INTERNATIONAL STANDARD

ISO 2631-2

Second edition
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Mechanical vibration and shock — Evaluation of human exposure to whole-body vibration —

Part 2: Vibration in buildings (1 Hz to 80 Hz)

Vibrations et chocs mécaniques — Évaluation de l'exposition des individus à des vibrations globales du corps —

Partie 2: Vibrations dans les bâtiments (1 Hz à 80 Hz)

Reference number
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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

This second edition cancels and replaces the first edition (ISO 2631-2:1989) which has been technically revised, as follows. The whole text was redrafted in order to harmonize it with ISO 2631-1:1997 and to take account of international practice. The frequency weighting defined in this part of ISO 2631 has not been changed compared to the first edition, except in the method of presentation and designation, i.e. W_{m} instead of W.B.combined used in previous documents. This is the result of a questionnaire held in 1995. A further reason is the use of this frequency weighting in other fields of application, e.g. evaluation of ship vibration. Consequently an adjustment of the frequency weighting at the lower end has not been made.

Subclause 4.5 “Evaluation of vibration” defines categories of vibration in order to give guidance for the application of this part of ISO 2631. The content of Clause 5 “Human responses to building vibration” was restricted to the first paragraph of the former edition. The rest of the text was deleted because its content is now included in ISO 2631-1.

Guidance values above which adverse comments due to building vibration could occur are not included any more since their possible range is too widespread to be reproduced in an International Standard.

A normative Annex A has been added to define the frequency weighting W_{m} in a manner compatible with the mathematical definition of frequency weightings in ISO 2631-1.

An informative Annex B has also been added which gives guidelines to consider associated phenomena such as reradiated noise and visual effects. Finally, the Bibliography has been updated.

ISO 2631-2 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration and shock*, Subcommittee SC 4, *Human exposure to mechanical vibration and shock*.

ISO 2631 consists of the following parts, under the general title *Mechanical vibration and shock — Evaluation of human exposure to whole-body vibration:*

— *Part 1: General requirements*

— *Part 2: Vibration in buildings (1 Hz to 80 Hz)*

— *Part 4: Guidelines for the evaluation of the effects of vibration and rotational motion on passenger and crew comfort in fixed-guideway transport systems*

— *Part 5: Method for evaluation of vibration containing multiple shocks*

Introduction

Structural vibration to which human beings are exposed in buildings can be detected by the occupants and can affect them in many ways. More particularly, their comfort and quality of life may be reduced.

For the evaluation of vibration in buildings with respect to comfort and annoyance, overall weighted values of the vibration are preferred. The value obtained with the appropriate frequency weighting characterizes the place or site within the building where people may be present, by giving an indication of the suitability of that place.

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

Mechanical vibration and shock — Evaluation of human exposure to whole-body vibration —

Part 2: Vibration in buildings (1 Hz to 80 Hz)

1 Scope

This part of ISO 2631 concerns human exposure to whole-body vibration and shock in buildings with respect to the comfort and annoyance of the occupants. It specifies a method for measurement and evaluation, comprising the determination of the measurement direction and measurement location. It defines the frequency weighting W_m which is applicable in the frequency range 1 Hz to 80 Hz where the posture of an occupant does not need to be defined.

NOTE 1 The frequency weightings given in ISO 2631-1 can be used if the posture of the occupant is defined.

Whilst it is often the case that a building will be available for experimental investigation, many of the concepts contained within this part of ISO 2631 would apply equally to a building in the design process or where it will not be possible to gain access to an existing building. In these cases, reliance will have to be placed on the prediction of the building response by some means.

This part of ISO 2631 does not provide guidance on the likelihood of structural damage, which is discussed in ISO 4866. Further, it is not applicable to the evaluation of effects on human health and safety.

Acceptable magnitudes of vibration are not stated in this part of ISO 2631.

NOTE 2 At present it is not possible to give guidance on acceptable magnitudes of vibration until more information has been collected in accordance with this part of ISO 2631.

The mathematical definition of the frequency weighting W_m is given in Annex A. Guidelines for collecting data concerning complaints about building vibration are given in Annex B.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 2631-1:1997, *Mechanical vibration and shock — Evaluation of human exposure to whole-body vibration — Part 1: General requirements*

ISO 8041, *Human response to vibration — Measuring instrumentation*

IEC 61260:1995, *Electroacoustics — Octave-band and fractional-octave-band filters*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
evaluation
range of activities which includes survey, measurement, processing, ordering, characterization, rating and presentation of relevant data

3.2
building
static construction used for habitation or allocated to any other human activity, including offices, factories, hospitals, schools, day-care centres

3.3
work time
period of activity, or working hours, of the vibration source defined by the daily start and finish times

3.4
exposure time
period during which exposure to the vibration occurs

4 Measurement of building vibration

4.1 General

The general requirements for signal conditioning and the duration of measurement as specified in 5.4 and 5.5, respectively, of ISO 2631-1:1997 shall be followed.

4.2 Direction of measurement

The vibration shall be measured in all three orthogonal directions simultaneously. For this purpose, the directions of vibration are related to the structure rather than to the human body. The orientations of the structure-related x-, y- and z-axes shall be those for a standing person as given in ISO 2631-1.

4.3 Location of measurement

The evaluation with respect to human response shall be based solely on the expected occupation, the tasks performed by the occupants, and the expected freedom from disturbance. Each relevant place or room shall be assessed with respect to these criteria. The vibration shall be measured at that location in the room where the highest magnitude of the frequency-weighted vibration occurs, or as specifically directed, on a suitable surface of the building structure.

NOTE It may be necessary to take measurements at several locations in the building to determine the local variation of the vibration.

4.4 Frequency weighting

The vibration measured at the relevant location and in the three directions according to 4.2 and 4.3 shall be frequency weighted. This part of ISO 2631 (as well as ISO 2631-1) uses frequency-weighted acceleration to express the vibration magnitude.

It is recommended that the frequency weighting W_{m} according to Annex A be used irrespective of the measurement direction.

NOTE 1 The frequency weightings given in ISO 2631-1 can be used if the posture of the occupant is defined.

Annex A gives the exact definition of the frequency weighting W_m. The values given in Table A.1, applicable to vibration acceleration as the input quantity, are calculated using the true one-third-octave band mid-frequencies and include the band limitation between 1 Hz and 80 Hz. Figure A.1 shows the frequency weighting W_m in a schematic way.

NOTE 2 W_m was previously designated as W.B.combined.

4.5 Evaluation of vibration

4.5.1 Vibration measurement

Vibration values should be determined by application of the methods given in ISO 2631-1. The vibration axis with the highest frequency-weighted vibration magnitude should be identified, and values obtained in this direction used for the evaluation.

In order to allow different kinds of future evaluation, it is recommended, wherever practicable, to use a measurement technique which records vibration time histories unweighted at least within the frequency range 1 Hz to 80 Hz.

4.5.2 Categories of source

For an evaluation, it is useful to categorize the vibration according to the major types of source which have been found in practice to give rise to adverse comments. Different magnitudes of vibration may be acceptable for the different categories. To establish international consistency of approach, the following categories are defined:

a) continuous or semi-continuous processes, e.g. industry;

b) permanent intermittent activities, e.g. traffic;

c) limited duration (non-permanent) activities, e.g. construction.

The categories have been selected to reflect the human perception of different vibration sources. They are not intended to be exclusive but to give guidance for the application of this part of ISO 2631.

4.6 Measuring instrumentation

The requirements for measuring instrumentation, including tolerances, as given in ISO 8041 shall be followed.

5 Human responses to building vibration

Experience in many countries has shown that adverse comments regarding building vibration in residential situations may arise from occupants of buildings when the vibration magnitudes are only slightly in excess of perception levels (see ISO 2631-1:1997, Annex C). In some cases complaints arise due to secondary effects associated with vibration, e.g. reradiated noise (see Annex B). In general, satisfactory magnitudes are likely to be related to general expectations and to economic, social and other environmental factors. They are not determined by factors such as short-term health hazards and working efficiency. Indeed, in practically all cases the magnitudes are such that fatigue directly induced by the motion is very unlikely.

Situations exist where significantly higher vibration magnitudes can be tolerated, particularly for temporary disturbances and transient events. Examples of this are construction projects. Any startle factor can be reduced by a proper programme of public relations which may include announcements such as warning signals and/or concerning regularity of occurrence. Only in extremely rare cases should it be necessary to consult the criterion “health” as given in ISO 2631-1. For situations in which vibration occurs over an extended period, long-term familiarization may give rise to a change in adverse comment thresholds.

Annex A
(normative)

Mathematical definition of the frequency weighting W_m

The frequencies f_i (i = 1 to 3) are parameters of the transfer function determining the overall frequency weighting W_m. The transfer function, $H(p)$, is expressed as the product of three factors [high-pass filter $H_h(p)$, low-pass filter $H_l(p)$ and pure weighting function $H_t(p)$], as follows, where $\omega_i = 2\pi f_i$ and $p = j2\pi f$:

Band limiting (filter with second-order Butterworth characteristic; f_1 and f_2 are the corner frequencies):

a) High pass

$$H_h(p) = \frac{1}{1 + \sqrt{2}\,\omega_1 / p + (\omega_1 / p)^2} \tag{A.1}$$

$$\left|H_h(p)\right| = \sqrt{\frac{f^4}{f^4 + f_1^4}} \tag{A.2}$$

where $f_1 = 10^{-0,1}$ Hz = 0,7943... Hz.

b) Low pass

$$H_l(p) = \frac{1}{1 + \sqrt{2}\,p / \omega_2 + (p / \omega_2)^2} \tag{A.3}$$

$$\left|H_l(p)\right| = \sqrt{\frac{f_2^4}{f^4 + f_2^4}} \tag{A.4}$$

where f_2 = 100 Hz.

Pure frequency weighting (for acceleration as the input quantity):

$$H_t(p) = \frac{1}{1 + p / \omega_3} \tag{A.5}$$

$$\left|H_t(p)\right| = \sqrt{\frac{f_3^2}{f^2 + f_3^2}} \tag{A.6}$$

where

$$f_3 = \frac{1}{0,028 \times 2\pi}\ \text{Hz} = 5,684...\ \text{Hz}$$

The transfer function, $H(p)$, of the band-limited frequency weighting W_m is given by the product of the high-pass filter $H_h(p)$, the low-pass filter $H_l(p)$ and the pure weighting function $H_t(p)$:

$$H(p) = H_h(p) \cdot H_l(p) \cdot H_t(p) \tag{A.7}$$

NOTE In the most common interpretation of this equation (in the frequency domain) it describes the modulus (magnitude) and phase in the form of a complex number as a function of the imaginary angular frequency $p = j2\pi f$. Sometimes the symbol s is used instead of p. Alternatively p may be interpreted as the variable of the Laplace transform.

The modulus (magnitude) $|H(p)|$ is shown schematically in Figure A.1 for illustration.

Values of the frequency weighting W_m in one-third-octave bands, calculated using the true mid-frequencies, frequency band limitation 1 Hz to 80 Hz included, are given in Table A.1 for acceleration as the input quantity.

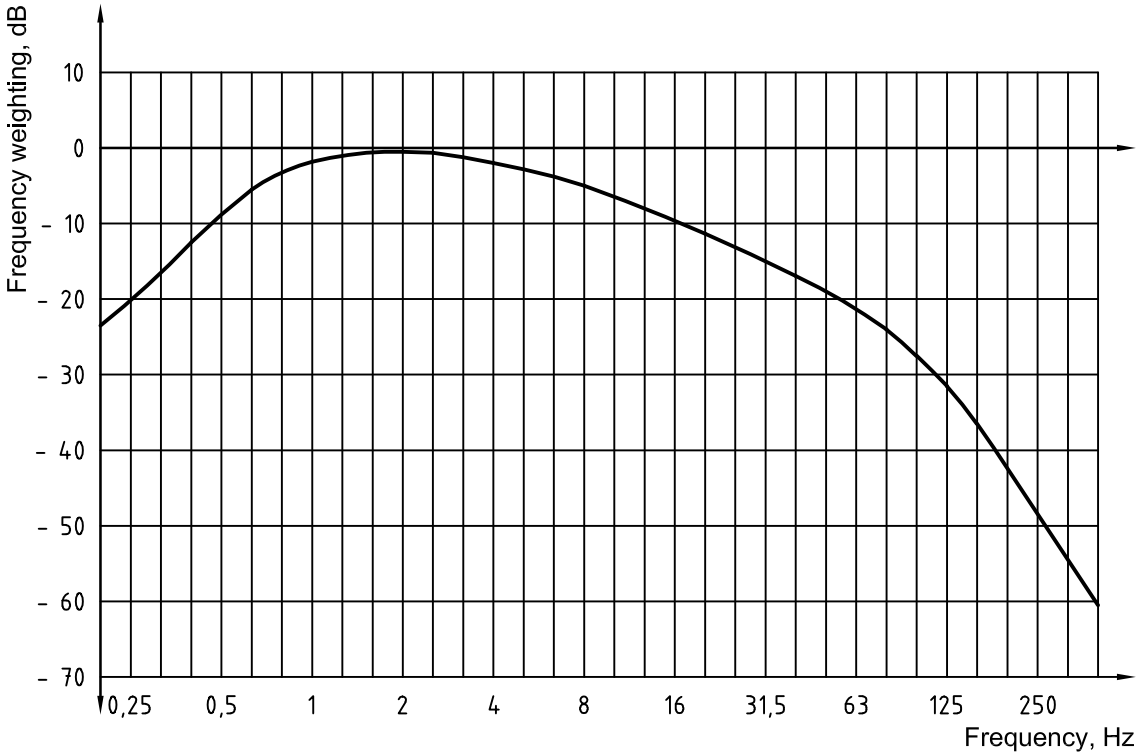

Figure A.1 — Frequency weighting W_m, with acceleration as the input quantity (schematic)

Table A.1 — Values of the frequency weighting W_m for acceleration as the input quantity
(in one-third-octave bands, calculated using the true mid-frequencies, band limitation 1 Hz to 80 Hz included)

x	**Frequency**, Hz		W_m	W_m
	Nominal	True	Factor	dB
−7	0,2	0,1995	0,0629	−24,02
−6	0,25	0,2512	0,0994	−20,05
−5	0,315	0,3162	0,156	−16,12
−4	0,4	0,3981	0,243	−12,29
−3	0,5	0,5012	0,368	−8,67
−2	0,63	0,6310	0,530	−5,51
−1	0,8	0,7943	0,700	−3,09
0	1	1,000	0,833	−1,59
1	1,25	1,259	0,907	−0,85
2	1,6	1,585	0,934	−0,59
3	2	1,995	0,932	−0,61
4	2,5	2,512	0,910	−0,82
5	3,15	3,162	0,872	−1,19
6	4	3,981	0,818	−1,74
7	5	5,012	0,750	−2,50
8	6,3	6,310	0,669	−3,49
9	8	7,943	0,582	−4,70
10	10	10,00	0,494	−6,12
11	12,5	12,59	0,411	−7,71
12	16	15,85	0,337	−9,44
13	20	19,95	0,274	−11,25
14	25	25,12	0,220	−13,14
15	31,5	31,62	0,176	−15,09
16	40	39,81	0,140	−17,10
17	50	50,12	0,109	−19,23
18	63	63,10	0,0834	−21,58
19	80	79,43	0,0604	−24,38
20	100	100,0	0,0401	−27,93
21	125	125,9	0,0241	−32,37
22	160	158,5	0,0133	−37,55
23	200	199,5	0,00694	−43,18
24	250	251,2	0,00354	−49,02
25	315	316,2	0,00179	−54,95
26	400	398,1	0,000899	−60,92

NOTE x is the frequency band number according to IEC 61260:1995.

Annex B
(informative)

Guidelines for collecting data concerning human response to building vibration

B.1 Introduction

The basic human response to vibration in buildings is adverse comment. The main body of this part of ISO 2631 concerns the measurement and the evaluation of whole-body vibration. This annex is intended to encourage users to collect data taking into consideration all of those parameters that affect human beings in buildings and which give rise to complaints.

Human response to vibration in buildings is very complex. In many circumstances the degree of annoyance and complaint cannot be explained directly by the magnitude of monitored vibration alone. Under some conditions of amplitude and frequency, claims may arise while measured whole-body vibration is lower than the perception level.

Analysis of these complaints shows that other parameters related to the vibration source (e.g. work time) or produced by the vibration in the exposure area (e.g. reradiated noise) may also give an explanation of the complaints.

Measured vibration parameters, complemented by the evaluation of these phenomena, allow better quantification of the degree of annoyance by vibration in buildings.

Vibration sources outside and inside buildings may generate whole-body vibration, together with the associated phenomena of structure-borne noise, airborne noise, rattling, movement of furniture and other objects, as well as visual effects (e.g. movement of hanging objects). To evaluate human complaints, all of these effects need to be considered.

The aim of collecting data for these associated phenomena is to facilitate the eventual definition of a more general indicator of the annoyance due to vibration. This indicator may be used as the basis to update future editions of this part of ISO 2631.

B.2 Parameters to be considered

B.2.1 General

The following factors should be considered and, where appropriate, recorded.

B.2.2 Parameters related to the source

The daily start and finish times of the activity of the vibration source during the period of measurement should be described in the report.

The total duration and the daily or weekly number of events, and the nature of the vibration, should also be noted, for example as:

— permanent source: day, night, or day and night;

— intermittent source: duration of events and number of events per day and/or night;

— isolated or infrequent source: event duration and number of events per day, week or month.

B.2.3 Parameters related to measured vibration

B.2.3.1 Vibration measurement

The place of measurement, the method of measurement and the weighting procedure should be applied in accordance with this part of ISO 2631.

B.2.3.2 Character of the vibration

Subjective response is also a function of the character of the vibration. The character can be defined according to the nature of the vibration that is measured, for example:

— vibration may be continuous, with magnitudes varying or remaining constant with time;

— vibration may be intermittent, with the magnitude of each event being either constant or varying with time;

— vibration may be impulsive, such as in shocks.

B.2.3.3 Exposure time

The exposure time of the people affected may also be important for the evaluation. Times of occupation of the building should be recorded.

The actual time and duration of the incident vibration should also be registered.

B.2.4 Associated phenomena

B.2.4.1 Structure-borne noise

A major phenomenon associated with vibration in buildings is structure-borne noise (also known as ground-borne noise) which may become audible as re-radiated noise. This noise is related to the vibration present.

Structure-borne noise should be measured at that location in the room where its effect is considered to be most disturbing. It may often be masked by ambient noise from other sources, making its unambiguous determination difficult. Evaluation of such noise should be performed in such a manner as to identify its nature and magnitude with respect to the ambient conditions.

B.2.4.2 Airborne noise

Airborne noise may be produced by and related to vibration and its sources. Noise measurement should be performed according to ISO 1996-1.

For the airborne noise level, consideration should be given to whether measurements should be performed when windows are opened or closed. Caution is necessary, since the windows may themselves be rattling, and their behaviour may change.

Low-frequency airborne noise can also be an issue in vibration-related complaints. Typical sources of this include elevated highways and railway bridges, and building air-handling systems. Care should be taken in the investigation to identify correctly the various sources of noise and to ensure the distinction between low-frequency noise and vibration.

B.2.4.3 Induced rattling

Effects such as the rattle of windows or ornaments may be due to vibration or to acoustic excitation. Their occurrence may emphasize the presence of vibration and should be reported.

B.2.4.4 Visual effects

In case of low-frequency vibration (< 5 Hz), visual effects may be observed, such as the swinging of suspended features. These factors may emphasize the disturbance and should also be reported.

B.3 Information to be reported

In addition to the measured vibration magnitude, information should be reported regarding the associated phenomena:

— measured noise level;

— visually observed phenomena;

— description of human complaints determined, for example, by questionnaire or interviews.

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