

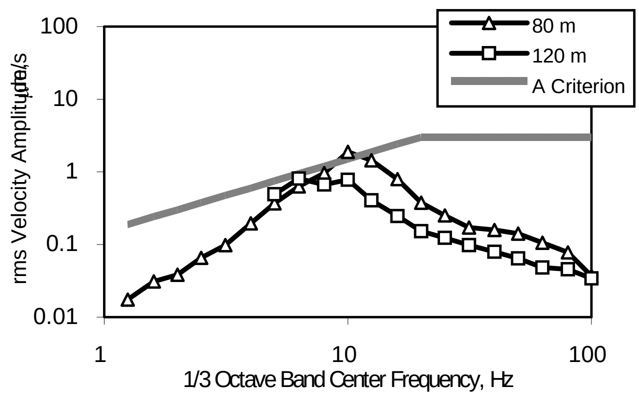

Fig. 3. L1 Spectra at 80 and 120 m with Criterion A

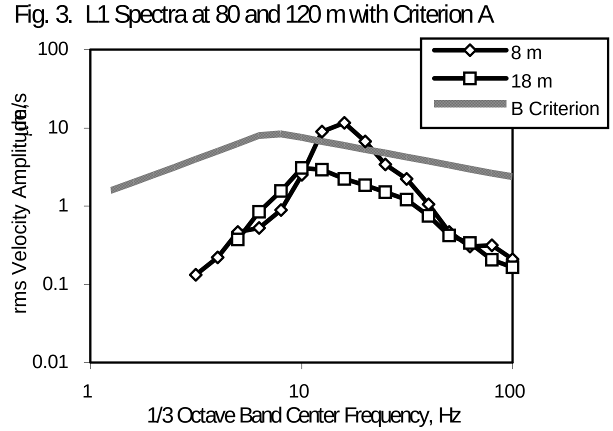

Fig. 4. L1 Spectra at 8 and 18 m with Criterion B

There are several popular analytical models for the propagation of vibrations in the soil, the most common of which is simple spreading which can be expressed as $w = w_1 (r_1 / r)^{\gamma}$, where w is the amplitude at distance r from the source and w_1 is the known or assumed amp-litude at distance r_1. The exponent of $\gamma = 0.5$ is quite commonly used when site-dependent data are not available. However, with the availability of measured amplitudes as a function of distance, γ could be calculated explicitly for each frequency using the two spectral points at distances bracketing the distance of interest: $\gamma = \log(w_2 / w_1) / \log(r_1 / r_2)$.

The "optimal" location between the two facilities was determined by interpolating spectra at 1-meter intervals and comparing the "headroom" between the calculated L1 spectra and the respective criteria. The two headroom values were equal—3 decibels—for the case in which the road centerline was 105 m from Facility A and 15 m from Facility B. Figure 5 shows the predicted centile spectra for Facility A at 105 m from the road

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centerline. Figure 6 shows the same spectra for Facility B at 15 m. Each Ln centile curve was interpolated from the corresponding measured Ln curve in the manner discussed previously.

Given the two setback distances, the design team traced on a site plan two curves representing distances of 105 m and 15m from the research areas in Facilities A and B, respectively. This defined the "window" through which the road could be routed.

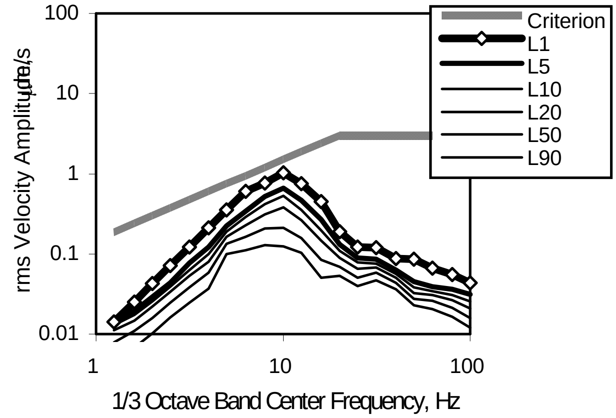

Fig. 5. Centile Spectra - Facility A - 105 m

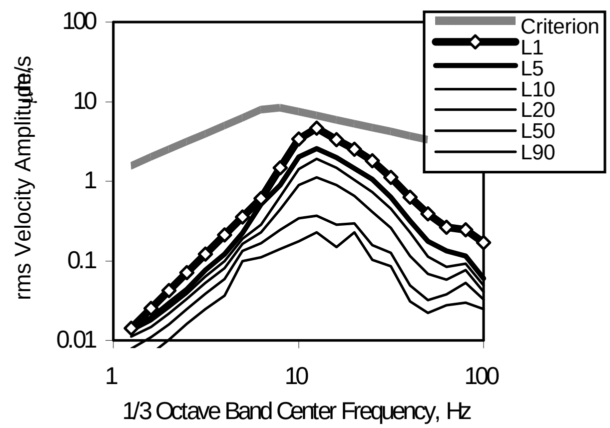

Fig. 6. Centile Spectra - Facility B - 15 m

6. SUMMARY

Practical design problems involving conflicting vibration criteria can be addressed by restating the criteria in a mutually compatible frequency domain using compatible bandwidths. For a given source model—in this case the traffic vibrations defined by measurements at several distances—a "buffer" distance can be established be-tween the source and a laboratory area that will keep the laboratory vibrations below the appropriate criterion. When the situation involves more than one laboratory—as in the case reported herein—then a buffer distance can be established for each laboratory and used to define a "window" of acceptable locations.