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RELATIVE INFLUENCE OF NOISE AND WHOLE BODY VIBRATION ON THE RESPONSE OF HUMANS

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INTRODUCTION

In the assessment of human response to combined effects of noise and vibration these aspects are often investigated separately and independent conclusions drawn. A method for assessment of human response to combined noise and vibration is presented in this paper which also includes guidance on the application of the method to particular situations and provides details of a number of case studies.

ASSESSMENT CATEGORIES AND EVENT TYPES

For users of buildings and structures, apart from those who seek enjoy -ment from noise and mechanical vibration, the human response to noise and vibration may be divided into four categories namely:-
a) basic threshold effects; b) intrusion, alarm and fear which may be associated with minor or major adverse comment; c) interference with activities; d) possibility of injury or health risk. The criterion for the lower boundary of category d) is the requirement for provision of restraint harness or hand holds to reduce the risk of injury to personnel caused by mechanical vibration or the necessity for ear protection to avoid damage to hearing.

Probable human response to noise and vibration in categories a), b) and c) above is assessed in terms of the form of occurrence as:-
A. steady environment; B. impulsive events; C. infrequent storm action.

HUMAN RESPONSE ASSESSMENT PROCEDURES FOR NOISE AND VIBRATION COMBINED

A. Steady Environment

i) Measure or calculate the frequencies and magnitudes of the acceleration components, the noise level and predominant frequency range.
ii) Where ax and ay are orthogonal horizontal translational acceleration components in m/s^2 rms, sum these vectorially, taking account of phase, to obtain parameter ah.

iii) Evaluate $a\theta h = ah + r.a\theta$ .... [1] where $a\theta$=yaw acceleration in radians/s^2rms; $r=|1/f\theta-0.57/f\theta|+0.2(1-0.8/\sqrt{f\theta})$ .... [2] ; $f\theta$=yaw frequency.
iv) Obtain N from Fig.2 at the noise frequency fN and appropriate noise level dBA. Compute $aN = N.S$ .... [3] where $S=0.001(1/(3fv)+\sqrt{fv})$ · [4] $fv=(fx+fy+fz+f\theta)/4$ .... [5] for 'f' of the same order.
v) Evaluate $ab = \sqrt{az^2 + aN^2 + 2.a\theta h^2}$ .... [6] .
vi) Compare ab from [6] to the appropriate 'as' value from Fig.3 at frequency fv and the curve corresponding to the multiplier chosen from column 3 in Table 1. If 'ab' is less than 'as', the satisfactory magnitude, then probably the great majority of an average population would find the environment to be satisfactory.

B. Impulsive Events

For impulsive events and other relatively isolated events, each of duration less than 60 seconds, where noise and mechanical vibrations are of predominantly sinusoidal form then follow the procedure steps i) to v) above and compare 'ab' at 'fv' to the curve value 'as' in Fig.3, when the appropriate multiplier taken from column 4 of Table 1 is 1 or 1.4. If the appropriate multiplier from column 4 of Table 1 is 20, 60, 90 or 128 then compare 'ab' to 'as' from: $as=\sqrt[4]{C/t}$ .... [7] where C= value from Table 2 and t= sum of the durations of impulsive events, above a base of curves 4 in Fig. 3, taken over a 16 hour day. When 'ab' is less than 'as' then only minor adverse comment would normally be generated by such events, especially if prior warning is given.

If an impulsive event produces predominantly non-sinusoidal motion, with or without accompanying sound waves, then proceed as follows: 1. Evaluate 'Vv', the peak velocity and assess the frequency range for 'fv' from the form of the decay signal. 2. Obtain 'N' from Fig.2 and evaluate $VN = N.S/(\pi fv\sqrt{2})$ ... [8] 3. Compute $Vb = \sqrt{VN^2 + Vv^2}$ .... [9] 4. Compare 'Vb' with $Vs = \sqrt[4]{C/t}/(\pi fv\sqrt{2})$ .... [10] with C, t as above.

C. Infrequent Storm Action

When noise and mechanical vibration result from infrequent storm action then the probable response of a population can be assessed as follows: 1) Measure or calculate the motion frequencies and the average rms acceleration components for the worst consecutive 10 minutes of the worst wind storm for the region and return period under consideration. 2) Evaluate 'ah' as in Aii) where 'ax' and 'ay' are in a narrow band or at a discrete frequency. 3) If yaw motion is present within the frequency band then evaluate '$a\theta h$' as in Aiii). 4) For the same part of the storm as used in 1) above, evaluate 'N' from Fig.2 and 'aN' as in Aiv) and using 'fv' from [12]. 5) Compute $ab = a\theta h + aN$ .... [11] . 6) Compare 'ab' from [11] with the appropriate 'as' value from the curve in Fig.3 corresponding to the multiplier chosen from Table 3 and at frequency $fv=(fx+fy+f\theta)/3$ for 'f' of the same order [12]. The curve chosen to obtain the 'as' value depends upon the population type (average or trained personnel), the storm return period (1 or 5 years say) and the level of adverse comment considered satisfactory for the structure use. The adverse comment levels of Table 3 are for those parts of the structure most affected by the storm.

REFERENCES

A W Irwin 1981 Jnl Sound & Vibration, 76(4),481-497. Perception,comfort and performance criteria for human beings exposed to whole body pure yaw vibration and vibration containing yaw and translational components.
M J Griffin & E M Whitman 1980 Jnl Acoust. Soc. Am. 68(5). Discomfort produced by impulsive whole-body vibration.

Place	Time	Steady Environment	Impulsive Events
Critical Area	Any	1	1
Residential	Day Night	2 to 4 1.4	60 to 90* 20
Office	Any	4	128*
Workshop	Any	8	128*

*with prior warning.

Table 1 Satisfactory environment multipliers above base curve.

Table 1 multiplier	Constant C
20	1.0×10^{-5}
60	8.1×10^{-4}
90	4.1×10^{-3}
128	1.7×10^{-2}

Table 2 Values of C for use with equations [7] and [10]

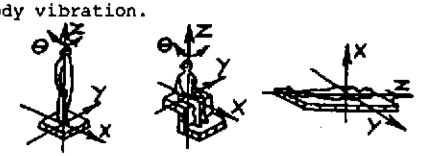

Fig.1 Directions of coordinate systems

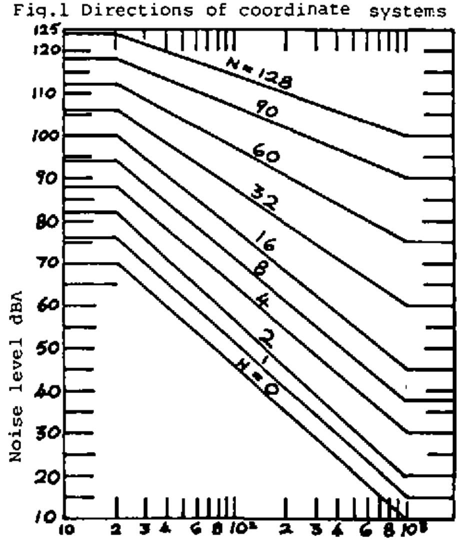

Fig.2 N factor curves for noise

Application	Buildings			Offshore or Utility structures			
Curve	C1	C2		C3	C4		C5
Return period in years	1	5	1	1	5	1	----
% adverse comment	2	2	12	2	2	12	hand holds or restraint harness required

Table 3 Max 10 min storm magnitude curves and adverse comment levels

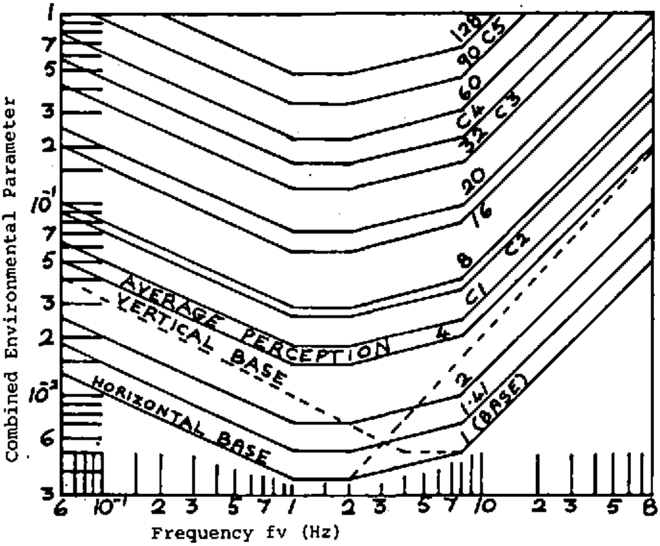

Fig.3 Curves of environment assessment values

CASE STUDY EXAMPLES

a. Office building - satisfactory to users. az=.01m/s^{2}rms, fz=4.0 Hz. 70dBA, range 80 Hz. N=4, aN=.0833. ab=.013. Table 1 column 3 factor is 4; curve 4, Fig.3 at 4.0 Hz, as=.017>ab. b. Mill structure - high com -plaint level even with ear protectors. az=.58m/s^{2}rms at 3.3Hz,ax=.0669 m/s^{2}rms at 2.9Hz,ay=.14m/s^{2}rms at 3.2Hz. ah=.155m/s rms. fv=3.13Hz. 95dBA at 100Hz. N=80, aN=.15. ab=.638. Fig.3 curve 8 at 3.13 Hz,as=.03 <<ab. c. Multi-storey factory - fairly high complaint level from occu -pants, fear induced in visitors. ax=.152m/s^{2}rms at 3.3Hz. 75dBA at 70Hz. N=8, aN=.0153. ab=.216. Fig.3 curve 8 at 3.3Hz, as=.03<ab.
d. Building, average population - 5 year return wind storm - some adverse comment. ax=.02m/s^{2}rms at 1.2Hz, ay=.005m/s^{2}rms at 0.7Hz, aθ=.015 rad/s^{2}rms at 0.8Hz for worst 10 consecutive minutes of storm peak. aθh=.0255+.0092=.0347. 70dBA at 80Hz. N=5.5, aN=.00725 for fv=0.9Hz. ab=.04195. Curve C2, Fig.3 at 0.9Hz, as=.03 slightly lower than ab.
- 3 blasts each 0.1s in one day - prior warning - satisfactory. 105dBA at <20Hz, N=30, aN=.121. az=.16m/s^{2}rms at 16Hz. ab=.20. C=.0041 from Table 2 and as=.342 from [7]. as>ab. e. Factory building - 4 non-sinusoidal pulses in one day - some adverse comment. Peak velocit=8.73 x10^{-3}m/s decaying at fz=22Hz. Duration of each impulse above curve 4, Fig.3 is 0.17s. 108dBA at ≃18Hz, N=40, VN=.00192 from 4 and [8]. From [9] Vb=8.94x10^{-3}. Table 2, C=.017 using [10] and fv=22Hz, Vs=4.372x10^{-3}<Vb.