THE PLANNING GUIDELINES FOR VIBRATION LIMITS AND CONTROL

Department of the Environment, Malaysia 2004

PLANNING GUIDELINES FOR VIBRATION LIMITS AND CONTROL IN THE ENVIRONMENT

Contents

Scope

1. This document presents guidance and recommendations for

(a) specifying vibration limits in the environment, including buildings, for the protection of the public from excessive vibration;
(b) procedures for environmental vibration measurements and impact assessment;
(c) vibration parameters for the assessment of different vibration sources; and
(d) abatement of excessive vibration through planning and control.

For the purpose of these Guidelines, definitions used are consistent with those given in ISO 2631, BS 6472 and DIN 4150. A glossary of definitions is also included in this document.

2. These guidelines present vibration acceptance criteria upon which a quantitative assessment of vibration could be made. This eliminates subjective judgment of parties involved, ambiguity in defining a disturbance, and places the assessment of a vibration source on a measurement basis.

Purpose

3. The purposes of these guidelines are:

(a) for planning purposes, typically by project proponents, local authorities, and consultants;
(b) to be used in vibration impact assessments, and pre- and post EIA compliance verification;
(c) in quantifying a vibration disturbance on a quantitative manner; and
(d) to offer an introductory treatise in environmental vibration control.

Legislative Background

4. The Environmental Quality Act 1974 in principle allows the Minister after consultation with the Environmental Quality Council, to define objectionable vibration and to prescribe standards for tolerable vibration. The Environmental Quality (Amendment) Act 1985 makes it mandatory for an Environmental Impact Assessment (EIA) on various activities scheduled by the Minister. Approval of such EIA and the projects in particular when appropriate may include maximum permissible vibration limits at affected receptors that must be complied with during the construction phase of the project, and upon completion of the project.

5. The Department of Environment in these guidelines present recommendations upon which acceptable vibration limits could be specified. In instances of new vibration sources or projects, compliance to these limits may be made mandatory using legislative instruments available to the Department of Environment, and other authorities (Local Authorities, City Halls, etc).

6. There are no prior guidelines for vibration stipulated by the Department of Environment. These Guidelines are intended to present a comprehensive and unambiguous manner upon which vibration could be measured and assessed against the prescribed standards for all applications.

Vibration Limits

7. Vibration limits may be set based on either of the following vibration parameter:

(a) an absolute limit based on the vibration in a particular designated direction which should not be exceeded;

(b) an absolute limit based on the vectorial sum of instantaneous vibration in three orthogonal axes (termed the peak particle velocity of

the vibration) which should not be exceeded.

The governing limits are depended on the repetitive nature and duration of the vibration (continuous, short term or single event).

8. For human response and annoyance evaluation, limits may be set for different period of the day (day and night).

9. It is often necessary to establish by measurements the existing ambient vibration levels in the absence of the offending source; and the contribution and severity of the offending source could be assessed with certainty against the existing ambient conditions.

10. Vibration acceptance could be assessed against the following criteria:

(a) potential structural damage in buildings;

(b) human response and annoyance; and

(c) re-radiated structure-borne noise.

Recommended vibration limits to minimize structural damage risk in buildings, and for human response and annoyance assessment are given in Annex A of these Guidelines.

11. Structural damage from vibration are inter-related and inter-dependent on numerous factors. These include, but are not limited to, factors related to structural design and integrity of the building, materials, quality of construction and workmanship, age of building, forcing frequency content, duration and amplitude of the vibration source. There is a statistical probability relating to potential structural damage. The recommended limits do not guarantee absence of damage, but reduce its probability of occurrence. The vibration limits as prescribed in these Guidelines are therefore offered as guidance only.

12. Schedule 1 prescribes recommended limits (vibration velocity peak levels in the frequency range 10 to 100 Hz) for potential structural damage in buildings from steady state vibrations.

13. Under normal circumstances, steady state vibration should not exceed the upper limit defined as "caution level" in Schedule 1.

14. Vibration level exceeding limits for "major damage" as prescribed in Schedule 1 is usually an issue of serious concern where structural damage may be likely.

15. Recommended limits for short-term vibrations (as measured at foundation or plane of floor slabs), as classified in accordance to the type of structure are given in Schedule 2.

16. Recommended limits for peak particle velocity for ground vibration from single event impulsive excitation (such as blasting and explosion) not exceeding 3 occurrences per day are given in Schedule 3.

17. Schedule 4 stipulates acceptable road traffic induced vibration in buildings, based on types of building foundation.

18. Recommended vibration limits for human response and annoyance for steady state continuous vibration and short-term within building are given in Schedule 5, and Schedule 6 respectively. These limits are categorised according to receiving land use and period of the day. These limits are based on multipliers of the human perception threshold (designated as "Curve 1" as defined in ISO 2631 and BS 6472).

Vibration Measurements

19. Measurements of vibration are often necessary for any of the following purpose:

(a) assessing the existing vibration climate;

(b) assessing compliance to vibration limits for vibration generation source(s) and/or project development; or

(c) assessing environmental impact and potential community response.

20. Vibration measurements shall usually include the following:

(a) background (ambient) vibration levels at a receiver location(s) and/or at the real property boundary of a source(s). These may be undertaken at locations prior to a project development. It could also be undertaken in the absence of the source(s) operating (for example with a plant not operating, or without construction activities).

(b) vibration levels at a receiver location(s) and/or at the real property boundary of a source with the plant operating, construction in progress, and/or completion and operation of a project (transit trains, industrial plant, etc.).

(c) vibration characteristics of each source as may be required to evaluate the contribution of each source.

21. Vibration measured indoors may be undertaken outdoors or indoors on building floor slabs or foundation as the case may be.

22. Procedures for measurement of vibration in the environment and vibration source(s) severity assessment as described in Annex B shall be used. Guidance on the use and selection of an appropriate vibration measurement parameter and sampling methods are also given in Annex B.

Monitoring point(s)

23. The vibration assessment should normally be at the nearest building and/or locations; and the best position for the monitoring point(s) would often be on the floor slab or foundation. Monitoring points should be accessible to all parties concerned.

Vibration Severity and Impact Assessment

24. Vibration could be assessed against an absolute numerical vibration limit (as proposed in the Schedules of Annex A), and/or assessed based on the increase of the vibration levels with respect to the ambient level without the offending source.

25. Assessment of vibration levels against an acceptance limit is fairly straight forward, as it merely requires comparison of the measured level against the permissible levels.

26. Further guidance is given in BS 6472: 1992 (Appendix A) on human response and annoyance for different receivers and duration of vibration exposure.

27. Buildings which exhibit evidence of threshold damage (defined as visible cracking in non-structural members) as a result of excessive vibration should be investigated. These could include building structural inspection, and vibration monitoring if this damage is suspected to be vibration induced.

28. In the event of vibration levels exceeding the minor or major damage limits for potential structural damage to buildings as prescribed in Schedule 1 of Annex A, further investigations, which include the determination and evaluation of stresses in building structural members, and long term structural integrity monitoring, should be undertaken. The reduction of the vibration generation or origin at source may also be necessary.

Vibration and Planning

29. The impact of vibration should be considered in the planning of a project development; and in general be guided by these Guidelines.

For the purpose of the consideration of vibration in planning, the following information may reasonably require:

(i) the existing vibration levels in the community, including identification of

the major sources of vibration generation.

(ii) any projected or proposed new or expanded sources of vibration which may affect exposure of the site.

(iii) where applicable, plans for vibration reduction measures.

30. The Project Proponent and any other Person(s) who would operate or cause to operate equipment, plant, process or activity with vibration generation should undertake all reasonable measures to control the source of, or limit exposure to vibration. Such measures should be proportionate and reasonable, and may include one or more of the following:

(a) Layout: adequate distance between source and vibration-sensitive neighbours, building or area. The usage and designation of buffer zones shall be in accordance to guidelines issued by the Department of Environment from time to time;

(b) Engineering measures: reduction of vibration at point of generation with the use of alternative methods, reduction of energy input for impactive activities, containment of vibration generated, and protection of adjacent vibration sensitive buildings by appropriate engineering measures; and

(c) Administrative measures: limiting the operating time of vibration source(s); restricting the activities and ensuring acceptable vibration generation limits of vibration source.

31. The Project Proponent and/or parties who undertakes construction, piling, drilling, excavation, demolition works, blasting and other construction related activities shall be required to inform the local authority in good time the nature of the proposed works and method statements to ensure that excessive vibration are not generated.

32. Person(s) responsible for the development, and operations of roads and highways should undertake all reasonable precautionary mitigation measures such that road traffic induced vibrations within buildings are not to exceed acceptable levels as prescribed in Schedule 4 of Annex A.

Vibration Reduction

33. The Project Proponent, and/or occupier of any industrial or construction sites, and/or person(s) responsible for excessive vibration generation should use the "best practical means" to minimise the vibration generation and reduce its propagation to the environment.

Excessive vibration generation is deemed to occur when vibration levels above the recommended vibration limits as prescribed in these Guidelines are exceeded. "Best practical means" in the context of these Guidelines, should include but not limited to:

(i) the size, design and inherent operation characteristics of the device, plant, process or activity;

(ii) the adjustment of operational parameters including reduction of energy input (per blow or cycle for piling for example) to limit the intensity of vibration generation;

(iii) the selection and usage of alternative methods with low vibration generation;

(iv) the provision of and appropriate use of vibration isolators, and attenuation dampers;

(v) the provision if necessary and appropriate use of vibration transmission structural breaks;

(vi) the proper conduct and adequate supervision of operation; and

(vii) regular and efficient maintenance of plant and control equipment.

34. In instances of excessive vibration severity, the Department of Environment at its discretion may make it mandatory for the Project Proponent and/or vibration source originator or person(s) responsible for the excessive vibration generation to institute measures for reducing vibration levels to comply with recommended limits as prescribed in these Guidelines.

GLOSSARY

"**community**" means the body of people gathered or living in the same locality.

"**impulsive vibration excitation**" means vibration which has a rapid build-up to a peak followed by a damped decay which may or may not involve several cycle of vibration, and is generally associated with single event occurrence such as blasting and explosions.

"**local authority**" means the local planning authorities or agents of the State as defined in the Town and Country Planning Act, 1976 and such rules, regulations and by-laws made there under. For the purpose of these Regulations, this shall include City Halls, City Councils, Municipal Councils, Town Councils and District Councils.

"**major damage**" means serious weakening of the structure with large cracks or shifting of foundations, bearing walls, or major settlement resulting in distortion or weakening of the superstructure.

"**real property boundary**" means an imaginary line along the ground surface, and its vertical extension, which separates the real property owned by one person from that owned by another person, but not including intra-building real property divisions, as delineated in the land title appearing in the Certificate of Title.

"**residential area**" means a designated area as gazetted by the local authority for the purpose of human dwellings and residence.

"**short term vibration**" means a vibration which is impulsive or transient in nature but are repeated periodically (but not necessarily at equal time period) over a duration of time, and is generally associated with repetitive impactive events such as piling and hammer blows.

"**steady state vibration**" means a vibration which continues uninterrupted for a period of time of assessment.

"**threshold damage**" means visible cracking in non-structural members such as partitions, facings and plaster walls.

"**vibration**" means an oscillatory motion of solid bodies of deterministic or random nature described by displacement, velocity, or acceleration with respect to a given reference point.

"**vibration perception threshold**" means the minimum ground-or structure-borne vibrational motion necessary to cause a normal person to be aware of the vibration by such direct means as, but not limited, sensation by touch or visual observation of moving objects.

"**vibration sensitive area**" means area where the absence of vibration is deemed necessary for the functional usage of the space, with requirements for the vibration level to be significantly below the human vibration perception threshold. These spaces include but are not limited to hospitals, operating theatres, precision laboratories, residential dwellings.

"**vibration velocity** v_i" means the vectorial sum of the instantaneous values of the vibration velocity in the three axis (x, y, z). This is computed from $v_i = \sqrt{(v_x^2+v_y^2+v_z^2)}$.

"**x axis**" means the orthogonal axis in the forward facing direction of a building or standing person.

"**y axis**" means the orthogonal axis in the transverse direction (at right angle to the x axis) of a building or standing person.

"**z axis**" means the orthogonal axis in the vertical direction (orthogonal to the floor plane containing the x and y axes) of a building or standing person.

ANNEX A

SCHEDULE OF RECOMMENDED VIBRATION LIMITS

SCHEDULE 1

RECOMMENDED LIMITS FOR DAMAGE RISK IN BUILDINGS FROM STEADY STATE VIBRATION

Damage Description	Vertical Vibration Peak Velocity v_{max}, mm/s (0 to Peak) (10 -100 Hz)
Safe	Less Than 3
Caution Level (Damage Not Necessary Inevitable)	3 to 5
Minor Damage	5 to 30
Major Damage	More Than 30

(Source: ISO DP 4688: 1975)

SCHEDULE 2

RECOMMENDED LIMITS FOR DAMAGE RISK IN BUILDINGS FROM SHORT TERM VIBRATION

Type of Structure	Vibration Velocity v_i [mm/s] at foundation (as defined by the respective rating curves of Figure 1)	Vibration Velocity v_i [mm/s] at plane of floor of uppermost full storey (all frequencies)
Industrial buildings and buildings of similar design	Curve C	40
Commercial building, dwelling and buildings of similar design and/or use	Curve B	15
Structures that, because of their particular sensitivity to vibration, do not correspond to those listed above, or of great intrinsic value (e.g. residential houses, or buildings that are under preservation order)	Curve A	8

(Source: DIN 4150/3)

SCHEDULE 3

RECOMMENDED LIMITS FOR DAMAGE RISK IN BUILDINGS FROM SINGLE EVENT IMPULSIVE EXCITATION *

Type of Structure	**Ground Vibration Peak Particle Velocity v_{max} [mm/s]**	
	At low frequency < 40 Hz	***At high frequency >40 HZ***
Industrial buildings and buildings of similar design	40	50
Commercial building, dwelling and buildings of similar design and/or use	20	50
Structures that, because of their particular sensitivity to vibration, do not correspond to those listed above, or of great intrinsic value (e.g. residential buildings, or buildings that are under preservation order)	12	50

* Single event impulsive excitation not exceeding 3 occurrences per day.

(Adapted from DIN 4150/3, and Swiss Standard for Vibration Damage to Buildings).

SCHEDULE 4

ACCEPTABLE ROAD TRAFFIC INDUCED VIBRATIONS IN BUILDINGS

Type of Building and Foundation	Recommended Vertical Velocity Limit, v_{max} [mm/s]
- Especially sensitive buildings, and buildings of cultural and historical value	1
- Newly built buildings, and/or foundation of a foot plate (spread footings)	2
- Buildings on cohesion piles	3
- Building on bearing piles or friction piles	5

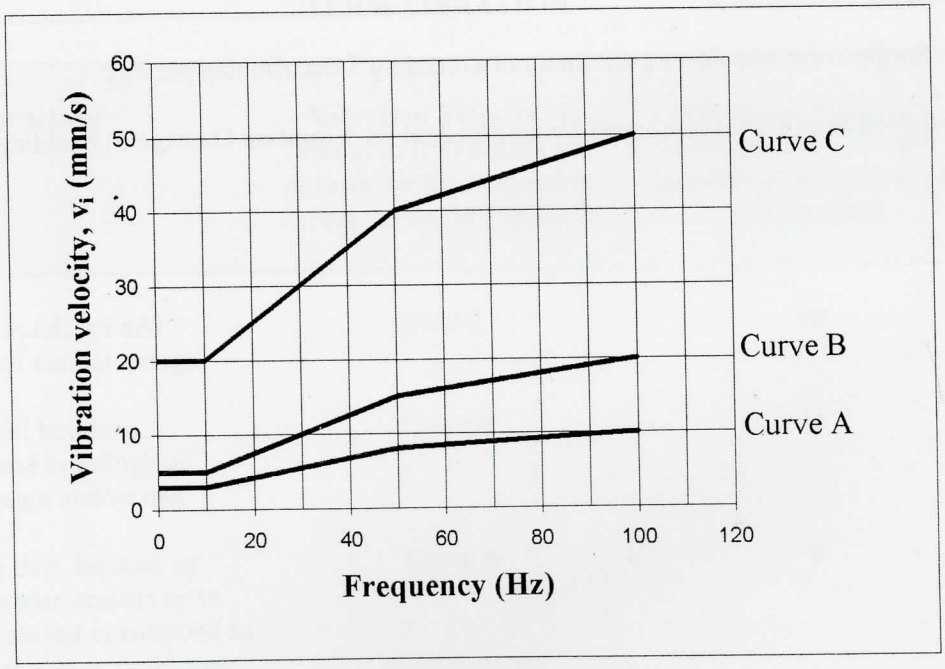

FIGURE 1
Foundation Vibration Velocity Limiting Values for Vectorial Sum of Vibration Levels in Three Orthogonal Axes.

SCHEDULE 5

RECOMMENDED LIMITS FOR HUMAN RESPONSE AND ANNOYANCE FROM STEADY STATE VIBRATIONS

Receiving Land Use Category	Day Time 7.00 am - 10.00 pm	Night Time 10.00 pm - 7.00 am
Vibration Sensitive Areas	Curve 1	Curve 1
Residential	Curve 2 to Curve 4	Curve 2
Commercial, Business	Curve 4 to Curve 8	Curve 4
Industrial	Curve 8 to Curve 16	Curve 8 to Curve 16

SCHEDULE 6

RECOMMENDED LIMITS FOR HUMAN RESPONSE AND ANNOYANCE FROM SHORT TERM VIBRATIONS

Receiving Land Use Category	Day Time 7.00 am - 10.00 pm	Night Time 10.00 pm - 7.00 am
Vibration Sensitive Areas	Curve 1	Curve 1
Residential	Curve 8 to Curve 16	Curve 4
Commercial, Business	Curve 16 to Curve 20	Curve 16 to Curve 20
Industrial	Curve 32	Curve 32

The above stipulated curves are defined in Figure 2 and 3. The base Curve 1 is based on the vibration perception threshold for human response as defined by BS 6472:1992 and ISO 2631. The designated numbers of subsequent curves are multiplying factors of the base curve. (Source: ISO 2631 and BS 6472)

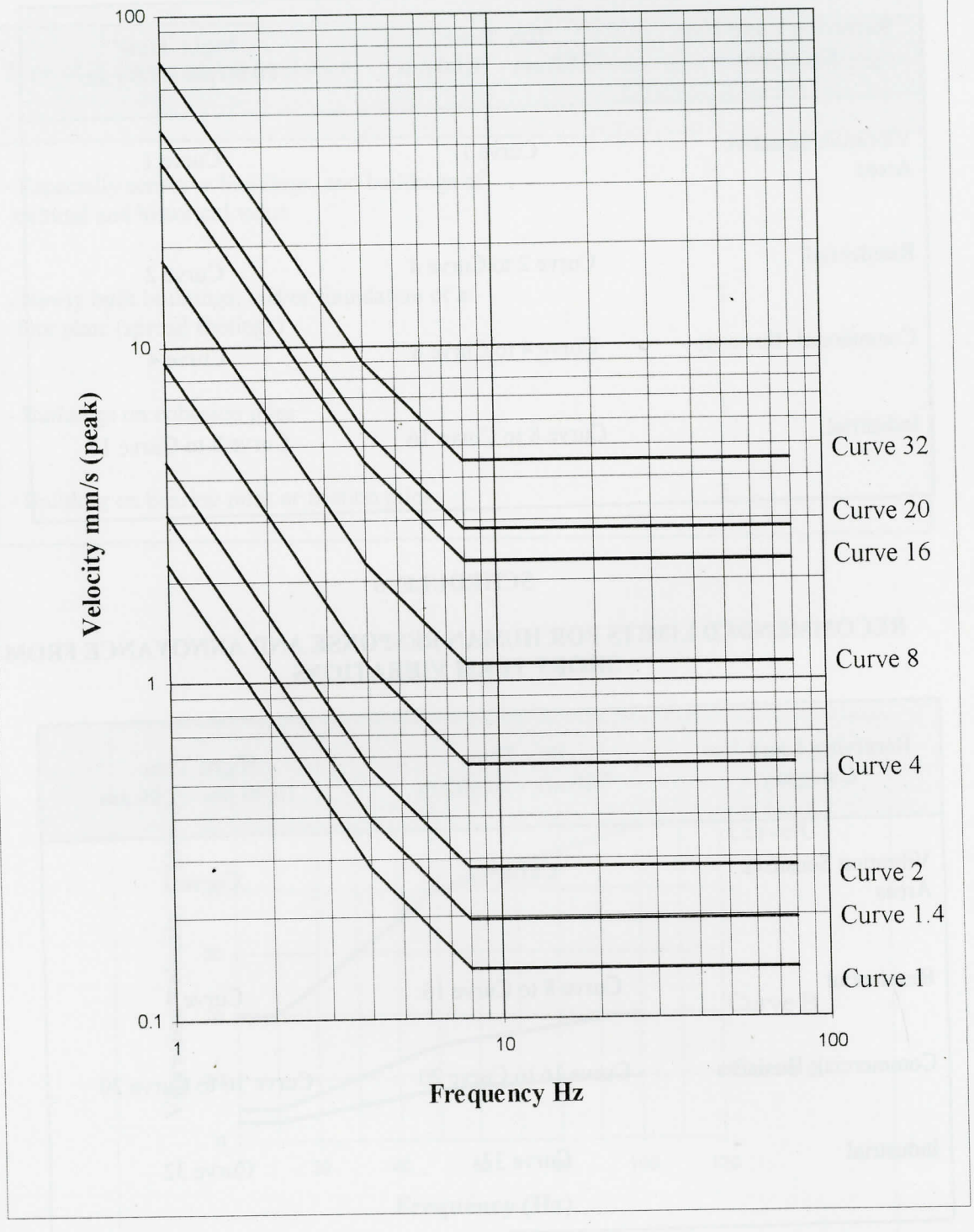

FIGURE 2. Building vibration z-axis curves for peak velocity

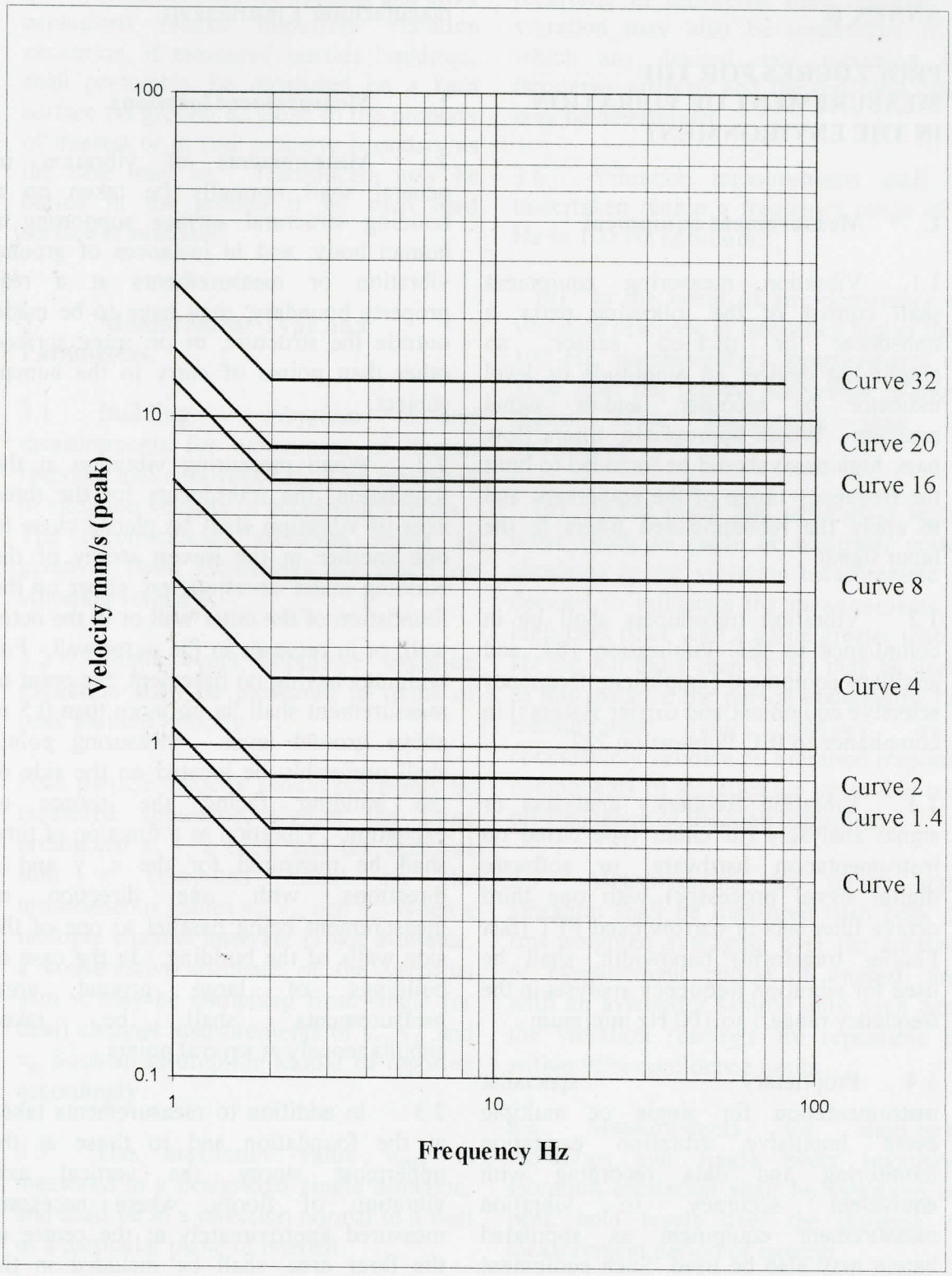

FIGURE 3. Building vibration x- and y-axis curves for peak velocity

ANNEX B

PROCEDURES FOR THE MEASUREMENT OF VIBRATION IN THE ENVIRONMENT

1. Measurement equipment

1.1 Vibration measuring equipment shall consist of the following parts: a transducer or pick-up sensor, an amplifying device, an amplitude or level indicator or recorder, and/or signal analyser. Where appropriate, filters (low pass, high pass) should be included to limit the frequency range of the equipment and to apply the recommended filters to the input signal.

1.2 Vibration transducers shall be in compliance to IEC Publication 184, and auxiliary equipment (amplifiers, frequency selective equipment and carrier systems) in compliance to IEC Publication 222.

1.3 Vibration frequency analysers or signal analysers (of either type based on instrumentation hardware, or software digital signal processor) with one third octave filter sets or narrow band FFT (fast Fourier transform) bandwidth, shall be used for vibration frequency analysis in the frequency range 1 to 100 Hz minimum.

1.4 Proprietary specialist instrumentation for single or multiple event impulsive vibration excitation monitoring and data recording with equivalent accuracy to vibration measurement equipment as stipulated herein may also be used. Such equipment shall be used in accordance to the manufacturer's instructions.

1.5 All vibration measuring equipment shall be properly calibrated in accordance with current standards and thereafter, or recommendations governing the calibration of such equipment in accordance to the equipment manufacturer's instructions.

2. Measurement locations.

2.1 Measurements of vibration in general shall normally be taken on a building structural surface supporting a human body; and in instances of ground vibration or measurements at a real property boundary, may have to be made outside the structure, or on some surface other than points of entry to the human subject.

2.2 When measuring vibration at the foundation, the transducers for the three axes of vibration shall be placed close to one another in the lowest storey of the building under investigation, either on the foundation of the outer wall or in the outer wall, or in recesses in the outer wall. For buildings having no basement, the point of measurement shall lie no more than 0.5 m above ground level. Measuring points shall preferably be located on the side of the building facing the source of excitation. Vibration as a function of time shall be measured for the x, y and z directions, with one direction of measurement being parallel to one of the side walls of the building. In the case of buildings of large ground area, measurements shall be taken simultaneously at several points.

2.3 In addition to measurements taken at the foundation and to those at the uppermost storey, the vertical axis vibration of floors, where necessary measured approximately at the centre of the floor area, shall be included in the evaluation.

2.4 When measuring the x and y axes vibration of the floor of the uppermost full storey, the transducers shall be placed in, or close to, the outer masonry. They shall be set up in the x and y directions; one direction of measurement shall be parallel to one of the side walls of the building.

2.5 Measurement for blasting and other explosions related impulsive vibration excitation, if measured outside buildings, shall preferably be measured on a hard surface on ground as close to the property of interest or at real property boundary as the case may be. Transducers may be buried in the ground if no such hard surface is available.

3. Measurement Type and Parameters.

3.1 Building vibration, and measurements for assessment of human response and annoyance shall be measured in vibration velocity or acceleration terms. The recommended vibration limits as given in these Guidelines are based on vibration velocity.

3.2 Single event impulsive vibration excitation shall be measured in terms of peak particle velocity.

Peak particle velocity should preferably be measured simultaneously in the three orthogonal x, y, z axes; and the vectorial sum v_i computed based on the instantaneous values v_x, v_y, and v_z. When a multiple channel analyzer is not available, a conservative estimate of the vectorial sum v_i may be computed from single (or dual) channel measurements of v_x, v_y, and v_z. Such an assumption should be reported accordingly.

3.3 The maximum value v_{max} is measured in a designated single direction, and shall be in a direction normal to a wall or a particular plane of interest.

3.4 Real time frequency domain measurements (in one third octaves or narrow bandwidth) may be undertaken to obtain the vibration frequency spectrum for evaluation in accordance to these Guidelines.

3.5 Measurements and/or data recording of unfiltered time histories of vibration may also be undertaken from which any desired data reduction for frequency analysis and the rms total value may be determined.

3.6 Vibration measurements shall be undertaken within a frequency range of 1 Hz to 100 Hz minimum.

(a) In the event of any occurrence of vibration response at frequency higher than 100 Hz, supplementary measurements up to at least the second harmonics of these higher order frequencies shall be undertaken.

(b) In the event that extraneous signal noise (such as cable or electrical noise) unrelated to the vibration measurement is deemed to influence the measurements, a high-pass filter with a value greater than 1 Hz but not more than 10 Hz may be used. In this instance the person undertaking the measurement and analysis must conclusively validate no vibration response components of significance up to this cut-off frequency of the high pass filter.

3.7 Measurements for steady state vibration shall be measured with peak or rms-weighted averaging over the duration of measurement period of interest, and with an averaging sample until such time the vibration readings are repeatable to within 95% confidence limits.

3.8 Measurements for short-term vibrations and single event impulsive vibration excitation shall be measured on peak hold levels over the duration of measurement period of interest.

4. Period of measurement.

4.1 Measurements in general shall be undertaken over the duration of operation of the device(s), process or activity which results in vibration generation to obtain a

fair representation and record keeping of actual vibrations generated.

4.2 In instances of vibration monitoring for potential structure damage concern in buildings, and for compliance record keeping arising from construction, maintenance, demolition or excavation works, and blasting, the measurement should be continuous or reported over regular period the entire duration of these activities. A time chart recording for this period is recommended.

Monitoring prior to the commencement of these activities is also required to establish existing ambient levels.

4.3 Hourly measurements of not less than 20 minutes sampling repeated over the entire day (daytime and night time) for human annoyance and response shall be acceptable for initial screening of vibration annoyance. The sampling must however include period(s) of vibration generation activities.

Continuous monitoring over a complete 24-hour cycle may be required in the event that human annoyance and response are of concern, and for confirmation of compliance to these Guidelines.

ANNEX C

CODE OF PRACTICE TO MINIMISE VIBRATION DISTURBANCE

(1) Vibration Disturbance

Under normal circumstances, Project Proponent, and/or any other Person(s) who would operate or cause to operate equipment, plant process or activity should not unreasonably make, continue, or cause to be made or continued, any vibration disturbance.

In the context of these Guidelines, vibration disturbance shall mean any vibration which:

(i) endangers or injures the safety or health of human or animals; or

(ii) annoys or disturbs a reasonable person of normal sensitivities; or

(iii) endangers personal or public property; or

(vi) exceeds the vibration limits as prescribed herein in these Guidelines.

(2) Construction.

Project Proponent and/or other Person(s) should not operate or permit the operation of any tools or equipment used in construction, maintenance, or demolition work:

(a) Between the hours of 10.00 p.m. and 7.00 a.m. the following day on weekdays or at any time on weekends or public holidays, that creates a vibration disturbance across a residential real property boundary or within a vibration sensitive zone, except for emergency work of public service, and utilities.

(b) At any other time, the vibration levels resulting from construction work activities or equipment, plant or process at or across real property boundary should not exceed the recommended acceptable vibration limits as defined in the respective Schedules of Annex A for the daily period of operation.

(c) The use of low vibration (and vibration) generation equipment, process or activity shall be required in vibration sensitive areas.

(d) The use of low impact piling methods and/or alternative piling methods (bore piles, micropiles for example) are preferred over conventional impact hammer piling methods.

(e) Recommendations for vibration control in accordance to BS 5228: 1992 (Noise Control on Construction and Open Sites: Part 4 Code of Practice for Noise and Vibration Control Applicable to Piling Operations) shall be used.

(3) Industrial Sites

(a) Project Proponent and/or other Person(s) should not operate or permit the operation of equipment or facilities in an industrial site such that vibration propagated to the adjacent community results in vibration levels exceeding the maximum recommended limits as prescribed in the Guidelines.

(4) Transportation

(a) Project Proponents of new highways, road re-development or expansion, and rail or transit trains system(s) should minimize vibration intrusion to residential areas and vibration sensitive premises, and with alignments offering the maximum possible buffer zones, and natural or man-made attenuation.

(b) In urban or suburban areas where a meaningful buffer zone is not possible, or/and when vibration immission to affected receivers exceed maximum recommended limits as prescribed in the Guidelines, the use of vibration attenuating or isolation materials, or structural breaks shall be required.

(c) For railway tracks (trains of all type: LRT, commuter, electric rail, passenger, cargo, etc) that are located in close vicinity or adjacent residential, or built up areas and/or any vibration sensitive areas, the use of tracks vibration isolation are recommended. These include floating track slabs, ballast mats, undersleeper pads, and resilient track fasteners.

(5) Explosions

No person unless duly authorized by law or carrying out legitimate duties shall use explosives, or results in an explosion which create a vibration disturbance across a real property boundary or on a public space or right-of-way.

(6) Buildings

(a) All reasonable and precautionary measures for the safe occupancy of a building must be taken by the Person(s) responsible for or in control of the building, and/or other Person(s) responsible or permit the operation of any equipment, plant, process or work activity within the building.

(b) All mechanical and electrical equipment (building services equipment, manufacturing or production equipment, and any other rotating or reciprocating equipment), or any other facilities with rotation or reciprocating dynamic motion that results in moderate to significant dynamic excitation or motion of structures, including floor slabs, when installed within buildings should be mounted with suitable vibration isolation systems or devices. Such systems or devices include elastomeric or rubber pads, steel spring isolators, or pneumatic isolators. The use of matching inertia blocks is recommended.

(7) Low frequency vibration

(a) Industrial plants or process that result in low frequency noise, and consequently perceivable as low frequency vibration and/or resulting in vibration of lightweight building elements or structures, should be located away from noise and vibration sensitive areas.

(b) The design and implementation of appropriate attenuating elements or devices within the discharge or emission points (exhaust stacks, blowout points, etc) of the low frequency noise source should be included in all new or retrofitted installation in proximity to residential and noise and vibration sensitive areas.

ANNEX D

STATUTORY INSTRUMENTS, STANDARDS AND OTHER GUIDANCE

Statutory instruments

Environmental Quality Act 1974.

Environmental Quality Act (Amendment) 1985.

Standards

ISO 2631-1: 1985 – Evaluation of human exposure to whole-body vibration – Part 1: General requirements.

ISO 2631-2: 1989 – Evaluation of human exposure to whole-body vibration – Part 2: Continuous and shock-induced vibrations in buildings (1 to 80 Hz).

ISO 2631-3: 1985 – Evaluation of human exposure to whole-body vibration – Part 3: Evaluation of exposure to whole-body z-axis vertical vibration in the frequency range 0.1 to 0.63 Hz.

ISO 8041: 1990 – Human response to vibration – Measuring instrumentation.

BS 6472: 1992 – Guide to Evaluation of human exposure to vibration in buildings (1 Hz to 80 Hz).

BS 5228: 1992 – Noise control on construction and open sites – Part 4: Code of practice for noise and vibration control applicable to piling operations.

DIN 4150 – Part 3: Structural vibration in buildings.

ANSI S3.29: 1983 – Guide to the evaluation of human exposure to vibration in buildings.