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Mechanical vibration and shock — Vibration of buildings — Guidelines for the measurement of vibrations and evaluation of their effects on buildings

AMENDMENT 2

Vibrations et chocs mécaniques — Vibrations des bâtiments — Lignes directrices pour le mesurage des vibrations et évaluation de leurs effets sur les bâtiments

AMENDEMENT 2

Reference number
ISO 4866:1990/Amd.2:1996(E)

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 voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Amendment 2 to ISO 4866:1990 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration and shock*, Subcommittee SC 2, *Measurement and evaluation of mechanical vibration and shock as applied to machines, vehicles and structures.*

Annex E is for information only.

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Mechanical vibration and shock — Vibration of buildings — Guidelines for the measurement of vibrations and evaluation of their effects on buildings

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Page iii

Change the last sentence to: Annexes A to F of this International Standard are for information only.

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Add the following annex as annex E and change the present annex E to annex F.

Annex E

(informative)

Vibrational interaction between the foundation of a structure and the soil

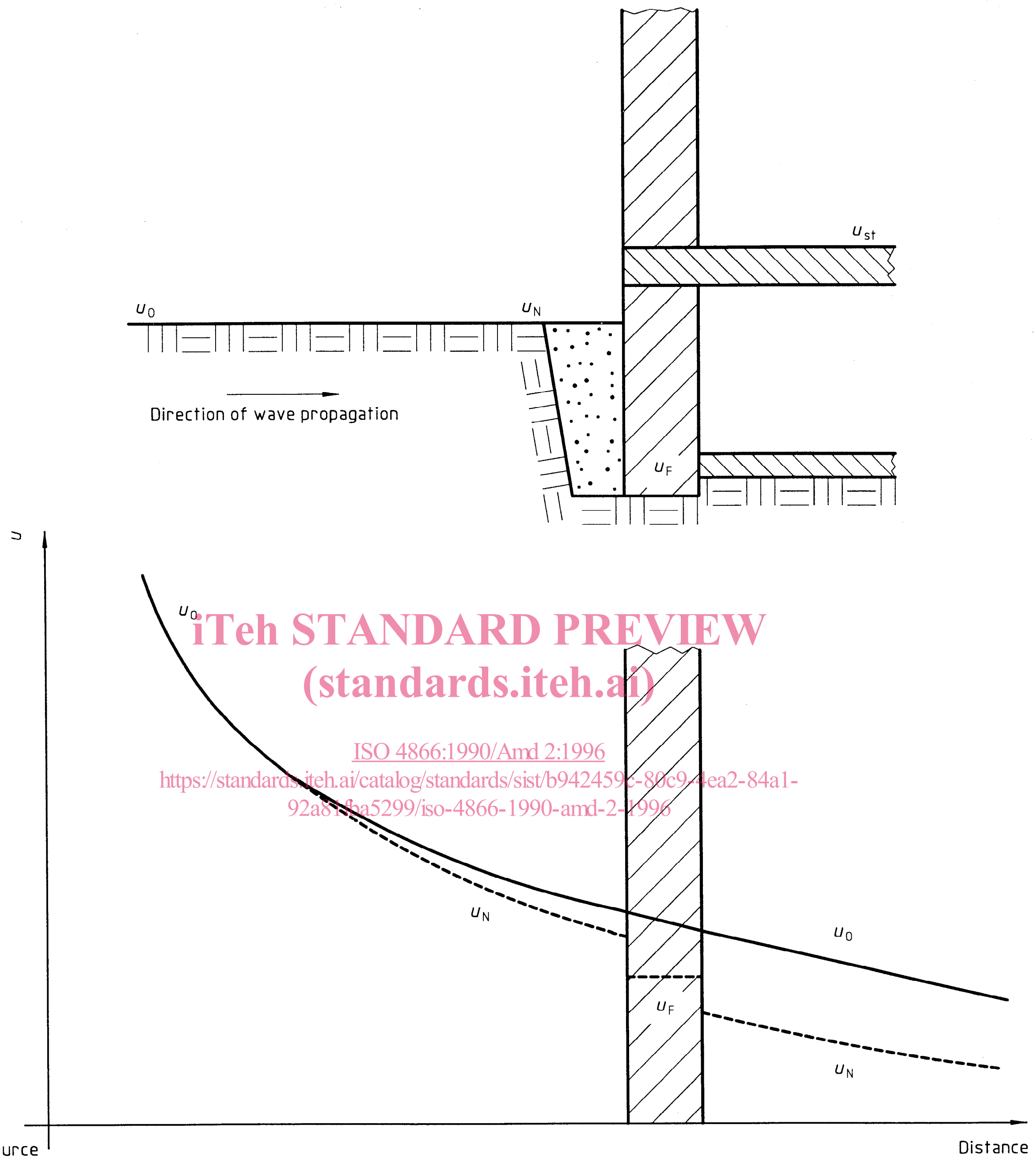
E.1 General

When vibration measurements cannot be made on the foundation of a structure or inside a building, ISO 4866 allows that measurements be made on the ground surface outside. It may also be necessary to predict the response of a building not yet constructed. In both cases there is a need to understand the dynamic interaction between a building and the ground.

In the first case, the most suitable position outside the building for measurement and the relationship between the signal at that position and that on the building foundation need to be established.

In the second case, the response of the foundation of the building may be expected to follow closely the motion of the ground in contact with the foundation unless interaction is significant. This annex seeks to indicate the nature of such an interaction and suggests procedures which allow it to be taken into account.

Figure E.1 illustrates the notation which will be used in this annex in terms of the peak amplitude, u, of a travelling wave passing across a foundation (u can be the displacement, velocity or acceleration amplitude of the sinusoidal wave). Free-field amplitude is denoted by u_0, amplitude in the base of the foundation by u_F, amplitude at an arbitrary position in the structure by u_{st}, and on the soil surface near an existing building by u_N. Far from the structure, $u_N = u_0$. Soil-structure interaction analysis is concerned generally with the relationship between free-field motion and structure motion, that is u_{st}/u_0 and, in particular, $u_F/u_0 = r_0$. The important ratio $u_F/u_N = r_N$ is given by the more sophisticated procedures which also address the problem of soil response involving the variation of vibration amplitude with depth.



Symbols:

u is the displacement, velocity or acceleration amplitude of the sinusoidal wave;

u_0 is the free-field amplitude;

u_N is the amplitude on the soil surface near an existing building;

u_F is the amplitude in the base of the foundation;

u_{st} is the amplitude at an arbitrary position in the structure.

$r_0 = u_F/u_0$

$r_N = u_F/u_N$

Figure E.1 — Notations, illustrated at a horizontally propagating wave

E.2 Theoretical considerations

Soil-structure interaction influences the dynamic response of all structures to some degree. Only a rigid building bonded to rigid ground would respond in the same way as the ground. In reality, the ground does not have an infinite rigidity and may provide a mechanism for the radiation and dissipation of energy. Hence it can be thought of as acting as a spring and dashpot system or a series of such systems just below the foundation.

The degree to which soil-structure interaction is a significant aspect of structural response depends on the dynamic parameters of the structure and of the ground, in particular on the natural frequencies of the structure and the shear stiffness of the ground. When considering relatively stiff low-rise buildings (low rise = 6 m to 7 m high), the problem may be examined as the vertical response of a rigid mass on a spring and a dashpot adjusted to match the analytical solution with the ground as semi-infinite isotropic and homogeneous elastic halfspace. Such simple concepts suggest that the maximum amplification to be expected in the vertical direction is not likely to exceed 2. Rocking and sliding modes can also be explored in a similar manner and suggest that somewhat higher magnifications can be theoretically achieved in most cases. However, vertical amplification is surely limited because energy captured by the structure from the passing wave is reradiated into the ground thus damping the amplitude response.

Full consideration of soil-structure interaction should take account of the layering of the soil, the variation of shear stiffness with depth, the effects of building load on soil stiffness, the effect of shear strains on soil stiffness, the geometry of the foundation, and foundation embedment, as well as the frequency content of the excitation.

Dynamic soil-structure interaction is one of the central problems in earthquake engineering, and over the last two decades methods of analysis have been highly developed, mainly for the nuclear industry, giving rise to a vast literature (see references [39] to [45]). Refined analysis has also been used for wind and man-made loading and some simplified rules have been derived (see references [46] and [47]).

These advanced analytical methods can be grouped into two classes:

a) the direct method, whereby the soil and structure are treated together; the ground may be represented by finite elements, lumped parameters or both (hybrid models);

b) the substructure method, whereby the response of the ground and structure are calculated as separate systems with a separation between ground and structure to which springs and dashpots or stiffness functions are applied.

Another approach is the response spectrum, widely used in earthquake engineering and other shock loading (see reference [48]). It can be adapted to take some account of soil-structure interaction by reducing the natural frequency assessed for a structure on soils of low stiffness. The effects of soil response can be allowed for, in part, by using design response spectra which vary according to the shear modulus depth profile of the soil.

Generally, the closer the frequency of the excitation is to the natural frequency of a building or building element the greater will be the response. Earthquakes, with low frequencies of 0,5 Hz to 8 Hz, will tend to excite the lower natural frequencies of buildings; man-made excitation is generally at higher frequencies and tends to excite the structural elements of a building. Furthermore, the range of vertical frequencies of building elements (6 Hz to 40 Hz) lies in the range of man-made excitation, leading to the relatively large bending responses which have been observed in ceilings (see reference [49]).

E.3 Relationship between vibration at the ground surface and at the foundation

There are difficulties associated with measurements on the ground near the building, for example:

— the measuring point is usually remote from the positions of interest within the structure;

— there are more uncertainties in coupling the transducer to the ground than in fixing it to a building part;

— the soil near a building is often disturbed;

— vibration amplitudes near a building may change with distance from the building as a proportion of the wavelength.

The direct methods for analysis of soil-structure interaction are expensive and need detailed knowledge of soil properties, however, they can give some guidance on the following factors influencing r_N.

a) The amplitude of vibration may be affected by reflection at the front of the foundation (with respect to the travelling wave) and decreased at the rear side by dissipation and front side reflection. Theses effects depend on the foundation size, depth and excitation wavelength.

b) Where the propagation behaves like a surface Rayleigh wave (which is usual for distant sources), the amplitudes decrease with depth (see, for example, figure E.2), so deeper foundations pick up less motion.

c) Strong earthquake motions are usually modelled as vertically propagating horizontally polarized shear waves with amplitudes increasing as the waves pass upwards from high rigidity. So again, deeper foundations may pick up smaller vibration.

Such complexities preclude a definitive set of rules relating r_N and r_0 to the category of structure and character of excitation, but both measurements (see reference [50]) and theoretical studies indicate that in most situations of man-made excitations the value of r_N is likely to be unity or less. This has been supported by results of a questionnaire[1] which has indicated that for vertical motion without regard to frequency, r_N was in the range 0,3 to 0,6. The maximum magnification recorded was in the horizontal response and amounted to a 13 % increase. Histograms of the replies to the questionnaire are given in figures E.3 and E.4.

This general reduction of vertical vibration on the foundation as compared with that on the soil surface near a building may not hold in cases where there is a marked rocking response to continuous vibration.

As for preferred positions of measurement near a building, it is suggested that these positions should be less than 2 m or 1/10 of the dominant wavelength away from the building.

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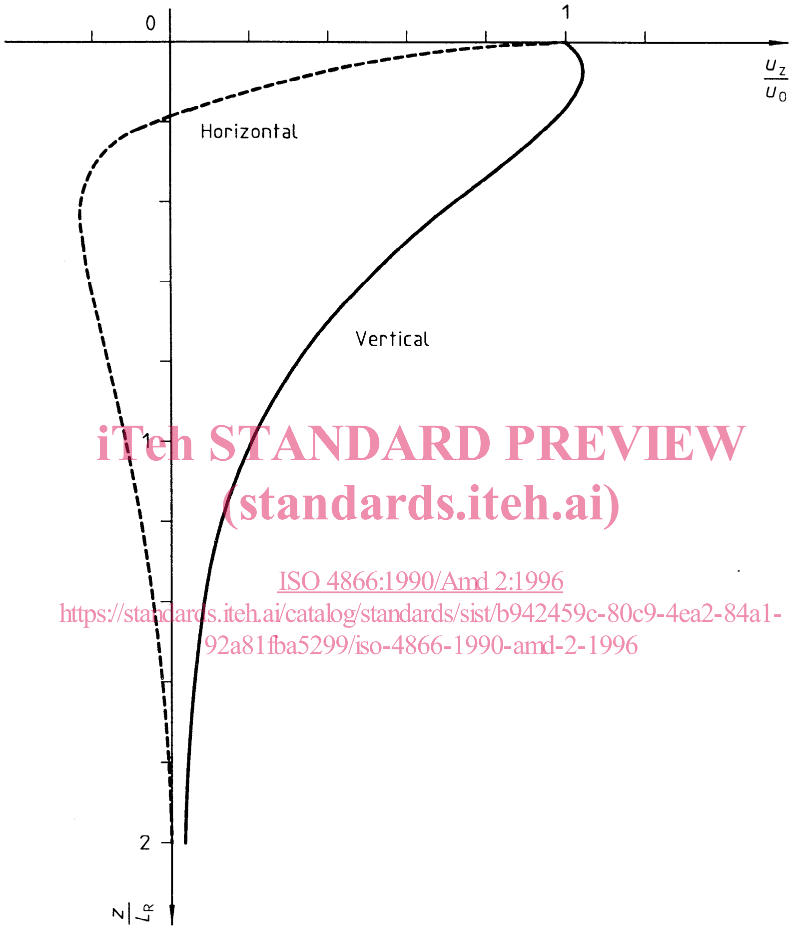
[1] The questionnaire contained various ground conditions as well as various types of vibration excitation.



L_R is the Rayleigh wavelength.

Figure E.2 — Variation of vibrational amplitude u_z with depth z of a Rayleigh wave

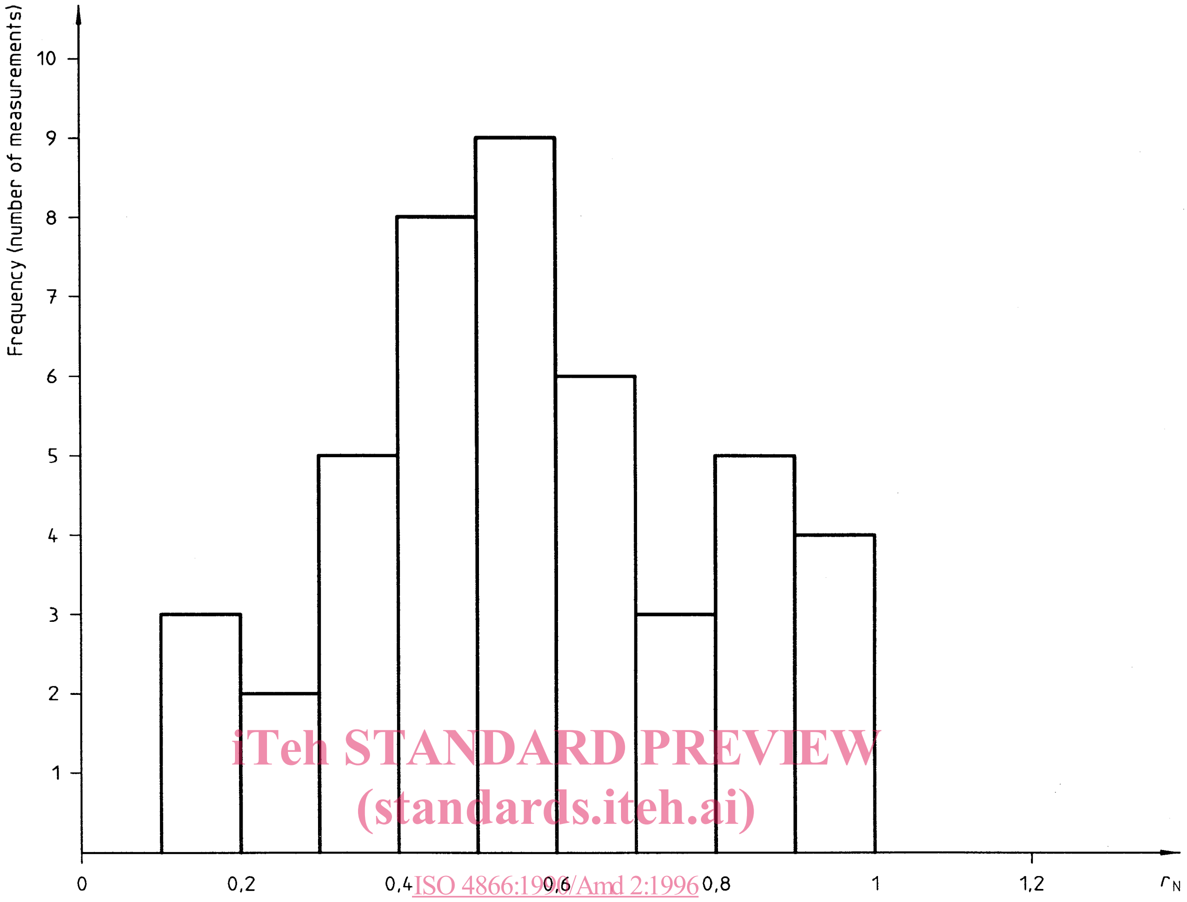


Figure E.3 — Frequency distribution of r_N (vertical direction of vibration)

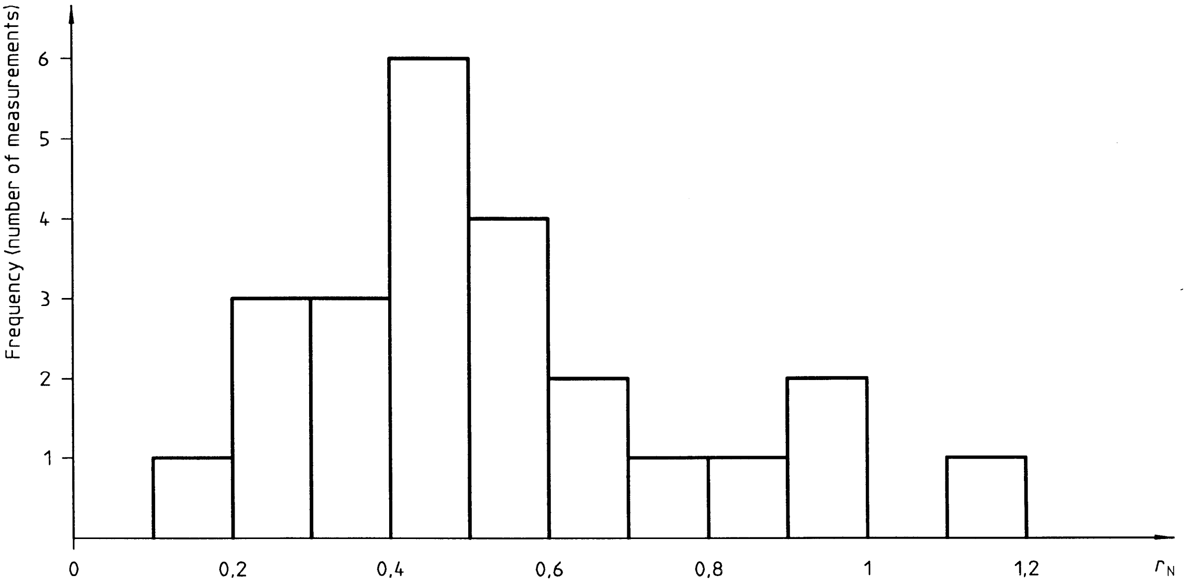


Figure E.4 — Frequency distribution of r_N (horizontal direction of vibration)