INTERNATIONAL STANDARD

# ISO 2631-2

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# Evaluation of human exposure to whole-body vibration —

## Part 2 :
## Continuous and shock-induced vibration in buildings (1 to 80 Hz)

*Estimation de l'exposition des individus à des vibrations globales du corps —*

*Partie 2: Vibrations continues et induites par les chocs dans les bâtiments (1 à 80 Hz)*



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# Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.



International Standard ISO 2631-2 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration and shock.*

ISO 2631 will consist of the following parts, under the general title *Evaluation of human exposure to whole-body vibration*:



— *Part 1: General requirements*

— *Part 2: Continuous and shock-induced vibration in buildings (*1 *to* 80 Hz*)*

— *Part 3: Whole-body z-axis vertical vibration (*0,1 *to* 0,63 Hz*)*

— *Part 4: Vibration on board sea-going ships (*1 *to* 80 Hz*)*

Users should note that all International Standards undergo revision from time to time and that any reference made herein to any other International Standard implies its latest edition, unless otherwise stated.

# Evaluation of human exposure to whole-body vibration — Part 2 : Continuous and shock-induced vibration in buildings (1 to 80 Hz)

## 0 Introduction

Structural vibration in buildings can be detected by and affect the occupants in many ways. The quality of life can be reduced just as can the working efficiency.

This part of ISO 2631 offers guidance on the application of ISO 2631-1 to human response to building vibration. This part of ISO 2631 is also intended to encourage the uniform collection of data on human response to building vibration.

No guidance is given on complaint levels from occupants of buildings subject to vibration or to any acceptable magnitudes or limits of building vibration, but this part of ISO 2631 does contain weighting curves for human response to vibration of buildings.

## 1 Scope and field of application

Primarily with respect to annoyance of human beings subject to building vibration, this part of ISO 2631 is limited to the following considerations :

a) continuous vibration;

b) intermittent vibration.

The state of the art on transient (impulsive) vibration is presented in annexes A and B.

General guidance is given on human response to building vibrations and weighting curves of frequency response for equal annoyance of humans are included together with measurement methods to be used.

Consideration is given to the time of the day and the use made of the occupied space in the building, whether workshop, office, residential, hospital operating-theatre or other critical area.

Acceptable magnitudes of vibration are not stated in this part of ISO 2631 since these cannot be specified rigidly and depend upon specific circumstances. Tentative guidance is given in annex A on the magnitude of vibration at which adverse comment may begin to arise. In cases where sensitive equipment or delicate operations impose more stringent criteria than human comfort, the corresponding more stringent values should be applied.

Adjustments and variances may be allowed for short-term engineering works (for example foundation excavation and tunnelling) where good public relation practices are followed and prior warning is given.

This part of ISO 2631 is not intended to provide guidance as to the likelihood of structural damage to buildings or injury to occupants of buildings subject to vibration, as defined in ISO 2631-1.

This part of ISO 2631 is concerned only with tactile perception and does not take into account auditory perception of re-radiated sound.



## 2 References

ISO 2041, *Vibration and shock — Vocabulary.*

ISO 2631-1, *Evaluation of human exposure to whole-body vibration — Part 1 : General requirements.*

ISO 5805, *Mechanical vibration and shock affecting man — Vocabulary.*

## 3 Characteristics of building vibration

### 3.1 Direction of vibration

As a building may be used for many different human activities, for example standing, sitting, lying or a combination of all three, vertical vibration of the building may enter the body as either $z$-axis, $x$-axis or $y$-axis vibration, as shown in figure 1.

The measured vibration should normally be referred to the appropriate axis. If it is not clear which direction is appropriate, it may be more convenient to consider the combined curve as explained in 4.2.3.

### 3.2 Multi-frequency vibration

There is evidence from research concerning the building environment to suggest that there are summation effects for vibration at different frequencies. Therefore for the evaluation of building vibration with respect to the annoyance and comfort effects on occupants, overall weighted vibration values are preferred, as described in ISO 2631-1. A suitable weighting curve for investigation is described in 3.5.

### 3.3 Characterization of transient, continuous and intermittent vibration with respect to human response

The borderline between transient and intermittent vibration is difficult to define. For the purpose of this part of ISO 2631, transient (sometimes called impulsive) vibration is defined as a rapid build-up to a peak, followed by a damped decay which may or may not involve several cycles of vibration (depending on frequency and damping). It can also consist of several cycles at approximately the same amplitude, providing that the duration is short (i.e. less than 2 s).

Intermittent vibration is a string of vibration incidents, each of short duration, separated by intervals of much lower vibration magnitudes. Intermittent vibration may originate from impulse sources (for example pile drivers and forging presses) or repetitive sources (for example pavement breakers) or sources which operate intermittently, but which would produce continuous vibration if operated continuously (for example intermittent machinery, lifts, railway trains and traffic passing by).

In this part of ISO 2631, continuous vibration is vibration which remains uninterrupted over a time period under consideration (see annex A).

Single high-magnitude events, such as blasting, which occur only a few times per day are a special case. It is generally recommended that operations of this nature should not take place at night in order to avoid disturbance. During the daytime, they should be limited to a small number of events. An event may comprise a single significant impulse vibration or a group of transient vibrations with individual impulses separated by a short period (with the group lasting no longer than 1 min).

Under practical conditions, vibration due to impulsive events may be acceptable even if it is an order of magnitude greater than those due to traffic and general building vibration. The magnitudes of vibration for minimum adverse comment will depend upon the time period over which events occur in an area.

### 3.4 Classification of buildings and building areas

The classification with respect to human response should be performed solely on the basis of the expected occupation, tasks performed by the occupants and the expected freedom from intrusion. Each occupied room of a building shall be analysed with respect to these criteria.

NOTE — For state-of-the-art guidance, see annex A.

### 3.5 Measurement of vibration

The preferred measurement technique is one which records unfiltered time histories from which any desired value can later be determined. If possible, building vibrations should be measured in acceleration terms, but in some cases it may be found appropriate to measure in terms of velocity or displacement.

The preferred method for assessing the influence of continuous vibrations is to determine the r.m.s. value of the weighted acceleration (as recommended in ISO 2631-1).

NOTE — For methods dealing with crest factors other than small crest factors, see annexes A and B.

If the position of the occupants with respect to the vibration environment is constant and known, the weighting functions established for the $z$-direction and the $x$-, $y$-directions shall be used. If the position of the occupants varies or is unknown with respect to the interfering or annoying vibration, then either the most stringent of $z$-, $x$- and $y$-directions or a weighting characteristic obtained by the combination of the $z$-axis and $x$-, $y$-axes can be used. Where the combined weighting function is used it has a corner frequency of 5,6 Hz and an attenuation given by:

$$\text{attenuation} = \sqrt{1 + (f/5{,}6)^2}$$

where $f$ is the frequency, in hertz. (See curves explained in 4.2.3.)

There are insufficient data on human response to transient (impulsive) vibration to justify inclusion here of a preferred method for analysing such motions. Guidance on assessment currently used in some countries is illustrated in annex A and additional methods at present being researched and tested are identified in annex B.

Measurement of vibration should be taken on a structural surface supporting the human body at the point of entry to the human subject.

NOTE — In some conditions, measurements may have to be made outside the structures or on some surface other than points of entry to the human subject. In these cases, transfer functions need to be determined.

Measurements should be taken along the three orthogonal axes and reference should be made to the appropriate human axis curve. Alternatively, the combined $x$-, $y$- and $z$-curve could be considered in relation to the worst case found (see 4.2.3).

## 4 Characterization of building vibration with respect to human response

### 4.1 Criteria of satisfactory magnitude with respect to human response

All the following proposals are based on the recommendations for general vibration on humans given in ISO 2631-1.

Experience has shown in many countries that complaints regarding building vibrations in residential situations are likely to arise from occupants of buildings when the vibration magnitudes are only slightly in excess of perception levels. In general, the satisfactory magnitudes are related to the minimum adverse comment level by the occupants and are not determined by any other factors, such as short-term health hazard and working efficiency. Indeed, in practically all cases the magnitudes are such that there is no possibility of fatigue or other vibration-induced symptoms. Situations exist where motion magnitudes above those for minimum adverse comment level can be tolerated, particularly for temporary disturbances and infrequent events of short duration. An example is a construction or excavation project. Any startle factor can be reduced by warning signals, announcements and/or regularity of occurrence and a proper programme of public relations. Only in extremely rare cases should it be necessary to consult the "fatigue-decreased proficiency boundary" and "exposure limits" as given in ISO 2631-1 as guidance.

For situations in which vibration occurs over an extended period, long-term familiarization may give rise to a change in adverse comments.

## 4.2 Base curves

The base curves represent magnitudes of approximately equal human response with respect to human annoyance and/or complaints about interference with activities. The base curves for acceleration and for velocity are given in figures 2a, 3a and 4a, and in figures 2b, 3b and 4b, respectively. Satisfactory vibration magnitudes in rooms and buildings should be specified in multiples of the base curve magnitudes specified in 4.2.1, 4.2.2 and 4.2.3. At vibration acceleration and/or velocity magnitudes below the values corresponding to the base curves shown in figures 2a, 3a and 4a and/or figures 2b, 3b and 4b in general no adverse comments, sensations or complaints have been reported. However, this statement does not imply that, depending on circumstances and expectations, annoyance and/or complaints shall be expected at higher magnitudes.

NOTE — Weighted acceleration values shall be evaluated with respect to the base acceleration magnitudes in the frequency band of maximum sensitivity as stated in ISO 2631-1.

Establishing design criteria and aims by raising the base curves shown in this part of ISO 2631 should be done by consulting state-of-the-art experience and proper consideration should be given to social, public relations and economic factors.

NOTES

1 Annex A summarizes the state of the art of multiplication factors frequently used in connection with the base curves shown in this part of ISO 2631. It is hoped that use of this part of ISO 2631 facilitates uniform collection of additional data.

2 The base curves presented do not take into account the possibility that, at frequencies above approximately 30 Hz, wall vibration can introduce undesired acoustical disturbances.

### 4.2.1 Base curves for foot-to-head (*z*-axis) vibration

For *z*-axis vibration, the base curves are shown in figures 2a and 2b. Table 1 gives the corresponding acceleration and velocity/frequency values at the preferred one-third octave band centre frequencies for the curves in figures 2a and 2b.

At magnitudes of acceleration below the base curve, adverse comment is very rare. This does not mean that values above this curve will give rise to adverse comment, as the magnitude which is considered to be satisfactory depends on circumstances.

### 4.2.2 Base curves for side-to-side or back-to-chest (*x*- or *y*-axis) vibration

For *x*- and *y*-axis human vibration, different base curves apply which are shown in figures 3a and 3b. Table 1 gives the corresponding acceleration and velocity/frequency values at the preferred one-third octave band centre frequencies for the curves in figures 3a and 3b.

For frequencies from 1 to 2 Hz, an acceleration magnitude of $3{,}6 \times 10^{-3}$ m/s$^2$ will apply.

For frequencies greater than 2 Hz, a constant velocity curve applies.

It will be noted that the base curves for *x*- and *y*-axis vibration are more stringent than the *z*-axis case at low frequencies. This is due to the sensitivity of the human body to *x*- or *y*-axis motion at these low frequencies.

### 4.2.3 Combined-standard base curves for undefined axes of human vibration exposure

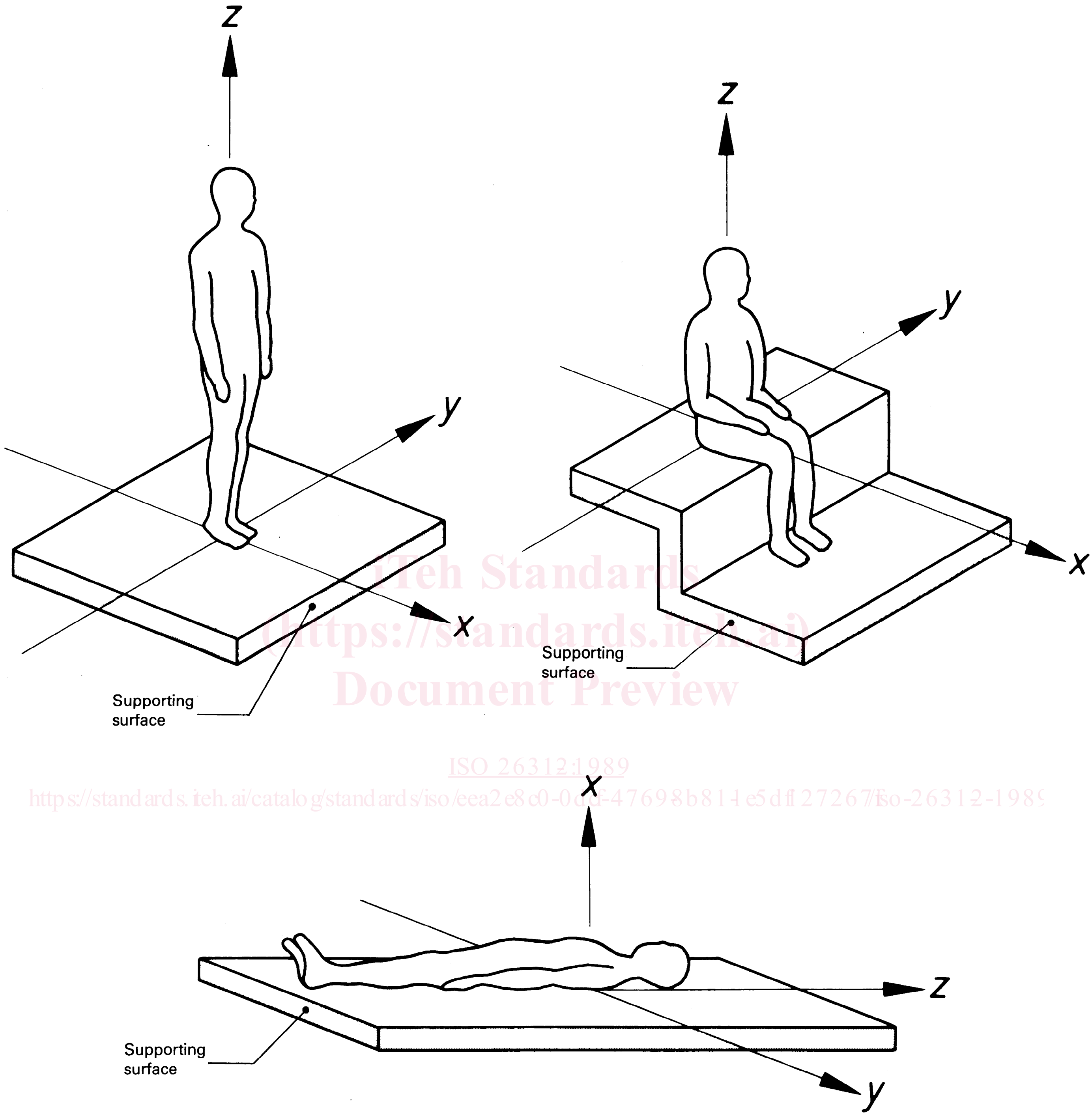
In many situations the same building area may be used by humans in both the lying and standing positions at different times of the day. If this is the case, then a combined standard using the worst case combination of both the *z*-axis and *x*- and *y*-axis conditions may be applied. This has to be obtained by using the *z*-axis response from 8 to 80 Hz and the *x*/*y*-axis response from 1 to 2 Hz. For frequencies between 2 and 8 Hz, there is an interpolation between the two curves. These combination curves are shown in figures 4a and 4b. Table 1 gives the corresponding acceleration and velocity/frequency values for the curves in figures 4a and 4b.

These combined standard base curves (see annex A and figure 5a) could be used for preliminary investigations to decide whether further investigation is necessary.

NOTE — In some countries it is preferred to use the *z* and *x*, *y* base curves separately rather than the provisional combined weighting curve.

**Table 1 — Acceleration and velocity at the one-third octave band centre frequencies for the base curves shown in figures 2a, 2b, 3a, 3b, 4a and 4b**

| Frequency (Centre frequency of one-third octave band) Hz | Acceleration (r.m.s.) $m/s^2$ Base curve figure 2a | Base curve figure 3a | Base curve figure 4a | Velocity (r.m.s.) m/s Base curve figure 2b | Base curve figure 3b | Base curve figure 4b |
|---|---|---|---|---|---|---|
| 1 | $1 \times 10^{-2}$ | $3,6 \times 10^{-3}$ | $3,6 \times 10^{-3}$ | $1,59 \times 10^{-3}$ | $5,73 \times 10^{-4}$ | $5,73 \times 10^{-4}$ |
| 1,25 | $8,9 \times 10^{-3}$ | $3,6 \times 10^{-3}$ | $3,6 \times 10^{-3}$ | $1,13 \times 10^{-3}$ | $4,58 \times 10^{-4}$ | $4,58 \times 10^{-4}$ |
| 1,6 | $8 \times 10^{-3}$ | $3,6 \times 10^{-3}$ | $3,6 \times 10^{-3}$ | $7,96 \times 10^{-4}$ | $3,58 \times 10^{-4}$ | $3,58 \times 10^{-4}$ |
| 2 | $7 \times 10^{-3}$ | $3,6 \times 10^{-3}$ | $3,6 \times 10^{-3}$ | $5,57 \times 10^{-4}$ | $2,87 \times 10^{-4}$ | $2,87 \times 10^{-4}$ |
| 2,5 | $6,3 \times 10^{-3}$ | $4,51 \times 10^{-3}$ | $3,72 \times 10^{-3}$ | $4,01 \times 10^{-4}$ | $2,87 \times 10^{-4}$ | $2,37 \times 10^{-4}$ |
| 3,15 | $5,7 \times 10^{-3}$ | $5,68 \times 10^{-3}$ | $3,87 \times 10^{-3}$ | $2,88 \times 10^{-4}$ | $2,87 \times 10^{-4}$ | $1,95 \times 10^{-4}$ |
| 4 | $5 \times 10^{-3}$ | $7,21 \times 10^{-3}$ | $4,07 \times 10^{-3}$ | $1,99 \times 10^{-4}$ | $2,87 \times 10^{-4}$ | $1,62 \times 10^{-4}$ |
| 5 | $5 \times 10^{-3}$ | $9,02 \times 10^{-3}$ | $4,3 \times 10^{-3}$ | $1,59 \times 10^{-4}$ | $2,87 \times 10^{-4}$ | $1,36 \times 10^{-4}$ |
| 6,3 | $5 \times 10^{-3}$ | $1,14 \times 10^{-2}$ | $4,6 \times 10^{-3}$ | $1,26 \times 10^{-4}$ | $2,87 \times 10^{-4}$ | $1,16 \times 10^{-4}$ |
| 8 | $5 \times 10^{-3}$ | $1,44 \times 10^{-2}$ | $5 \times 10^{-3}$ | $9,95 \times 10^{-5}$ | $2,87 \times 10^{-4}$ | $9,95 \times 10^{-5}$ |
| 10 | $6,3 \times 10^{-3}$ | $1,8 \times 10^{-2}$ | $6,3 \times 10^{-3}$ | $9,95 \times 10^{-5}$ | $2,87 \times 10^{-4}$ | $9,95 \times 10^{-5}$ |
| 12,5 | $7,81 \times 10^{-3}$ | $2,25 \times 10^{-2}$ | $7,8 \times 10^{-3}$ | $9,95 \times 10^{-5}$ | $2,87 \times 10^{-4}$ | $9,95 \times 10^{-5}$ |
| 16 | $1 \times 10^{-2}$ | $2,89 \times 10^{-2}$ | $1 \times 10^{-2}$ | $9,95 \times 10^{-5}$ | $2,87 \times 10^{-4}$ | $9,95 \times 10^{-5}$ |
| 20 | $1,25 \times 10^{-2}$ | $3,61 \times 10^{-2}$ | $1,25 \times 10^{-2}$ | $9,95 \times 10^{-5}$ | $2,87 \times 10^{-4}$ | $9,95 \times 10^{-5}$ |
| 25 | $1,56 \times 10^{-2}$ | $4,51 \times 10^{-2}$ | $1,56 \times 10^{-2}$ | $9,95 \times 10^{-5}$ | $2,87 \times 10^{-4}$ | $9,95 \times 10^{-5}$ |
| 31,5 | $1,97 \times 10^{-2}$ | $5,68 \times 10^{-2}$ | $1,97 \times 10^{-2}$ | $9,95 \times 10^{-5}$ | $2,87 \times 10^{-4}$ | $9,95 \times 10^{-5}$ |
| 40 | $2,5 \times 10^{-2}$ | $7,21 \times 10^{-2}$ | $2,5 \times 10^{-2}$ | $9,95 \times 10^{-5}$ | $2,87 \times 10^{-4}$ | $9,95 \times 10^{-5}$ |
| 50 | $3,13 \times 10^{-2}$ | $9,02 \times 10^{-2}$ | $3,13 \times 10^{-2}$ | $9,95 \times 10^{-5}$ | $2,87 \times 10^{-4}$ | $9,95 \times 10^{-5}$ |
| 63 | $3,94 \times 10^{-2}$ | $1,14 \times 10^{-1}$ | $3,94 \times 10^{-2}$ | $9,95 \times 10^{-5}$ | $2,87 \times 10^{-4}$ | $9,95 \times 10^{-5}$ |
| 80 | $5 \times 10^{-2}$ | $1,44 \times 10^{-1}$ | $5 \times 10^{-2}$ | $9,95 \times 10^{-5}$ | $2,87 \times 10^{-4}$ | $9,95 \times 10^{-5}$ |






$a_x$, $a_y$, $a_z$ = acceleration in the directions of the $x$-, $y$-, $z$-axes

$x$-axis = back-to-chest

$y$-axis = right side to left side

$z$-axis = foot-(or buttocks-)to-head

**Figure 1 — Directions of basicentric coordinate systems for mechanical vibrations influencing humans**


**Figure 2a — Building vibration $z$-axis base curve for acceleration**
(this represents the foot-to-head vibration base curve, see 4.2.1)

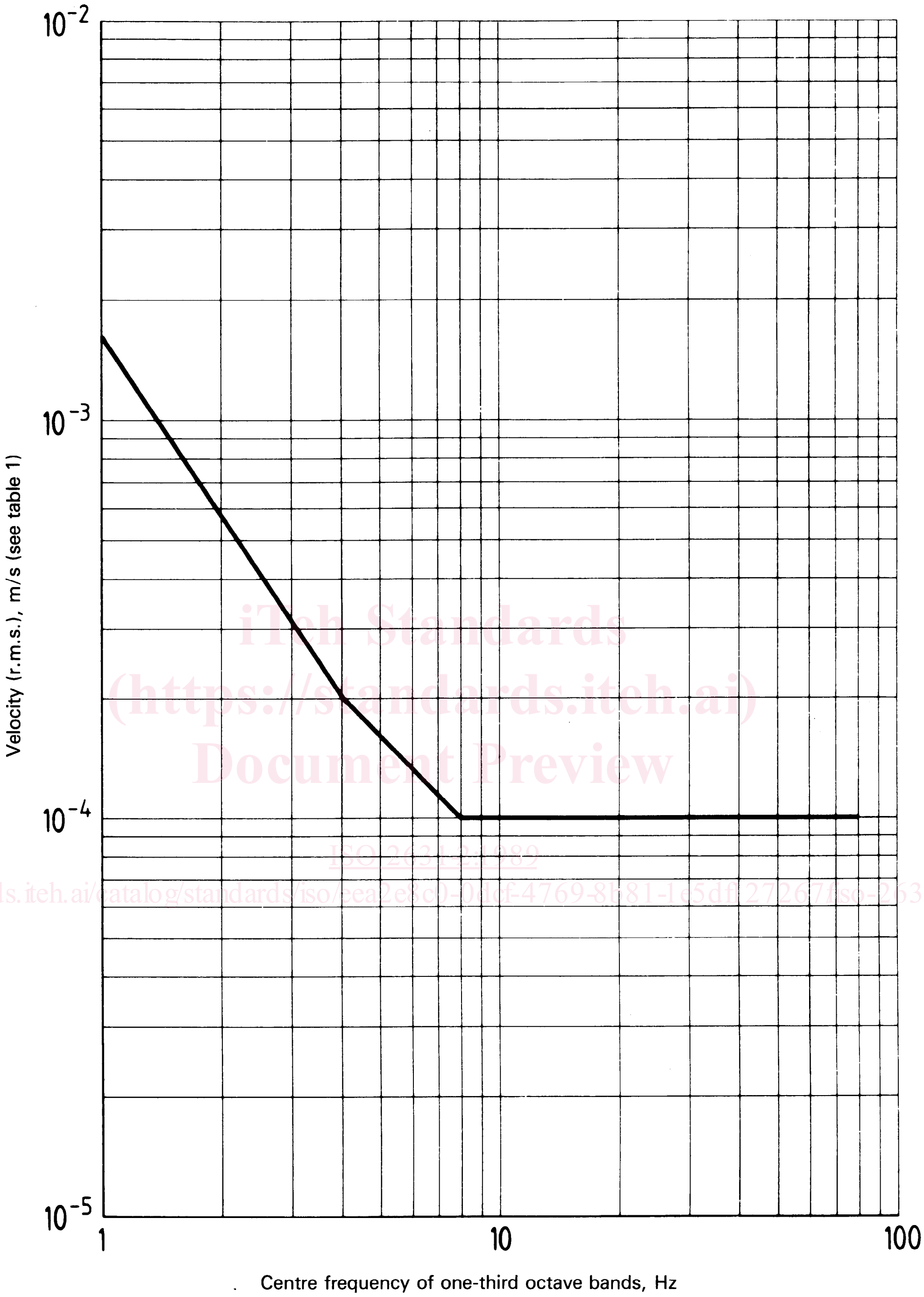





**Figure 2b — Building vibration *z*-axis base curve for velocity**
(this represents the foot-to-head vibration base curve, see 4.2.1)

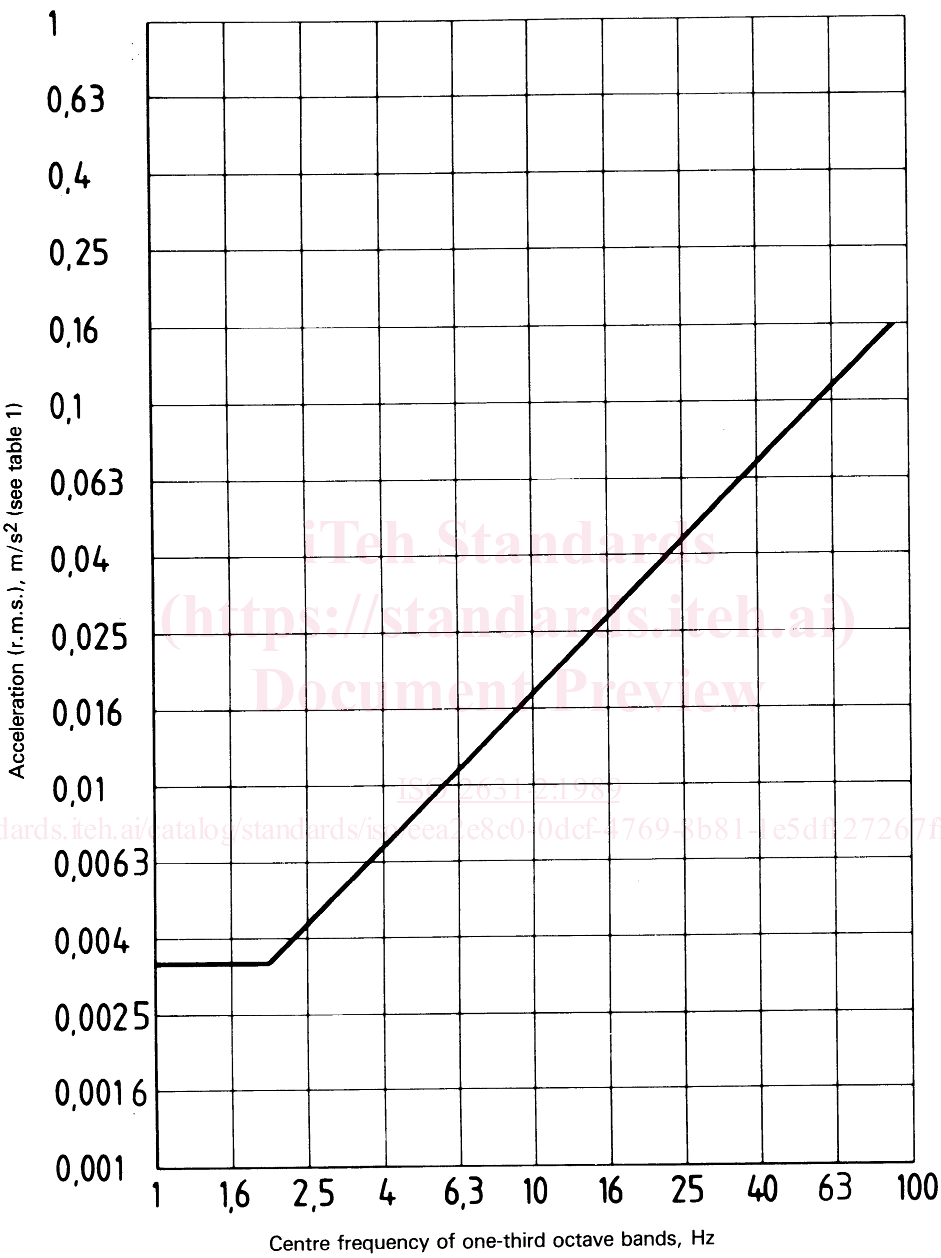



**Figure 3a — Building vibration *x*- and *y*-axis base curve for acceleration**
(this represents the side-to-side and back-to-chest vibration base curve, see 4.2.2)