APPENDIX 9A: INTRODUCTION TO THE PRINCIPLES OF NOISE AND VIBRATION

9A.1 Noise

9A.1.1 Between the quietest audible sound and the loudest tolerable sound, there is a million to one ratio in sound pressure (measured in pascals, Pa). Because of this wide range, a noise level scale based on logarithms is used in noise measurement called the decibel (dB) scale. Audibility of sound covers a range of approximately 0 to 140dB.

9A.1.2 The human ear system does not respond uniformly to sound across the detectable frequency range and consequently instrumentation used to measure noise is weighted to represent the performance of the ear. This is known as the 'A weighting' and annotated as dB L_A.

Table 9.A.1 Sound Pressure Level in dB L_A for Common Situations

Typical Noise Level, dB L_A	Example
0	Threshold of hearing
30	Rural areas at night, still air
40	Public library Refrigerator humming at 2m
50	Quiet office, no machinery Boling kettle at 0.5m
60	Normal conversation
70	Telephone ringing at 2m Vacuum cleaner at 3m
80	General factory noise level
90	Heavy goods vehicle from pavement Powered lawnmower, operator's ear
100	Pneumatic drill at 5m
120	Discotheque – 1m in front of loudspeaker
140	Threshold of pain

9A.1.3 The noise level at a measurement point is rarely steady, even in rural areas, and varies over a range dependent upon the effects of local noise sources. Close to a busy motorway, the noise level may vary over a range of 5dB L_A, whereas in a suburban area this may increase up to 40dB L_A and more due to the multitude of noise sources in such areas (cars, dogs, aircraft etc.) and their variable operation. Furthermore, the range of night-time noise levels will often be smaller and the levels significantly reduced compared to daytime levels. When considering environmental noise, it is necessary to consider how to quantify the existing noise (the ambient noise) to account for these second to second variations.

9A.1.4 A parameter that is widely accepted as reflecting the underlying background noise level is the L_{A90} index. This is the noise level exceeded for 90% of the measurement period and generally reflects the noise level in the lulls between individual noise events. Over a 1-hour period, the L_{A90} will be the noise level exceeded for 54 minutes.

9A.1.5 The equivalent continuous A-weighted sound pressure level, L_{Aeq}, is the single number that represents the total sound energy measured over that period. L_{Aeq} is the sound level of a notionally steady sound having the same energy as a fluctuating sound over a specified measurement period. It is commonly used to describe environmental noise from individual sources that vary in level over their operational cycle.

9A.1.6 The index historically adopted by the government since the early 1970s to assess road traffic noise is the L_{A10}. This is the noise level exceeded for 10% of the measurement time, over a 1-hour period the L_{A10} will be the noise level exceeded for 6 minutes.

9A.1.7 Time weighting determines how quickly the sound level meter responds to changes in noise level. The ‘fast’ time weighting averages the measured level every eighth of a second, whereas the ‘slow’ weighting averages every one second. The ‘fast’ time weighting most closely follows the response of the human ear to sound level changes and is most commonly specified for environmental noise measurement purposes (including the L_{A10} and L_{A90} statistical parameters).

9A.1.8 Most environmental noise measurements and assessments are undertaken in ‘free-field’, away from any existing reflecting surfaces (other than the ground). However, it is sometimes necessary to consider noise levels immediately external to a façade when considering the impact on residents inside properties and this normally requires the addition of up to 3dB L_A to the predicted (or measured) free-field level due to noise reflection from the façade. The assessment of road traffic noise in the UK, for example, is based on a predicted (or measured) ‘façade’ noise level (using the L_{A10} statistical parameter).

9A.1.9 Human subjects, under laboratory conditions, are generally only capable of noticing changes in steady levels of 3dB L_A or more (PPG 24, 1994 (Ref. 9.5)). It is generally accepted that a change of 10dB L_A in an overall, steady noise level is perceived to the human ear as a doubling (or halving) of the noise level (PPG 24, 1994 (Ref 9.5)). These findings do not necessarily apply to transient, non-steady or intermittent noise sources.

9A.2 Vibration

9A.2.1 When an object is in contact with a vibrating surface it is displaced about its reference (stationary) position. Displacement (in mm) is therefore one parameter that can be used to describe the magnitude of a vibration. For sinusoidal signals, displacement, velocity (m/s) and acceleration (m/s^2) amplitudes are related mathematically by a function of frequency and time. If phase is neglected (as is always the case when making time-average measurements), then the velocity can be obtained by dividing the acceleration signal by a factor proportional to frequency (measured in Hertz, Hz) and the displacement can then be obtained by dividing the acceleration signal by a factor proportional to the square of frequency.

9A.2.2 For a complex acceleration signal giving rise to a complicated time history, there are several additional quantities that may be used to describe the vibration:

9A.2.3 The root mean square value (rms) is obtained by taking the square root of the mean of the sum of the squares of the instantaneous acceleration measured during the total measurement time (T);

9A.2.4 The peak value is the maximum instantaneous acceleration measured during the measurement time, (T). It is a useful indicator of the magnitude of short duration shocks; and

9A.2.5 The Peak Particle Velocity (PPV) is the maximum instantaneous velocity of a particle at a point during a given time interval.

9A.2.6 The limit of human perception to vibration is of the order of 0.15mm/s to 0.3mm/s PPV, in the frequency range 0.1Hz to 1500Hz. The human body is not equally sensitive to all frequencies of vibration and weighting curves to reflect the frequency dependency of the body have been developed and are contained within International Organisation of Standardisation (ISO) Standards. The weighting gives a good correlation between the measured vibration level and the subjective feeling or impact produced by the vibration.

9A.2.7 The weightings can be incorporated into modern vibration meters, thus enabling measurement of vibration levels that correspond to human perception. Those vibrations occurring between 1-80Hz are of particular interest when measuring exposure to whole-body vibration.

9A.2.8 Sensitivity to vibration is also known to be dependent on the direction of excitation and the human body responds differently when standing (longitudinal) compared to when lying down (lateral). Whole-body vibrations are measured in the directions of an orthogonal co-ordinate system having its origins at the location of the heart and day and night-time assessment routines differ to account for longitudinal (daytime) body position and lateral (night-time) body position.

9A.2.9 Vibration-induced damage to buildings can arise in different ways, making it difficult to arrive at universal criteria that will adequately and simply indicate damage risk. Damage can occur directly due to high dynamic stresses, due to accelerated ageing or indirectly when high quasi-static stresses are induced by, for example, soil compaction.

9A.2.10 Figure B.1 of British Standard BS 5228: 2009 'Code of practice for noise and vibration control on construction and open sites', Part 2. 'Vibration' (Ref. 9.14) indicates, for example, that for a residential building (line 2) a PPV of greater than 15mm/s at 4Hz or greater than 50mm/s at 40Hz or above, measured at the base of the building, may be expected to result in cosmetic damage.

9A.2.11 However, buildings are reasonably resilient to ground-borne vibration and vibration-induced damage is rare; there are less than 12 confirmed instances of vibration-induced damage to buildings in the UK over the last 10 years.