Noise Pollution

1. Introduction

Definitions

- Unwanted sound;
- Any sound independent of loudness that can produce an undesired physiological or psychological effect in an individual, and that may interfere with the social ends such as communication, work, rest, recreation and sleep, of an individual or group.;

History

- B.C. 800's, Old Greek City Sybaris, noise zoning for factories;
- B.C. 300's, 마차나 전차의 심야 통행 제한;
- 1500's, "심야 부녀자 구타 금지" 칙령;
- After industrial revolution, noise pollution becomes significant.

Why the noise pollution is slow in coming?

- Noise, i.e., unwanted sound, is a subjective experience;
- Noise does not remain in the environment for extended periods;
- Effects of noise on human are subtle and insidious (잠행성);
- Noise had been associated with the technological advances.

1.1 Properties of Sound Waves

See Fig. 7-2 (p. 554)

$$P = \frac{1}{f}$$

$$\lambda = \frac{c}{f}$$

where P = period [T];

f = frequency [1/T];
λ = wavelength [L]; and
c = sound speed [L/T].

The root mean square (rms) sound pressure (p_{rms}),

$$p_{rms} = \left(\overline{p^2}\right)^{1/2} = \left[\frac{1}{T}\int_0^T P^2(t)dt\right]^{1/2}$$

1.2 Sound Power and Intensity

Sound Power : Traveling waves of sound pressure transmit energy in the direction of propagation of the wave. The rate at which is done.

Sound Intensity

$$I = \frac{W}{A}$$

where I = sound intensity (W/m^2);

W = sound power (W); and
A = unit area perpendicular to the direction of wave motion (m^2).

also,

$$I = \frac{(p_{rms})^2}{\rho \cdot c}$$

where p_{rms} = root mean square sound pressure (Pa);

ρ = density of medium, kg/m^3; and
c = speed of sound in medium, m/sec.

Speed of sound in air vs. Temperature

$$c(m/\sec) = 20.05 \cdot \sqrt{T}$$ (at 101.325 kPa)

where T = absolute temperature, (K).

1.3 Levels and the Decibel

Sound Level Unit

Unit of levels = "bel" (after Alexander Graham Bell)

Decibels (dB)

$$L' = \log \frac{Q}{Q_o}$$

where L' = level (bels);

Q = measured quantity; and

Q_0 = reference quantity.

L = 10 L'

where L = level (dB).

Sound Power Level

For noise measurements, the reference power level (W_0) has been established as 10^{-12} watts.

$$L_w = 10 \cdot \log \frac{W}{10^{-12}}$$

where L_w = sound power level (dB re: 10^{-12} W).

Sound Intensity Level

For noise measurements, the reference sound intensity (I_0) has been established as 10^{-12} W/m^2.

$$L_I = 10 \cdot \log \frac{I}{10^{-12}}$$

where L_I = sound intensity level (dB re: 10^{-12} W/m^2) .

Sound Pressure Level

For noise measurements, the reference pressure ($p_{rms,0}$) has been established as 20 μPa.

$$L_p = 10 \cdot \log \frac{(p_{rms})^2}{(p_{rms,o})^2} = 20 \cdot \log \frac{p_{rms}}{p_{rms,0}}$$

where L_p = sound pressure level (dB re: 20 μPa).

Combining Sound Levels

Logarithmic computation.

1.4 Characterization of Noise

Weighting Networks

- Human reaction by sound is more interested than the physical properties.
- Sound pressure level means "How loud it sounds"
- Frequency of the noise is important.
- "weighting network is necessary to measure the noise.

Three weighting characteristics (or networks):

see Fig. 7.6,(p.559) and Table 7.1.(p.560)

For example, if the measured sound level of a noise is much higher on C weighting than on A weighting, much of the noise is probably of low frequency.

Averaging Sound Pressure Levels

$$\overline{L_p} = 20 \cdot \log \frac{1}{N} \sum_{j=1}^{N} 10^{(L_j/20)}$$

where $\overline{L_p}$ = average sound pressure level (dB re: 20μPa);

N = number of measurements;

Lj = the jth sound pressure level (dB re: 20μPa);; and

J = 1,2,3,…N.

<u>Types of Sounds</u>

- Continuous noise : uninterrupted sound level that varies less than 5dB.
- Intermittent noise : persists more than 1 second that is interrupted for more than 1 second.
- Impulse noise : change of second pressure of 40dB or more within 0.5 second with a duration of less than 1 second. (duration, see Fig. 7.7, 8, p.563)

2. Effects of Noise on People

(reading assignment)

3. Rating Systems

3.1 Goals of a Noise-Rating System

- The statistical rating system is practical difficult because the frequency of the sound, type of noise, time of days that it occurred, et al. are significant factors in annoyance.

3.2 The L_N Concept

- L_N = How frequently a particular sound level is exceed.
  For example, "L40 = 72 dBA, 72 dB(A) was exceeded for 40% of the measuring time.
- Cumulative distribution curve (Fig. 7-23, p.581) vs.
  Probability distribution plot (Fig. 7-24, p.582)

3.3 The L_{eq} Concept

- L_{eq} = constant noise level, over a given time, expends the same amount of energy as the fluctuating level over the same time period.

$$L_{eq} = 10 \cdot \log \frac{1}{t} \int_0^t 10^{L(t)/10} dt$$

where t = time over which L_{eq} is determined; and
L(t) = time varying noise level in dBA.

$$L_{eq} = 10 \cdot \log \sum_{i=1}^{i=n} 10^{L_i/10} \cdot t_i$$

where n = time over which L_{eq} is determined;
L_i = time varying noise level in dBA; and
t_i = fraction of total sample time.

4. Community Noise Sources and Criteria

4.1 Transportation Noise

- Aircraft noise
- Highway vehicle noise

4.2 Other Internal Combustion Engines

4.3 Construction Noise

4.4 Zoning and Siting Considerations

4.5 Levels to protect Health and Welfare

5. Transmission of Sound Outdoors

5.1 Inverse Square Law

$$I = \frac{W}{4\pi r^2}$$

where I = sound intensity, watts/m^2; and

W = sound power of source, watts.

5.2 Radiation Fields of a Sound Source

5.3 Directivity

5.4 Airborne Transmission

6. Traffic Noise Prediction

6.1 National Cooperative Highway Research Program 174

6.2 Methodology

6.3 Procedure

6.4 L_{eq} Prediction

$$L_{eq} = 42.3 + 10.2 \cdot \log\left(V_c + 6 \cdot V_t\right) - 13.9 \cdot \log D + 0.13 \cdot S$$

where L_{eq} = energy equivalent sound level during one hour, dBA;

V_c = volume of automobiles (four tires only), veh/h;

V_t = volume of trucks (six or more tires), veh/h;

D = distance from edge of pavement to receiver, m; and

S = average speed of traffic flow during one hour, km/h.

6.5 L_{dn} Prediction

$$L_{dn} = 31.0 + 10.2 \cdot \log\left[AADT + \left(T\% \cdot AADT / 20\right)\right] - 13.9 \cdot \log D + 0.13 \cdot S$$

where L_{dn} = equivalent A-weighted sound level during 24-hour time period with 10 dBA weighting applied to 2200-0700 h, dBA;

AADT = annual average daily traffic, veh/d; and

%T = average percentage of trucks during a typical day, %.

7. Noise Control

7.1 Source-Path-Receiver Concept

- Sound arise from a source;
- Travels over a path;
- Affects a receiver (or listener).

Thus,

- Modifying the source to reduce its noise output;
- Altering or controlling the transmission path and the environment to reduce the noise level reaching the listener;
- Providing the receiver with personal protective equipment.

7.2 Control of Noise Source by Design

<u>Reduce Impact Forces</u>

- Reduce the weight, size, or height of fall of the impacting mass;
- Cushion the impact by inserting a layer of shock-absorbing materials
- Non-metallic material
- Large impact force over a short period -> Small force over a long period
- Avoid high acceleration
- minimize the linkages between parts (e.g., gears, cams, etc.)

<u>Reduce Speeds and Pressures</u>

<u>Reduce Frictional Resistance</u>

<u>Reduce Radiating Area</u>

The larger the vibrating part or surface, the greater the noise output.

<u>Reduce Noise Leakage</u>

<u>Isolate and Dampen Vibrating Elements (see Fig. 7.41, p.615)</u>

<u>Provide Mufflers/Silencers</u>

7.3 Noise Control in the Transmission Path

Separation

Absorbing Materials

Acoustical Lining

Barriers and Panels (see Fig. 7-42, p.618)

Transmission loss

Enclosures

7.4 Control of Noise by Redress

- Balance rotating parts;
- Reduce frictional resistance;
- Apply damping materials;
- Seal noise leaks; and
- Performance routine maintenance.

7.5 Protect the Receiver

When all else fails,

<u>Alter Work Schedule</u>

- An intermittent schedule is preferable.
- Between 10 P.M. and 7 A.M. are 10dBA higher effective.

<u>Ear Protection</u>

- Maximum protection can be obtained when both plugs and muffs are employed. (See Fig. 7.45 (p.623)