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The Prediction of Noise from Construction Sites

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1. Introduction

The sources and characteristics of noise from construction sites are quite different to those of other noises. The characteristics of interest include frequency spectra, durations and movements of noise sources. There are many kinds of noise source in construction sites, including both static and moving sources, steady noise, fluctuating noise and impulsive noise often simultaneously. It is possible to identify four phases of construction each with quite distinctive noise sources and characteristics.

The most important method of noise control is a rational plan and layout based on noise prediction. Frequently it is possible to meet the noise limits at the boundary of the construction site, which are set by environmental authorities in most countries, by planning and layout together with noise control of specific sources.

This paper analyses construction noise characteristics from several construction sites and identifies the major noise sources. Typical Sound Power Levels (L_W), determined according to the ISO recommended method, of major noise sources in each construction phase are given. These provide the basic information for predicting noise from construction sites.

As well as sound power and directional characteristics, the effect of reflection from the ground and from surrounding buildings, excess attenuation due to barriers (including typical thick barriers such as buildings) and other factors are taken into account in the Prediction Scheme.

2. The characteristics of noise from construction sites

We divide a construction process into four phases: (i) pile driving (ii) earth moving, (iii) erection of structural framework, (iv) installation of equipment and cladding. Perimeter noise levels at several types of construction site have been measured and analyzed in terms of these four phases. It is interesting to note that each phase appears to have its own distinctive noise characteristics and that the statistical noise levels (L_{10}, L_{50} and L_{90}) and equivalent continuous level L_{eq} in each phase obey a normal distribution.

Table 1 shows these statistical parameters derived from the data obtained at a number of construction sites.[1] Fig. 1 shows the corresponding distribution curves for L_{eq}. The curves in Fig. 1 are predicted by using the data in Table 1 and the following equation:

$$F(L_x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\left(\frac{L_x - L}{\sigma}\right)^2 / 2} \qquad (1)$$

where $F(L_x)$ is the probability function of measuring a particular noise level.

It is clear that the noise level at the boundary of a construction site mainly depends on the characteristics of the noise sources operating during each phase. If these characteristics and the transmission conditions at the site are known, then the noise level at the boundary of the site can be predicted.

Table 1 Some statistical parameters of construction noise

Construction	L_{10}		L_{50}		L_{90}		L_{eq}	
Phase	$\bar{L}_{10}$	σ	$\bar{L}_{50}$	σ	$\bar{L}_{90}$	σ	$\bar{L}_{eq}$	σ
Pile driving	85.6	5.9	74.0	9.9	69.8	9.2	83.4	6.0
Earth moving	75.3	3.5	71.5	3.8	69.0	4.3	72.9	8.0
Erection of Structural Framework	71.4	4.6	65.8	4.0	61.7	4.0	68.3	3.4
Installation of equipment and cladding	66.6	2.0	59.6	2.0	55.3	2.0	62.8	3.0

In Table 1

$\bar{L}$ is the statistical mean value, dB(A);
σ is the standard deviation for L, dB(A);
L_{10} is the noise level exceeded 10% of the time during the observation period;
L_{50} is the median percentile noise level, dB(A); and
L_{90} is the noise level exceeded 90% of the time during the observation period.

3. The characteristics of noise sources in different construction phases

In this section we distinguish between the major sources in each phase and give the sound power levels of these major noise sources.

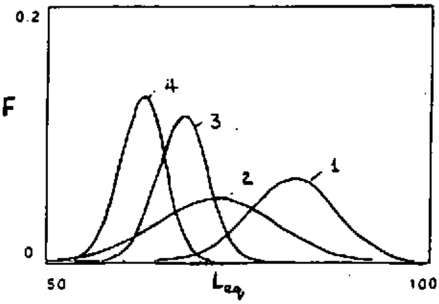

Figure 1 Normal distribution curves of Leq for each construction phase.

3.1 Earth moving

The major noise sources in the earth moving phase are construction engineering machinery, including bulldozer, excavator, etc, and transportation vehicles.

The sound power level of 60 different machines under simulated operating conditions have been measured according to the relevant ISO standard. The equivalent continuous sound power level and the mechanical power of the machinery are highly correlated (the correlation coefficient is 0.93) such that:

$$L_{W_{eq}} = 20\log N_l + 73 \qquad (2)$$

where $L_{W_{eq}}$ - equivalent continuous sound power level, dB(A);
and N_l - machinery output power, KW.

Table 2 shows the empirical relation between the sound power level of different types of transportation vehicle and the speed. The empirical relationship is based on experimental data obtained from approximately 100 different types of vehicle according to ISO standard R362.

Table 2 Sound power level of transportation vehicles

Vehicle type	Empirical relation for level in dB(A)	Correlation coefficient
Heavy truck	70 + 24 lgV	0.92
Medium truck	64 + 25 lgV	0.83
Light truck	60 + 24 lgV	0.90

3.2 Pile driving

The major noise sources during this phase are shown in Table 3. The pile driver is the most dominant source and is a typical impulsive source.

Table 3 Major sources and their sound power levels during pile driving

Name of equipment	dB(A) Sound power level $L_{W_{eq}}$
Impulsive type pile driver	132 ± 3
Liquid pressure pile driver	107 ± 2
Pneumatic drill	110 ± 2
Crane	102 ± 2

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3.3 Erection of structural framework

The structural erection is the longest phase during the construction process. The major noise sources and their sound power levels are shown in Table 4.

Table 4 Major noise sources and their sound power levels during the erection of structures

Name of equipment	dB(A) Sound power level $L_{W\,eq}$
Vehicle-concrete mixer	108 ± 2
Concrete mixer	93 ± 2
Concrete Vibrator	100 ± 2
Crane	102 ± 2
Circular Saw	110 ± 2

3.4 Installation of equipment and cladding

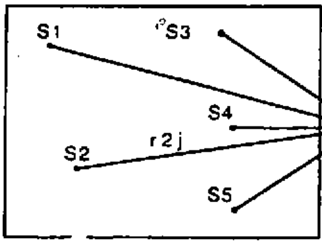
This phase is quite long, but involves sources with lower sound power levels than those of sources involved during other phases (Fig. 1). The major sources during installation of equipment and cladding and their sound power levels are shown in Table 5.

Table 5 Major noise sources and their sound power levels during the installation of equipment and cladding

Name of equipment	dB(A) Sound power level $L_{W\,eq}$
Installation crane	87 ± 2
Hoister	87 ± 2
Cutting Machine	95 ± 2
Polishing machine for stone	90 ± 1

4. Prediction of construction noise

Distances from sources to construction site perimeters range from tens of metres to hundreds of metres. Although the whole of a construction site can be considered a noise source, experiments show that the attenuation of noise with distance from construction site does not increase systematically (attenuation per double distance varies between 2-6 dB). An alternative model is that the construction site can be considered as an area containing several sources (Fig. 2). The effects of reflection from the ground and from surrounding buildings, the excess attenuation of barriers (including typical thick barriers buildings) have to be taken into account in a prediction scheme in addition to distance attenuation. The resulting model for noise prediction is described by equation (3).



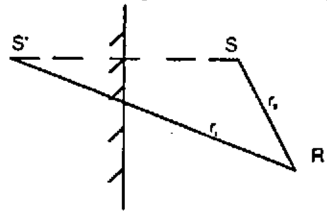


Figure 3. Reflection from surrounding buildings

Figure 2. Model of noise source of construction sites

$$L_{p_j} = 10 \log \sum_{i=1}^{n} 10^{0.1 L_{p_{ij}}} \qquad (3)$$

$$L_{p_{ij}} = L_{W_{eq_i}} + 10 \log \frac{Q_i}{4\pi r_{ij}^2} + \Delta L_{1_{ij}} + \Delta L_{2_{ij}} + \Delta L_{3_{ij}}$$

where L_{p_j} is predicted equivalent continuous noise level (L_{eq}) at receiver point R_j;
$L_{p_{ij}}$ is the Leq at receiver point R_j from noise source S_i;
Q_i is the directivity factor of source related to the position of source;
ΔL_1 is the attenuation due to ground reflection;
ΔL_2 is the correction due to surrounding building reflection; and
ΔL_3 is the excess attenuation of barriers.

4.1 The effect of ground reflection

A widely accepted model [3] for effect of ground reflection is shown in equation (4):

$$\Delta L_1 = 20 \log \frac{P_1 e^{ikr_1}/r_1 + Q(P_1 e^{ikr_2}/r_2)}{P_1 e^{ikr_1}/r_1} \qquad (4)$$

where $Q = R_p + (1-R_p) F_{(w)}$, spherical wave reflection coefficient;
and R_p is the plane wave reflection coefficient.

Q and R_p are the function of the angle of incidence and the normalised impedance of ground surface. There are several methods for predicting the impedance of ground surface together with typical input parameters.[4]

The attenuation value for octave band sound pressure levels and A weighted noise level can be calculated by using equations (5) and (6) in conjunction with equation (4).

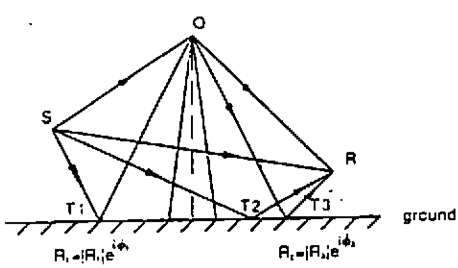
$$\Delta L_t = 20 \log \frac{\int_{fi/\alpha}^{\alpha fi} P_t df}{\int_{fi/\alpha}^{\alpha fi} P_d df} \qquad (5)$$

$$\Delta L_A = 10 \log \frac{\Sigma 10^{0.1(L_{t_i} - \Delta Li)}}{\Sigma 10^{0.1(L_{d_i} - \Delta Li)}} \qquad (6)$$

where ΔL_t is the attenuation value due to ground effect in ith octave band;
f_i is the ith octave center frequency;
$\alpha = 1.414$;
ΔL_A is the attenuation of A weighting network in the octave and; and
ΔL_i is the correction for A weighting network in ith octave band.

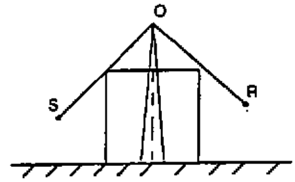
4.2 The effect of surrounding of building reflection

Usually there are buildings around construction sites. The effect of reflections from these buildings has to be considered. Typically the surfaces of building are acoustically hard and their absorption coefficients are in the range of 0.05 to 0.15. The effect of surrounding buildings can be calculated by using the method of images and sound energy addition (Fig. 3).



SR and ST2R propagation paths without barrier
SOR, SOT3R propagation paths with barrier
ST1OR and ST1OT3R

Figure 4. barrier extending to ground surface



Figuer 5. Effective thin barrier instead of thick barrier

$$\Delta L = 10 \log \left[1 + \left(\frac{r_0}{r_1}\right)^2 \alpha\right] \qquad (7)$$

where α is the absorption coefficient of the building surface.

4.3 Excess attenuation of barriers

Typically screens at the boundaries of construction sites are either specially constructed or formed by other buildings.

For a barrier extending to the ground surface, we must take account of sound reflected by the ground surface in addition to refraction by the barrier. If reflection by the barrier is neglected, we can calculate the excess attenuation of the barrier by considering the paths shown in Figure 4.

Thus

$$\Delta L3 = 10 \log \frac{20N_3 + 20N_4|\dot{R}_2|^2 + 20N_5|\dot{R}_1|^2 + 20N_6|\dot{R}_1|^2|\dot{R}_2|^2}{1 + \left[\frac{r_1}{r_2}|\dot{R}_2|^2 + 2\frac{r_1}{r_2}\cos k\left(r_2 - r_1 + \frac{\alpha}{k}\right)\right]} \quad (8)$$

where $N_i = 2(r_i - r_1)/\lambda$;

r_1, r_2, r_3, r_4, r_5 and r_6 are distances corresponding to paths SR, ST_1R, SOR, SOT_3R and ST_2OT_3R respectively;

k is the wave number and λ is the wavelength.

In equation (8) we have supposed that although sound pressures P_{SR} and P_{ST1R} would add coherently in the absence of the barrier, the paths P_{SOR}, P_{SOT_3R}, P_{ST_2OR} and $P_{ST_2OT_3R}$ resulting from the presence of the barrier should be considered to add incoherently.

Most building may be considered as thick barriers.[5] Here we suggest application of a simple method which calculates the attenuation of an effective thin barrier instead of the attenuation of the thick barrier (Fig. 5).

An example prediction of construction site noise during erection of structural framework is shown in Fig. 6. Four noise sources including two concrete vibrators, two concrete mixers and a circular saw are considered. The concrete mixer and circular saw heights have been assumed to be 1.5m. The vibrators source heights have been assumed to be 0.2m. The predictions have been made for receivers at 1.2m height. Ground effect has been included according to a variable porosity impedance model [4] with effective flow resistivity of 200 000 MKS rayls/m and an effective exponential rate of decrease of porosity of 100/m. This corresponds to a fairly compact soil. The ground has been assumed to be flat. Typically at over 70% of receiver positions the ground effect results in a decrease in levels of between 1 and 4 dB(A) compared with free field values. If the source spectrum has a peak that coincides with a ground effect interference minimum, as is the case for certain positions on the perimeter where the vibrators are the major source, the reduction in level is as high as 5 to 7 dB(A). In a few positions (11%) the ground effect maxima result in enhancement of the "A" weighted noise level up to 4 dB(A) compared with free field levels.

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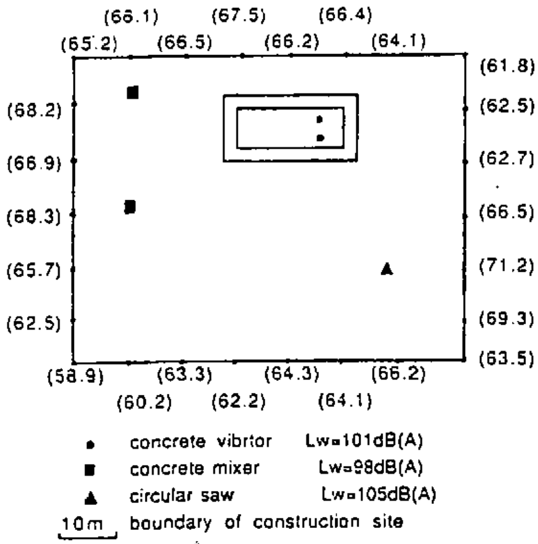

Figure 6. an exampe prediction of noise from construction site during erection of structural framework

5. Conclusion

The prediction, regulation and limits of noise from construction sites should take different phases of construction into account. This paper gives the statistical noise level characteristics and the sound power levels of major sources during four clearly identifiable phases. This together with corrections for distance, ground effect and barriers provides information for predicting and regulation noise from construction sites. In particular ground effect has been shown to be significant and greatly dependent on source spectrum.

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