Appendix K

Calculation Methods for Quantifying Noise and Ground Vibration Levels

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Noise Level Equations:

Mathematically, a decibel is defined as ten times the base 10 logarithm of the ratio between the two quantities of sound pressure (SPL)[1] squared, or:

$$SPL = 10 \log (p/p_o)^2 = 20 \log (p/p_o) \text{ dB}$$

where p is the sound pressure being measured and p_o is the reference sound pressure (standardized at 20 microPascals (µPa), which is the quietest sound that can be heard by most humans - the “threshold of hearing"). SPL attenuates with respect to the inverse distance law, where sound pressure is inversely proportional to the distance from the noise source (FTA 2006, Caltrans 2009).

The noise levels are calculated using the noise analysis tool developed by the USDOT, FHWA RCNM[2] version 1.1, using the following equations (Caltrans 2009):

To add equal sound pressure levels:

$$SPL_{Total} = SPL_1 + 10Log_{10}(N)$$

Where: SPL_{Total} = total sound pressure level produced

SPL_1 = SPL of one source

N = number of identical sources to be added (must be more than 0)

To add unequal sound pressure levels:

$$SPL_{Total} = 10Log_{10}[10^{SPL1/10} + 10^{SPL2/10} + \ldots 10^{SPLn/10}]$$

Where: SPL_{Total} = total sound pressure level produced

SPL_1, SPL_2, and … SPL_n represent the first, second, and n^{th} SPL, respectively

To calculate a noise level with respect to a known noise level at a known or referenced distance from a point source:

$$dBA_2 = dBA_1 + 20Log_{10}(D_1/D_2)$$

Where: dBA_1 = noise level at a distance D_1 from the point source

dBA_2 = noise level at distance D_2 from the same point source

To calculate a noise level from a point source moving along a line[3]:

$$dBA_2 = dBA_1 + 10Log_{10}(D_1/D_2)$$

Where: dBA_1 = noise level at a distance D_1 from the point source

dBA_2 = noise level at distance D_2 from the same point source

The vibration level (Lv) of equipment in vibration decibels (VdB) at any distance (D) is estimated using the following equation (FTA 2006):

1 Sound pressures can be measured in units of microNewtons per square meter ($\mu N/m^2$), also called microPascals (µPa): 1 µPa is approximately one-hundred-billionth (1/100,000,000,000) of the normal atmospheric pressure.

2 The RCNM is the FHWA’s national model for the prediction of construction noise (FHWA RCNM 2006).

3 Sound emanating from a point source moving along a line, or a line source, e.g., a continuous stream of roadway traffic and is independent of frequency, is called “cylindrical divergence” (FHWA TNM 2011).

$$Lv(D) = Lv(D_{ref}) – 30\log(D/D_{ref})\ VdB$$

Where: $Lv(D)$ = vibration level at any distance, D, from a vibration source; and

$Lv(D_{ref})$ = measured vibration level at a reference distance, D_{ref}, from the same vibration source

Ground Vibration Level Equations:

Vibration velocity level in decibels is calculated using the following equation:

$$L_v = 20 \text{ x } \log_{10} (V/V_{ref})\ VdB$$

where L_v is the velocity level in decibels (VdB), V is the root-mean-square velocity amplitude[4], and V_{ref} is the reference velocity amplitude. A reference must always be specified whenever a quantity is expressed in terms of decibels. The accepted reference quantity for vibration velocity is $1 \text{x} 10^{-6}$ in/sec in the US (FTA 2006).

The vibration level (Lv) of equipment in vibration decibels (VdB) at any distance (D) is estimated using the following equation (FTA 2006):

$$Lv(D) = Lv(D_{ref}) – 30\log(D/D_{ref})\ VdB$$

where Lv(D) is the vibration level at any distance, D, from a vibration source, and $Lv(D_{ref})$ is the measured vibration level at a reference distance, D_{ref}, from the same vibration source.

The PPV of equipment in in/sec is estimated using the following equation (FTA 2006):

$$PPV\mathit{equip} = PPV\mathit{ref} \text{ x } (25/D)^{1.5}$$

where PPV*equip* is the peak particle velocity in in/sec of the equipment adjusted for distance, PPV*ref* is the reference vibration level in in/sec at 25 feet from Table 3.9-7, and D is the distance from the equipment to the receptor.

4 Amplitude means the difference between the extremes of an oscillating signal. The root mean square (rms) of a signal is the square root of the average of the squared amplitude of the signal (measured in in/sec).