IEC 60721-2-6

Edition 2.0 2022-12

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Classification of environmental conditions – Part 2-6: Environmental conditions appearing in nature – Earthquake vibration and shock

Classification des conditions d'environnement – Partie 2-6: Conditions d'environnement présentes dans la nature – Vibrations et chocs sismiques

IEC 60721-2-6:2022-12(en-fr)

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CLASSIFICATION OF ENVIRONMENTAL CONDITIONS –

Part 2-6: Environmental conditions appearing in nature – Earthquake vibration and shock

FOREWORD

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IEC 60721-2-6 has been prepared by IEC technical committee 104: Environmental conditions, classification and methods of test. It is an International Standard.

This second edition cancels and replaces the first edition published in 1990. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) the main aim of this revision is to classify in a limited number of classes the seismic activity level of the zone where the equipment could be installed;
b) the correlation between intensity scales, magnitude scales and peak ground acceleration is deleted due to the scientific uncertainty to define such a correlation in a rigorous way;
c) updated scales are given both for intensity and for magnitude;

d) the earthquake zone map, which was not usable in practice, is replaced by an annex giving information about how to retrieve consistent peak ground acceleration distribution all over the world;

e) with regard to identification of the peak ground seismic acceleration of the zone, where the equipment could be installed, the user is made aware that national standards and laws can apply.

The text of this International Standard is based on the following documents:

Draft	Report on voting
104/946/FDIS	104/952/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

A list of all parts in the IEC 60721 series, published under the general title *Classification of environmental conditions*, can be found on the IEC website.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

INTRODUCTION

This part of IEC 60721 is one of a series dealing with the following subjects:

– environmental parameters and their severities (IEC 60721-1);
– environmental conditions appearing in nature (IEC 60721-2);
– classification of groups of environmental parameters and their severities (IEC 60721-3).

This part of IEC 60721 is intended to be used as background material when selecting appropriate severities of parameters relating to earthquakes for product application. Severities given in IEC 60721-1 [1][1] should be applied.

More detailed information can be obtained from specialist documentation and from technical literature, some of which is given in the bibliography.

[1] Numbers in square brackets refer to the Bibliography.

CLASSIFICATION OF ENVIRONMENTAL CONDITIONS –

Part 2-6: Environmental conditions appearing in nature – Earthquake vibration and shock

1 Scope

This part of IEC 60721 deals with environmental conditions appearing in nature related to earthquake vibrations and shocks.

Its object is to define some fundamental properties and quantities for characterization of earthquakes as background material for the severities to which products are liable to be exposed during storage and use. The accelerations given are for ground surface conditions only. Conditions related to structures are referred to but restricted to general case descriptions.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

IEC 60068-3-3:2019, *Environmental testing – Part 3-3: Supporting documentation and guidance – Seismic test methods for equipment*.

ISO 2041, *Mechanical vibration, shock and condition monitoring – Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60068-3-3 and ISO 2041 apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

4 General description of earthquake

4.1 General

Influences from earthquakes are vibrations which can be modelled as stochastic processes and can affect products and provide stress in many ways.

This Clause 4 is intended to provide information on earthquake behaviour, and on the dynamic performance of products during earthquakes. Numerical values given are typical and illustrative but should not be considered as standard.

4.2 Earthquake origin and propagation

An earthquake occurs when stresses have accumulated to such a degree that they cause the breaking of the earth's crust. These instabilities are located in areas known as active seismic zones, in connection with a series of geological accidents such as troughs, oceanic ridges, mountain ranges, volcanoes, ocean trenches, tectonic faults.

The sudden breaking releases elastic deformation energy which will spread from the hypocentre in the form of three typical basic waves with different speeds:

– longitudinal volume waves which compress and expand the rock in the propagation direction;
– transversal waves which shear the rock by distortion, perpendicular to the propagation;
– surface waves which are a combination of the two previous ones and subject to surface limit conditions.

4.3 Earthquake behaviour

Earthquakes produce random ground motions which are characterized by simultaneous but statistically independent horizontal and vertical components. A moderate earthquake can persist for 15 s to 30 s; a severe earthquake for 60 s to 120 s. In general, the strong part with the highest ground acceleration can last up to 10 s. The typical broadband random motion has its maximum energy over a frequency range from 1 Hz to 35 Hz, and produces more damaging effects from 1 Hz to 10 Hz. Usually the vertical component of the ground motion is assumed to be between 67 % and 100 % of the horizontal.

NOTE Maximum acceleration is commonly used in design to reflect earthquake "strength" at a particular site.

4.4 Products on foundations

The typical broadband spectra which describe the ground motion indicate that multiple frequency excitation predominates. The vibration nature of the ground motion (both horizontal and vertical) can be magnified in foundation-mounted products. For any given ground motion, the magnification depends on the characteristic frequencies of vibration of the system (soil, foundation and product) and on the mechanism of damping.

4.5 Products in buildings and structures

The ground motion can be filtered and amplified by intervening building structures to produce fluctuating sinusoidal floor motions. The typical narrowband spectra which describe a building floor motion indicate that single frequency excitation can predominate. The dynamic response of floor-mounted products can reach an acceleration many times that of the maximum ground acceleration, depending on the system damping and characteristic frequencies of vibration. The magnification and bandwidth depend on the dynamic response characteristics of each building and product structure. Products sensitive to frequencies ranging from 1 Hz to 10 Hz are most likely to be affected.

5 Seismic scales

5.1 Definition of intensity and magnitude

In seismology, earthquakes are classified with the aid of various scales according to their intensity or magnitude.

Intensity scales are determined empirically and classify earthquakes in degrees of intensity according to their effects. Intensity scales are based on the observed effects of the shaking, such as the degree to which people or animals were alarmed, and the extent and severity of damage to different kinds of structures or natural features.

Intensity is here considered a classification of the severity of the ground shaking on the basis of observed effects in a limited area. Intensity scales, and the concept of intensity itself, have been evolving through the course of the last century. From a pure hierarchical classification of effects more and more attempts have been made to develop intensity as a rough instrument for measuring the shaking; at least, it has been used in this sense. Intensity is descriptive of the earthquake effects, rather than analytical in the manner of an instrumental measurement.

Magnitude is related to the amount of seismic energy released at the hypocentre of the earthquake. It is based on the amplitude of the earthquake waves recorded on instruments which have a common calibration. The magnitude of an earthquake is thus represented by a single, instrumentally determined value.

Both these scales, intensity and magnitude, can roughly correspond with certain values of ground acceleration; their use for establishing test values is limited.

The relationship between the intensity scales and the acceleration level on products can only be approximated on account of the following factors:

– the soil or rock conditions (including water saturation);
– the proximity to the earthquake activity;
– the conditions of the structure or base of the product.

Also the relationship between the magnitude scale and the peak ground acceleration is limited by the following effects:

– the soil or rock base at the location;
– the focal depth of the earthquake;
– the duration of the earthquake activity.

5.2 Examples of intensity scales

Table 1 provides a list of different intensity scales adopted by some countries.

Table 1 – Earthquake intensity scales for some countries/regions

Country/Region	Seismic intensity scale used
China	Liedu Scale (GB/T 17742-2020)
Europe	European Macroseismic Scale (EMS-98)
Hong Kong, China	Modified Mercalli Scale (MM)
India	Medvedev-Sponheuer-Karnik Scale
Israel	Medvedev-Sponheuer-Karnik Scale (MSK-64)
Japan	JMA Seismic Intensity Scale
Kazakhstan	Medvedev-Sponheuer-Karnik Scale (MSK-64)
Philippines	PHIVOLCS Earthquake Intensity Scale (PEIS)
Russia	Medvedev-Sponheuer-Karnik Scale (MSK-64)
Taiwan, China	Central Weather Bureau Seismic Intensity Scale
United States	Modified Mercalli Scale (MM)

The European Macroseismic Scale EMS-98 is the first seismic intensity scale designed to encourage co-operation between engineers and seismologists, rather than being for use by seismologists alone. It comes with a detailed manual, which includes guidelines, illustrations, and application examples. The short form of the European Macroseismic Scale (see Table 2), abstracted from [2], is intended to give a very simplified and generalized view of the EMS.

Table 2 – European Macroseismic Scale (EMS-98)

EMS intensity	Definition	Description of typical observed effects (abstracted)
I	Not felt	Not felt.
II	Scarcely felt	Felt only by very few individual people at rest in houses.
III	Weak	Felt indoors by a few people. People at rest feel a swaying or light trembling.
IV	Largely observed	Felt indoors by many people, outdoors by very few. A few people are awakened. Windows, doors and dishes rattle.
V	Strong	Felt indoors by most, outdoors by few. Many sleeping people awake. A few are frightened. Buildings tremble throughout. Hanging objects swing considerably. Small objects are shifted. Doors and windows swing open or shut.
VI	Slightly damaging	Many people are frightened and run outdoors. Some objects fall. Many houses suffer slight non-structural damage like hair-line cracks and fall of small pieces of plaster.
VII	Damaging	Most people are frightened and run outdoors. Furniture is shifted and objects fall from shelves in large numbers. Many well built ordinary buildings suffer moderate damage: small cracks in walls, fall of plaster, parts of chimneys fall down; older buildings can show large cracks in walls and failure of fill-in walls.
VIII	Heavily damaging	Many people find it difficult to stand. Many houses have large cracks in walls. A few well built ordinary buildings show serious failure of walls, while weak older structures can collapse.
IX	Destructive	General panic. Many weak constructions collapse. Even well built ordinary buildings show very heavy damage: serious failure of walls and partial structural failure.
X	Very destructive	Many ordinary well built buildings collapse.
XI	Devastating	Most ordinary well built buildings collapse, even some with good earthquake resistant design are destroyed.
XII	Completely devastating	Almost all buildings are destroyed.

5.3 Example of magnitude scale

The Moment Magnitude Scale (MMS; denoted explicitly by M_w) is a measure of an earthquake's magnitude, size or strength, based on its seismic moment, which is a measure of the work done by the earthquake. The Moment Magnitude Scale (M_w) is considered the authoritative magnitude scale for ranking earthquakes by size. Caltech seismologist Hiroo Kanamori [3] using an approximate relation between radiated energy and seismic moment approximated M_w by

$$M_w = (\log M_o - 9{,}045)/1{,}5$$

where

M_o = seismic moment is a measure of the work accomplished by the faulting of an earthquake; it is measured in the units of newton metres (Nm) or joules.

An approximate indication of the relationship between seismic moment and the Moment Magnitude Scale is given in Table 3.

Table 3 – Moment Magnitude Scale

M_w	M_o J
0	$1{,}11 \times 10^{9}$
1	$3{,}51 \times 10^{10}$
2	$1{,}11 \times 10^{12}$
3	$3{,}51 \times 10^{13}$
4	$1{,}11 \times 10^{15}$
5	$3{,}51 \times 10^{16}$
6	$1{,}11 \times 10^{18}$
7	$3{,}51 \times 10^{19}$
8	$1{,}11 \times 10^{21}$
9	$3{,}51 \times 10^{22}$
10	$1{,}11 \times 10^{24}$

6 Description of the seismic environment by response spectra

6.1 Response spectrum

A commonly accepted design description of the seismic environment specially for testing purposes is the use of response spectra. In a response spectrum the maximum absolute value of the time history response (displacement, velocity or acceleration) of a family of oscillators, each having a single degree of freedom with fixed viscous damping ratio, is plotted versus the undamped natural frequency of these oscillators when subjected to the base movement caused by the earthquake. It can be noted that a response spectrum is not an analytic function and it should not be confused with a spectrum. See ISO 2041 and ISO 18431-4 [4].

In Figure 1 an example of an acceleration record (natural time history) of a real earthquake is given. The ground acceleration was recorded during the Irpinia-Basilicata-Italy 1980 earthquake in Calitri village; the moment magnitude scale M_w = 6,8 and the EMS-98 intensity = 8.

Figure 2 shows a model for composing a response spectrum. The time domain response to the base vibration amplitude of oscillators with natural frequencies f_{ri} (i = 1 to n) and constant damping ratio is registered and the absolute maximum value is picked for each oscillator and plotted against its natural frequency. The response amplitude of an oscillator will be all the greater the longer and stronger it is excited at its damped natural frequency.

6.2 Ground response spectrum

If a ground motion time history has been recorded at the site of an earthquake, or near it, this is used to establish a shock response spectrum (SRS) (Figure 3).

A representative number of ground response spectra determined from different earthquakes is used to describe the anticipated seismic stress for the site or area.

6.3 Required response spectrum

A dominating curve above the ground response spectra is termed a required response spectrum because it marks the limits of the seismic ground motion at a given site or area during earthquakes. This spectrum (Figure 4) gives the amplitude response (displacement, velocity or acceleration) versus the natural frequency and damping ratio of the oscillators excited by the ground motion.

Different mounting configurations of products at a certain site can lead to the use of different corrected required response spectra according to the behaviour of their support (building structure, floor, or enclosure, etc.), (see IEC 60068-3-3). For testing purposes it is common practice to make reference to the ground acceleration response spectrum from which to derive the test required response spectrum accommodating the earthquake excitation to the specific mounting conditions. This test required response spectrum gives the limits of the seismic excitation to which the product should be exposed to verify its capability to withstand the earthquake (see ETSI EN 300 019-1-3 [5]).

7 Seismic activity zone classification

In order to define a local seismic ground motion it would be necessary to measure some local seismograms from which to derive:

– the earthquake duration, and

– the response spectrum giving the distribution of the ground acceleration in the frequency domain and the zero period acceleration, that is the peak ground acceleration (PGA).

Moreover, a statistical study should be performed with regard to the repetition rate of the earthquake versus its intensity. Generally, a probable maximum intensity with probability exceeding 10 % in 50 years, equivalent to a "return period" of 475 years, is used.

Earthquake zonation maps are reported in national and international standards and in natural hazards studies made by insurance companies and research institutions [6], [7]. See also only for information Annex A.

The following Table 4 gives a limited number of classes of seismic activity zones, covering the whole range of possible values of the peak ground acceleration.

Table 4 – Seismic activity zones

Seismic activity zone	**Peak ground acceleration (PGA)** m/s^2
0	0,01 to 0,2
1	0,2 to 0,5
2	0,5 to 1
3	1 to 2
4	from 2 to more than 20

The user of this document should select the lowest classification necessary for covering the conditions of seismicity of the intended zone of installation.

The identification of the peak ground seismic acceleration of the zone where the equipment could be installed, can be subject to relevant national standards and laws.

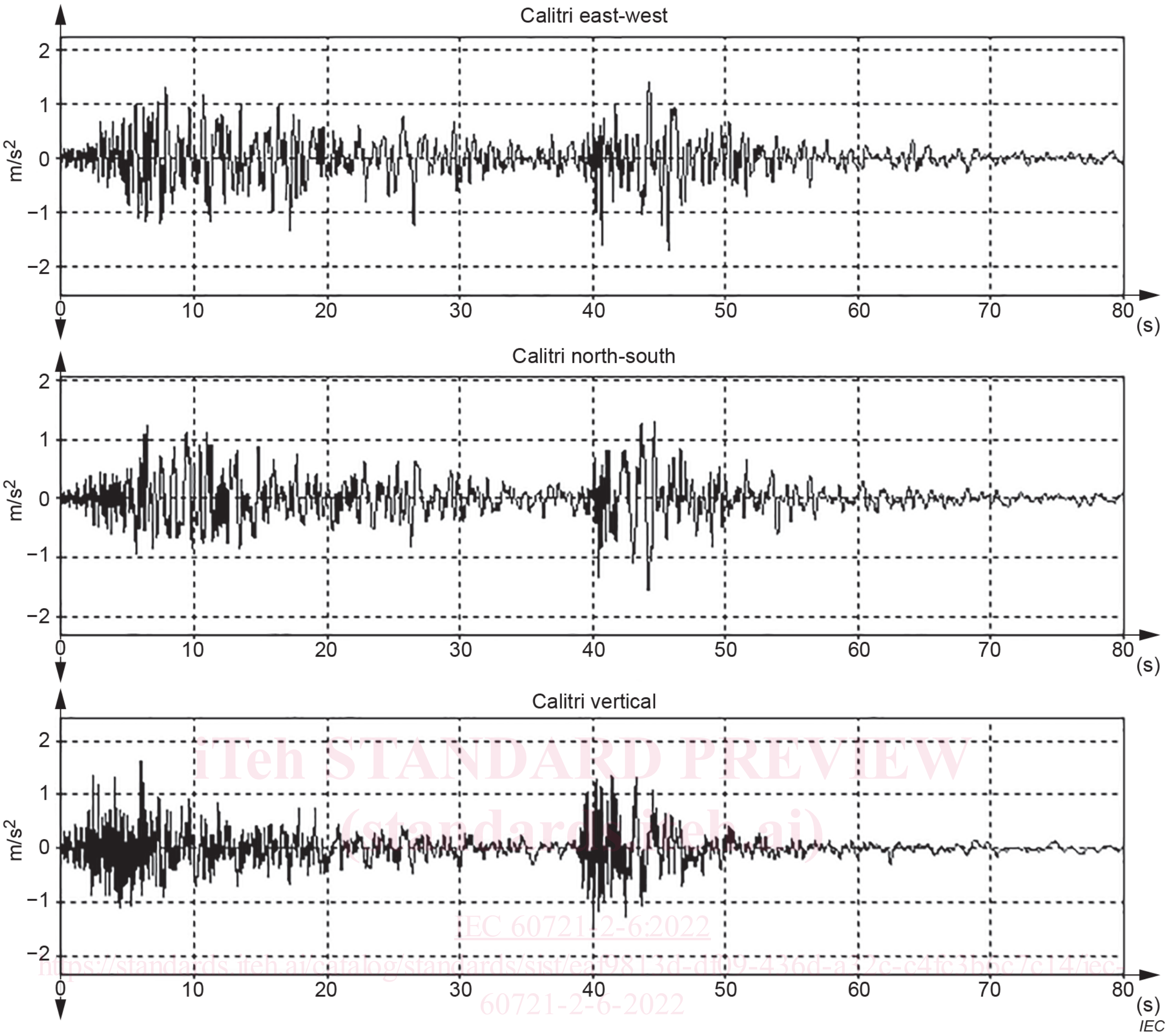
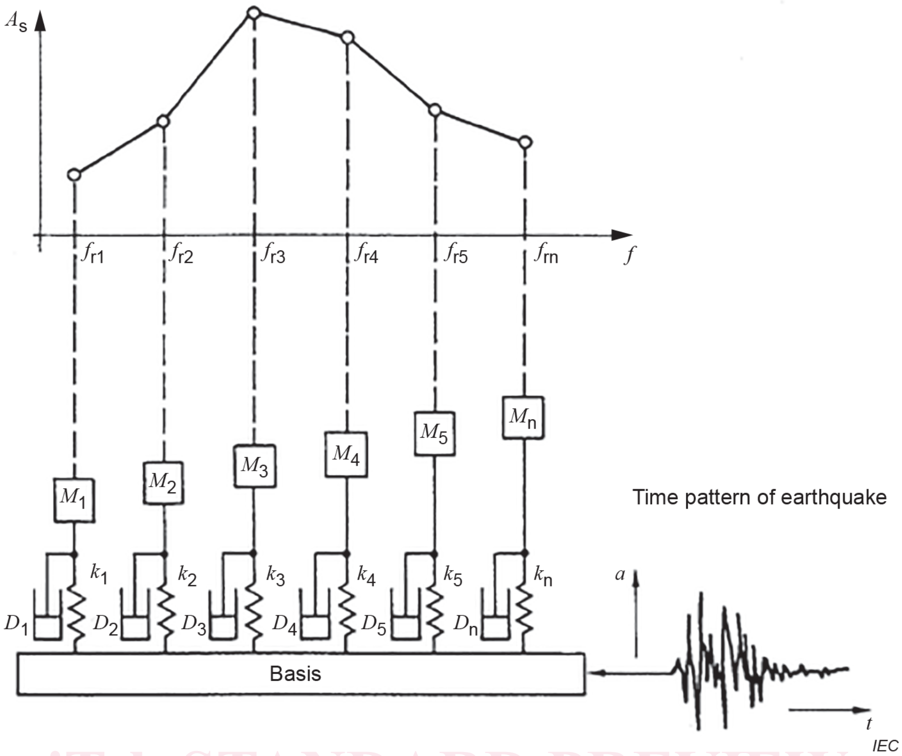


Figure 1 – Acceleration record of the Irpinia-Basilicata-Italy earthquake (1980)



Key

a	base acceleration amplitude	f	natural frequency
A_a	response acceleration amplitude	k_i	stiffness
D_i	damping	M_i	mass
f_{ri}	natural frequency of distinct oscillators	t	time

Figure 2 – Model for composing a response spectrum